Skull variability of mice and voles inhabiting the territory of a great cormorant colony

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Abstract: We investigated the influence of a colony of great cormorants on the skull morphometry of yellow-necked mice (*Apodemus flavicollis*) and bank voles (*Myodes glareolus*) of three age groups trapped in the territory of the colony in 2011–2014. In general, most of the skull differences in both species were related to character length (skulls tended to become longer). In *A. flavicollis*, the skull size differences between zones were most expressed in subadult and adult individuals, while in *M. glareolus* they were most expressed in juveniles, with only a few characters different in adults and none in subadult voles. For both species, the largest skull characters were found mostly in the zone characterized by both the greatest number of cormorant nests and the longest and strongest influence by the colony. Concluding we confirm that the great cormorant colony has an influence on the skull morphometry of *A. flavicollis* and *M. glareolus* and we hypothesize that these differences enhance the ability of survival in specific conditions.

Key words: *Apodemus flavicollis*; *Myodes glareolus*; skull size; cormorant colony

Introduction

Great cormorants (*Phalacrocorax carbo sinensis* Staunton, 1796) are colonial nesting birds faithful to sites for many years. As such, they are able to alter the surrounding environment, mainly due to altered soil pH and the influx of nutrients into environment. Various influences on the ecosystem and their components have been shown (Klimaszyk & Joniak 2011; Osono 2012; Żółkóś et al. 2013; Klimaszyk et al. 2015).

Under the National Research Programme "Ecosystems in Lithuania: Climate Change and Human Impact (2010–2014)", the negative influence of a great cormorant colony was shown on the abundance of myxomycetes (Adamonytė et al. 2013), mycorrhizal and coprophilous fungi (Kutorga et al. 2013) and lichen diversity (Motiejūnaitė et al. 2014). The impact of a studied colony on small mammal species diversity and abundance is also negative (Balčiauskienė et al. 2014). The population structure of the dominant small mammal, namely yellow-necked mouse *Apodemus flavicollis* (Melchior, 1834), is biased towards a higher representation of males and young individuals in the territory used most intensively by great cormorants. Here, mice are characterised by smaller body weight and body condition indexes (Balčiauskas et al. 2015).

In the presented study, we tested if there are changes in skull morphometry in the two most dominant rodent species, *A. flavicollis* and bank vole *Myodes glareolus* (Schreber, 1780), inhabiting the territory of a great cormorant colony. We based our study on the presumptions that skull size differences may be found in small spatial (Schlanbusch et al. 2011) and temporal (Pergams & Lawler 2009) scales. Pollution and other environmental disturbances may have influence on the size of animal bones (Nunes 2001; Oleksyk et al. 2004; Velickovic 2007). Both rodent species are used for zoomonitoring purposes (Martiniaková 2010a).

The above-mentioned studies (Balčiauskienė et al. 2014; Balčiauskas et al. 2015) are the only studies devoted to small mammals inhabiting the territory of a colony of great cormorants. Our results illustrating differences in population structure and body condition warranted our current working hypothesis that skull size variability may also be driven by the influence of the colony.

Material and methods

Yellow necked mice (*A. flavicollis*) and bank voles (*M. glareolus*) were trapped between 2011–2014 in a colony of great cormorants (*P. carbo sinensis*) situated within the Kuršių Nerija National Park near Juodkrantė on the Curonian Spit in western Lithuania (55°33'10" N, 21°07'30" E). The Curonian Spit separates a shallow lagoon from the Baltic Sea and is 98 km long, narrow and comprised of sand dunes.

Here, related to the duration and intensity of the impact of the colony, five zones were defined (Adamonytė et al. 2013; Balčiauskienė et al. 2014; Balčiauskas et al. 2015):

1. Control zone (I): at a distance from the colony, dry pine forest and mixed forest;

2. Zone of initial influence (II): expanding part of the colony, characterised by scarce herb and shrub layers, dying trees and fresh nests;

Table 1. Craniometric data of *Apodemus flavicollis* from cormorant-affected and adjacent territory in Juodkrantė (all measurements in mm).

| Skull character | Adults ($n = 111$–179) | | Subadults ($n = 85$–139) | | Juveniles ($n = 98$–141) | |
	Avg $\pm$ SE	Min–max	Avg $\pm$ SE	Min–max	Avg $\pm$ SE	Min–max
X1	13.7 ± 0.05	12.0–15.0	13.2 ± 0.05	11.8–14.6	12.6 ± 0.05	11.0–13.9
X2	12.7 ± 0.06	10.6–14.2	12.3 ± 0.05	10.5–13.7	11.6 ± 0.06	9.9–13.2
X3	4.7 ± 0.02	3.9–5.3	4.4 ± 0.02	3.8–5.1	4.2 ± 0.02	3.5–5.0
X4	6.8 ± 0.03	5.6–7.8	6.5 ± 0.03	5.6–7.5	6.2 ± 0.04	5.2–7.4
X5	7.1 ± 0.03	5.8–8.5	6.8 ± 0.03	5.7–7.5	6.5 ± 0.04	5.4–7.8
X6	4.0 ± 0.02	3.3–7.1	3.8 ± 0.02	3.3–4.3	3.6 ± 0.02	3.1–4.2
X7	3.6 ± 0.01	3.2–4.0	3.6 ± 0.01	3.2–4.0	3.6 ± 0.01	3.1–4.0
X8	1.4 ± 0.00	1.2–1.6	1.4 ± 0.01	1.2–1.6	1.4 ± 0.01	1.2–1.6
X9	9.5 ± 0.05	6.8–10.8	9.1 ± 0.05	7.1–10.8	8.4 ± 0.06	6.7–10.1
X10	11.9 ± 0.03	11.0–13.8	11.8 ± 0.03	11.1–13.3	11.6 ± 0.03	10.8–12.4
X11	14.0 ± 0.06	11.5–15.7	13.4 ± 0.06	11.3–14.6	12.6 ± 0.07	10.8–14.4
X12	7.6 ± 0.04	6.1–10.0	7.3 ± 0.04	6.0–9.9	6.8 ± 0.04	5.4–7.9
X13	8.6 ± 0.04	7.4–9.8	8.4 ± 0.06	7.3–14.5	7.9 ± 0.04	6.8–8.8
X14	5.4 ± 0.02	4.0–6.1	5.2 ± 0.02	4.2–6.3	4.9 ± 0.03	4.0–5.8
X15	4.3 ± 0.01	4.0–4.6	4.3 ± 0.01	3.9–4.7	4.2 ± 0.01	3.8–4.7
X16	1.5 ± 0.01	1.3–1.9	1.5 ± 0.01	1.2–1.7	1.4 ± 0.01	1.2–1.7
X17	2.2 ± 0.01	1.3–2.6	2.1 ± 0.01	1.7–2.5	1.9 ± 0.01	1.5–2.4
X18	27.8 ± 0.16	23.0–31.3	27.6 ± 0.18	23.8–30.4	26.3 ± 0.19	22.1–29.2
X19	14.6 ± 0.05	12.1–16.0	14.2 ± 0.05	12.3–15.7	13.4 ± 0.07	11.4–14.9
X20	12.7 ± 0.05	10.8–13.8	12.2 ± 0.05	10.6–13.5	11.6 ± 0.06	10.4–13.1
X21	4.5 ± 0.02	3.9–5.2	4.4 ± 0.02	3.6–5.0	4.3 ± 0.02	3.4–5.0
X22	4.2 ± 0.01	3.7–4.6	4.2 ± 0.01	3.7–4.7	4.1 ± 0.01	3.8–4.6
X23	9.8 ± 0.05	8.6–11.0	9.7 ± 0.06	8.6–10.8	9.5 ± 0.06	7.9–10.9

3. Zone of the longest-lasting and strongest influence (III): held the greatest number of cormorant nests in 2011–2013. Nitrophilic species of herbs dominated in the herb layer, the projection of which is less than 10%. The shrub layer was scarce or significantly reduced, trees were dying or dead;

4. Zone of strong former influence of the colony (IV): most nests are already abandoned. Tree saplings and shrubs were re-growing, the herb layer re-establishing and the moss layer absent.

5. Zone of ecotone (V): between the surrounding forest and zones II–IV.

Small mammals were trapped with snap-traps, using standard 25-trap lines (2 lines per zone, traps 5 m apart each other, baited by bread crust with sunflower oil) and 3 days exposition (Balčiauskas 2004; Balčiauskienė et al. 2014). Trapping was conducted in September and October 2011, in May, September and November 2012, in October and November 2013, and in June and November 2014. Trapping effort was equal to 5335 trap/days.

Under dissection, animals were attributed to one of the three age categories, based on the presence and involution of the *gl. thymus* and reproductive status of the animals (Balčiauskas et al. 2012).

We analyzed the skulls of 468 *A. flavicollis* and 151 *M. glareolus*. Of these, for zones I, II, III, IV and V, the numbers of *A. flavicollis* individuals were 89, 38, 50, 185 and 106, and the numbers of *M. glareolus* individuals 18, 4, 17, 77 and 35, respectively.

The skulls were cleaned using *Dermestes* beetle larvae. Under a binocular microscope with a micrometric eyepiece which has an accuracy of 0.1 mm, 23 skull characters were measured. Only the characters of the right side of the skull were used. Measurements included: X1 – total length of mandibula at *processus articularis*, excluding incisors; X2 – length of mandibula excluding incisors; X3 – height of mandibula at, and including, first molar; X4 –

maximum height of mandibula, excluding coronoid process; X5 – coronoid height of mandibula; X6 – length of mandibular diastema; X7 – length of mandibular tooth row; X8 – length of lower molar M1; X9 – length of *nasalia*; X10 – breadth of braincase, measured at the widest part; X11 – zygomatic skull width; X12 – length of cranial (upper) diastema; X13 – zygomatic arc length; X14 – length of *foramen incisivum*; X15 – length of maxillary toothrow; X16 – length of upper molar M1; X17 – incisor width across both upper incisors; X18 – condylobasal length; X19 – length of rostrum; X20 – length of the braincase; X21 – interorbital constriction; X22 – postorbital constriction; X23 – height of the braincase (according Balčiauskas & Balčiauskienė 2011).

We tested if differences in the size of skull characters were present and, if so, whether these differences were associated with possible drivers of change – i.e. zone of the colony, trapping year, trapping month, animal age and animal sex. Multifactor influence was tested using GLM (main effects ANOVA) for all skull measurements and all above-mentioned categorical predictors (according Tête et al. 2013). To evaluate differences in skull characters between zones, ANOVA was used. All calculations were done with Statistica for Windows, ver. 6.0 software (StatSoft 2004).

Results

The skull measurements of the different age groups of *A. flavicollis* are presented in Table 1. We found that sizes of these skull characters were significantly influenced by zone (Wilks $\lambda = 0.58$, $F = 1.33$, $P < 0.025$), year (Wilks $\lambda = 0.04$, $F = 18.32$, $P < 0.0001$) and month (Wilks $\lambda = 0.53$, $F = 1.25$, $P < 0.05$) of trapping, animal sex (Wilks $\lambda = 0.80$, $F = 2.30$, $P = 0.001$) and age (Wilks $\lambda = 0.47$, F $= 4.18$, $P = 0.0001$).

The aggregated influence of these five factors, including zone, was of different strengths. According mul-
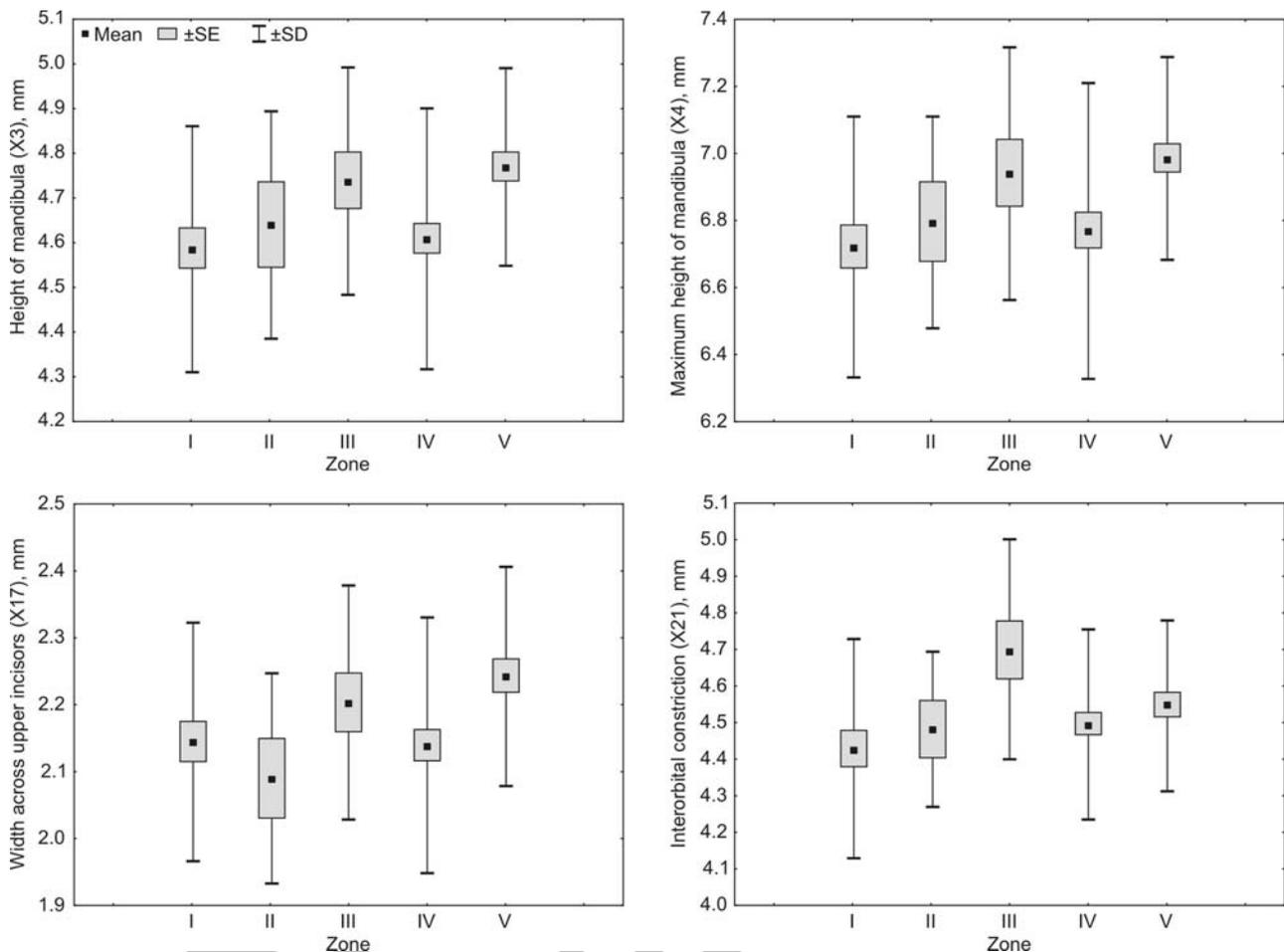
Fig. 1. Differences in skull characters of adult *Apodemus flavicollis* in the zones of the great cormorant colony. I – control zone, II – zone of initial influence, III – zone of the longest-lasting and strongest influence, IV – zone of strong former influence, V – zone of ecotone.

tiple determination coefficient, characters X7 and X15 were not influenced (i.e., were most stable) ($R^2 = 0.13$, $P < 0.005$), while X6, X8, X10, X16, X21 and X22 were weakly influenced ($R^2 = 0.15$–0.30, $P < 0.0001$), and X1–X5, X11–X14, X17 and X19–X20 were moderately influenced ($R^2 = 0.38$–0.48, $P < 0.0001$). X18 and X 23 were very strongly influenced (i.e. were most variable) ($R^2 > 0.70$, $P < 0.0001$).

The sizes of the skull characters of adult *A. flavicollis* in different zones of the cormorant colony are shown in Fig. 1. Although no significant differences were found in body measurements of animals (body mass highest in the zones II, III and V, smallest in zones I and IV, the same tendency with body length), differences in skull size between zones were significant for X3 (ANOVA, $F_{4,173} = 3.80$, $P < 0.006$), X4 ($F_{4,168} = 3.31$, $P = 0.012$), X17 ($F_{4,172} = 3.13$, $P = 0.016$) and X21 ($F_{4,166} = 3.03$, $P = 0.019$) and almost significant for X2 ($P = 0.06$), X5 ($P = 0.054$) and X20 ($P = 0.076$).

The influence of the zone on the skull size of subadult *A. flavicollis* was found to be stronger (Fig. 2). Significant size differences were found for X2 (ANOVA, $F_{4,133} = 3.30$, $P = 0.013$), X3 ($F_{4,134} = 2.88$, $P = 0.027$), X5 ($F_{4,126} = 2.78$, $P = 0.030$), X13 ($F_{4,121} = 4.02$, $P < 0.005$), X15 ($F_{4,131} = 2.58$, $P < 0.05$), X16 ($F_{4,132} =$

2.53, $P < 0.05$), X19 ($F_{4,129} = 2.66$, $P = 0.035$) and X21 ($F_{4,1262} = 3.59$, $P < 0.01$), while near significant for X14 ($F_{4,131} = 2.15$, $P = 0.078$) and X18 ($F_{4,84} = 2.64$, $P = 0.083$).

With juvenile *A. flavicollis*, there were no significant differences in skull measurements between zones (Fig. 3), but near-significant differences were recorded for X8 (ANOVA, $F_{4,136} = 2.39$, $P = 0.054$) and X21 ($F_{4,126} = 2.16$, $P = 0.078$).

The size of the skull characters of *M. glareolus* (Table 2) were most significantly influenced by the year of trapping (Wilks $\lambda = 0.007$, $F = 4.94$, $P < 0.0001$), then by animal age (Wilks $\lambda = 0.09$, $F = 2.72$, $P = 0.0002$) and sex (Wilks $\lambda = 0.26$, $F = 3.31$, $P = 0.002$) and month of trapping (Wilks $\lambda = 0.03$, $F = 1.66$, $P = 0.006$). Zone of the colony was not a significant influence (Wilks $\lambda = 0.07$, $F = 3.32$, $P = 0.37$).

Differences in the skull size of adult *M. glareolus* between zones, however, were significant for some characters (Fig. 4): X3 (ANOVA, $F_{4,34} = 2.88$, $P = 0.037$), X4 ($F_{4,34} = 3.25$, $P = 0.023$), X6 ($F_{4,34} = 3.38$, $P < 0.02$), X10 ($F_{4,24} = 3.37$, $P = 0.025$) and X20 ($F_{4,22} = 4.35$, $P = 0.009$), also near significant for X16 ($F_{4,35} = 2.45$, $P = 0.064$).

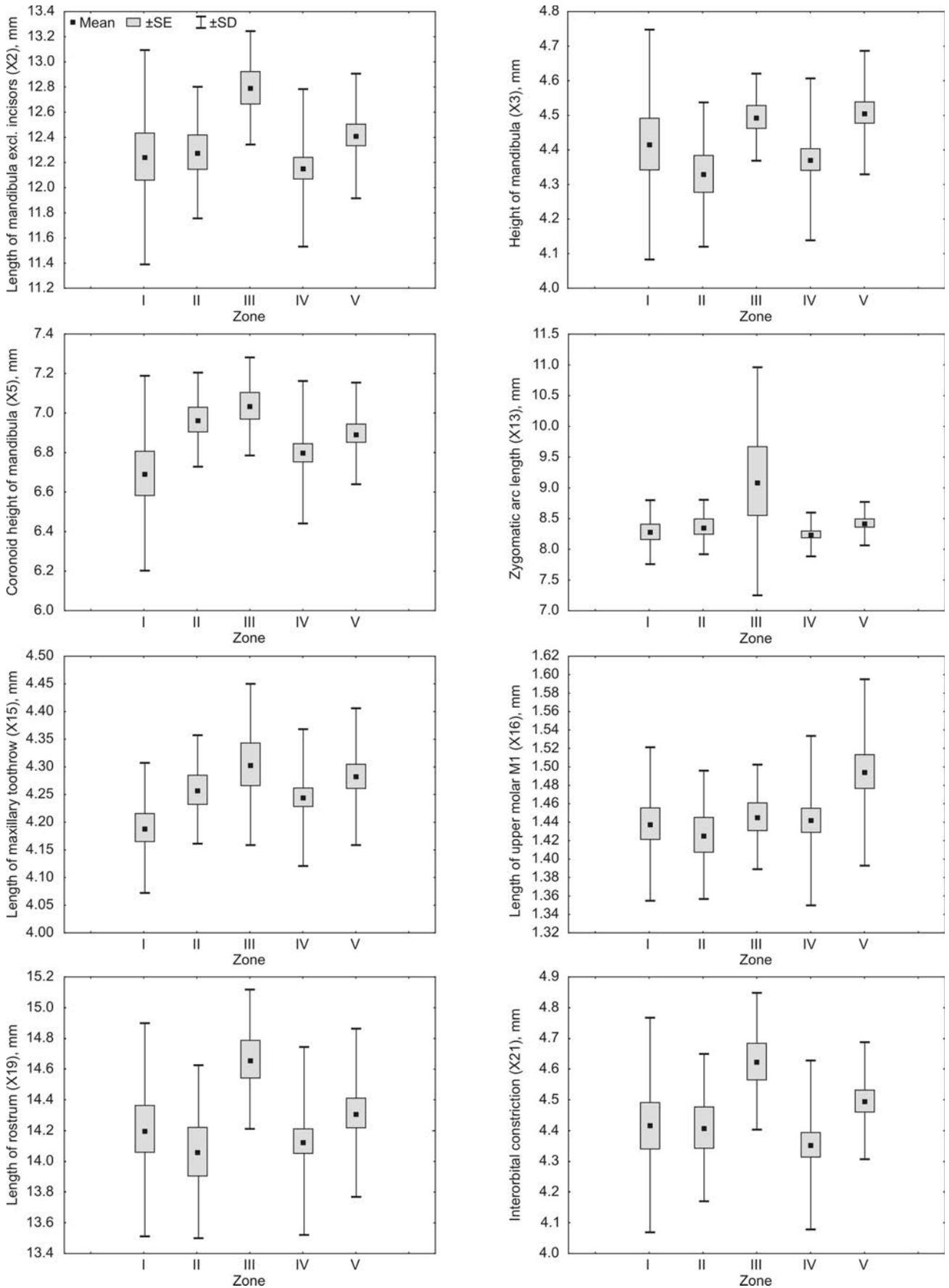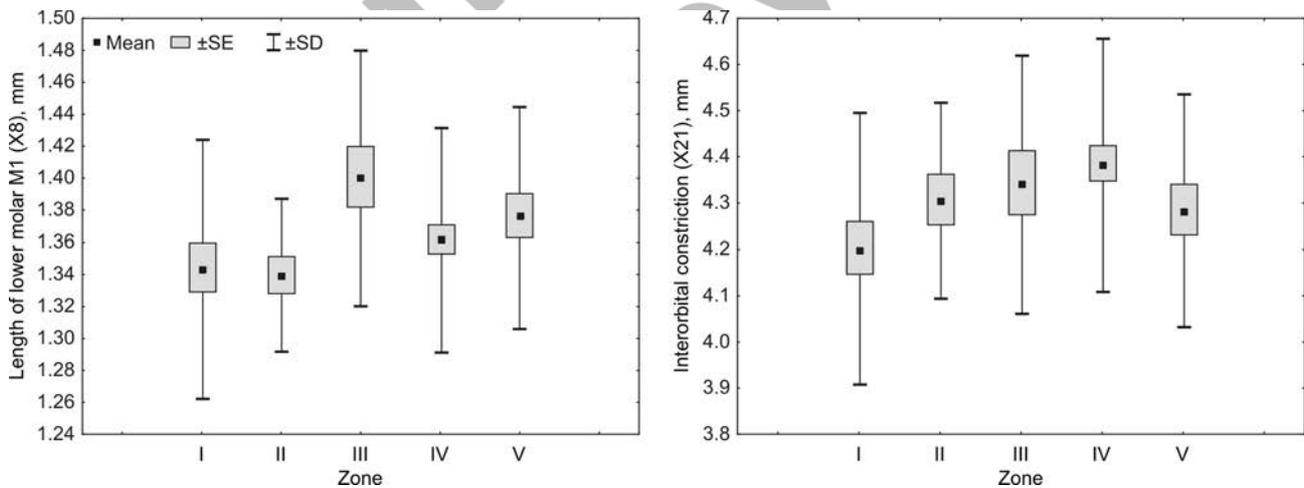No significant differences in skull measurements for

Fig. 2. Differences in skull characters of subadult *Apodemus flavicollis* in the zones of the great cormorant colony. I – control zone, II – zone of initial influence, III – zone of the longest-lasting and strongest influence, IV – zone of strong former influence, V – zone of ecotone.

Table 2. Craniometric data of *Myodes glareolus* from cormorant-affected and adjacent territory in Juodkrantė (all measurements in mm).

Skull character	Adults ($n = 26$–41)		Subadults ($n = 27$–40)		Juveniles ($n = 40$–66)	
	Avg $\pm$ SE	Min–max	Avg $\pm$ SE	Min–max	Avg $\pm$ SE	Min–max
X1	11.8 ± 0.07	10.9–12.9	11.5 ± 0.07	10.8–12.8	11.2 ± 0.04	10.4–12.0
X2	11.0 ± 0.05	10.3–11.8	10.8 ± 0.07	10.0–12.0	10.5 ± 0.05	9.5–11.3
X3	4.3 ± 0.03	4.0–4.6	4.2 ± 0.03	3.9–4.8	4.1 ± 0.02	3.6–4.5
X4	6.0 ± 0.04	5.4–6.6	5.9 ± 0.05	5.3–6.8	5.6 ± 0.03	4.9–6.2
X5	5.7 ± 0.03	5.4–6.2	5.7 ± 0.04	5.4–6.1	5.6 ± 0.04	4.6–6.1
X6	2.9 ± 0.02	2.6–3.2	2.9 ± 0.02	2.8–3.2	2.8 ± 0.02	2.5–3.3
X7	4.6 ± 0.02	4.2–5.0	4.6 ± 0.02	4.3–4.9	4.5 ± 0.02	3.7–4.8
X8	2.1 ± 0.01	1.9–2.3	2.1 ± 0.01	1.9–2.2	2.0 ± 0.01	1.6–2.4
X9	5.9 ± 0.06	5.0–6.8	5.6 ± 0.06	4.7–6.2	5.4 ± 0.05	4.2–6.4
X10	10.6 ± 0.04	10.2–11.0	10.6 ± 0.04	10.2–11.1	10.5 ± 0.03	10.1–10.9
X11	12.8 ± 0.06	12.1–13.6	12.4 ± 0.05	11.7–13.5	11.9 ± 0.05	10.8–12.7
X12	6.3 ± 0.04	5.9–7.1	6.0 ± 0.03	5.5–6.7	5.8 ± 0.03	5.1–6.3
X13	7.4 ± 0.05	6.8–8.0	7.2 ± 0.04	6.7–7.8	7.0 ± 0.04	6.2–7.5
X14	4.3 ± 0.03	3.9–4.7	4.1 ± 0.03	3.6–4.5	4.0 ± 0.03	3.3–4.9
X15	5.1 ± 0.02	4.9–5.6	5.1 ± 0.03	4.1–5.3	5.0 ± 0.02	4.2–5.3
X16	1.7 ± 0.01	1.6–1.8	1.7 ± 0.01	1.5–1.9	1.6 ± 0.01	1.5–1.8
X17	2.2 ± 0.02	2.0–2.6	2.1 ± 0.02	1.8–2.4	2.0 ± 0.02	1.6–2.3
X18	23.3 ± 0.20	21.3–24.6	22.1 ± 0.20	19.9–23.9	21.7 ± 0.15	20.1–23.3
X19	12.7 ± 0.07	11.9–13.4	12.3 ± 0.05	11.5–12.9	12.0 ± 0.05	10.5–12.7
X20	9.8 ± 0.06	9.3–10.4	9.4 ± 0.04	8.7–9.8	9.2 ± 0.05	8.4–9.8
X21	4.6 ± 0.04	4.0–5.2	4.6 ± 0.04	3.9–5.0	4.4 ± 0.02	4.0–4.9
X22	3.6 ± 0.02	3.3–3.9	3.6 ± 0.02	3.4–3.8	3.6 ± 0.01	3.3–3.8
X23	8.6 ± 0.08	7.8–9.3	8.4 ± 0.08	7.7–9.1	8.4 ± 0.08	7.7–9.3

Fig. 3. Differences in skull characters of juvenile *Apodemus flavicollis* in the zones of the great cormorant colony. I – control zone, II – zone of initial influence, III – zone of the longest-lasting and strongest influence, IV – zone of strong former influence, V – zone of ecotone.

subadult *M. glareolus* between zones were found, and the only near-significant one was for X16 (ANOVA, $F_{3,35} = 2.80$, $P = 0.054$). However, no subadult individuals were trapped in the zone II and only one in zone III (the two zones most strongly influenced of the colony).

Contrary to the findings for *A. flavicollis*, the influence of the zone on the skull size of juvenile *M. glareolus* was present for many characters (Fig. 5). Significant differences were found for X6 (ANOVA, $F_{4,61} = 3.19$, $P < 0.02$), X14 ($F_{4,61} = 3.00$, $P = 0.025$), X18 ($F_{4,32} = 3.22$, $P = 0.025$), X21 ($F_{4,61} = 3.55$, $P = 0.011$) and X23 ($F_{4,32} = 3.32$, $P = 0.022$), while near-significant differences were found for X12 ($F_{4,61} = 2.43$, $P = 0.057$),

X17 ($F_{4,60} = 2.28$, $P = 0.071$) and X19 ($F_{4,61} = 2.19$, $P = 0.080$).

Thus, in all age groups of *A. flavicollis*, the largest skull characters (10 cases, see Figs 1–3) were mostly found in zone III (i.e., the zone with the long-lasting and strongest influence, and with greatest number of cormorant nests), while in three cases (X17 for adult mice, X3 and X16 for subadult ones) the largest characters were found in zone V (ecotone).

In adult and juvenile *M. glareolus*, the largest skull characters (7 cases, see Figs 4 and 5) were also mostly registered in the zone III, while in two cases (X9 in adult voles and X6 in juveniles) they were in zone I
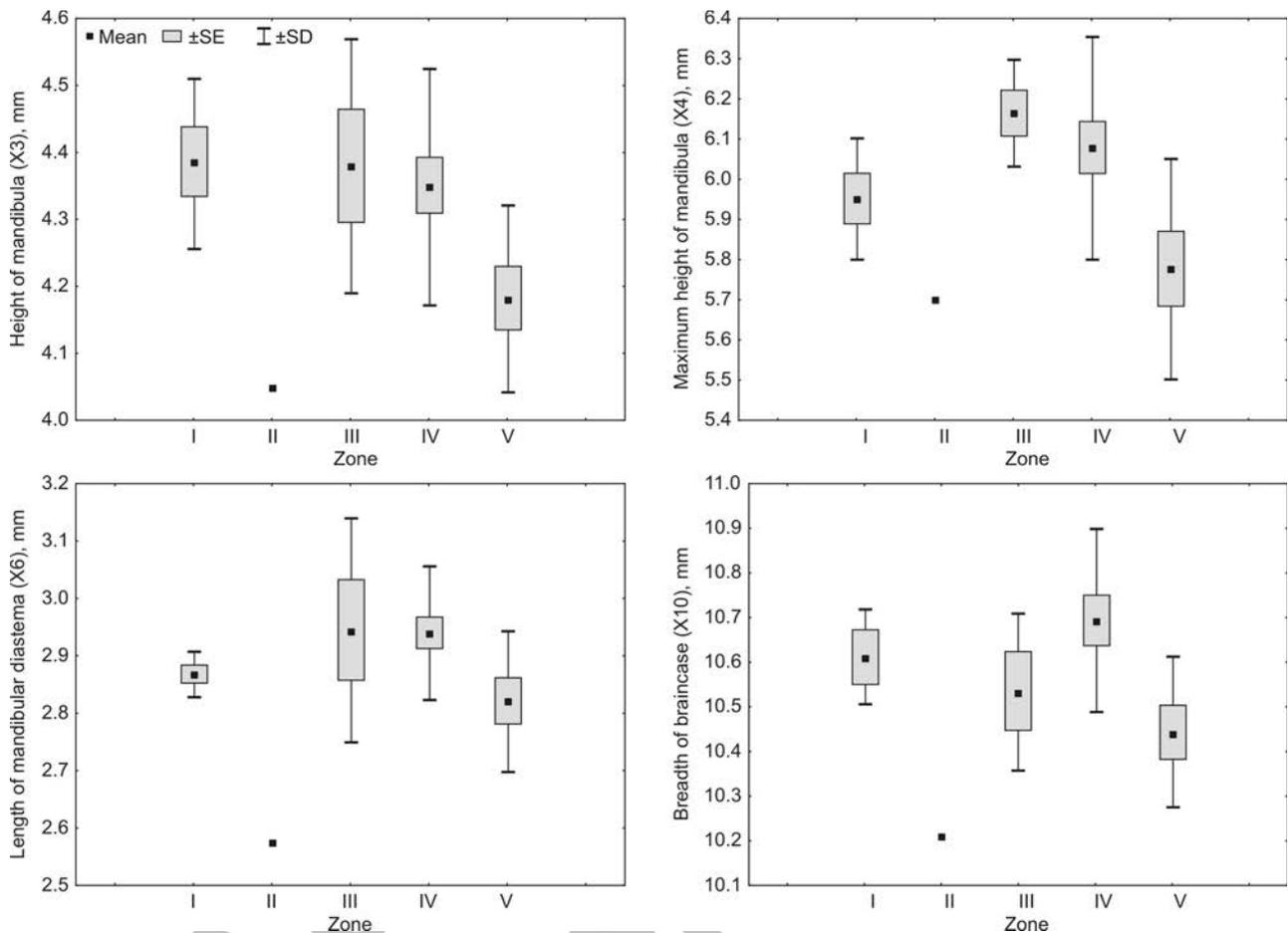
Fig. 4. Differences in skull characters of adult *Myodes glareolus* in the zones of the great cormorant colony. I – control zone, II – zone of initial influence, III – zone of the longest-lasting and strongest influence, IV – zone of strong former influence, V – zone of ecotone.

(control) and in one case (X2 in juvenile voles) in zone V.

Discussion

In the case of extreme disturbance, the response of small mammals may be nearly immediate. Populations under severe disturbance may exhibit greater-than-normal responses (Hendry et al. 1998). Life under the nests in the big colony of cormorants is by no doubts stressful to small mammals – in the oldest part of the colony, the forest ecosystem is destroyed and all coniferous trees are dead. Newly formed shrubs are mainly invasive black elderberry (*Sambucus nigra*) and red elderberry (*S. racemosa*), while greater celandine (*Chelidonium majus*) prevails in the herb layer and small balsam (*Impatiens parviflora*) is abundant. From the typical forest flora, only scarce hair grasses (*Deschampsia*) remain (Motiejūnaitė 2014).

Apodemus flavicollis and *M. glareolus* were chosen as the species for our study for several reasons. First of all, they are the dominant small mammal species living in the territory of the colony (Balčiauskienė et al. 2014) and only these two species are numerous enough to provide sufficient sample size. Secondly, both *A. flavicollis* and *M. glareolus* are well known as objects suitable for biomonitoring (Martiniaková 2010a; Petkovšek et

al. 2014). These species may coexist (Grüm & Bujalska 2000) and they do not migrate (Martiniaková 2010b).

Within this very specific territory, i.e. the zones under varying influences of the colony of great cormorants, differences in the skull size of the two rodent species (*A. flavicollis* and *M. glareolus)* were observed in our study. In general, most of the skull differences of both species were related to character length. Skulls tended to become longer.

In *A. flavicollis*, the skull size differences between zones were most expressed in subadult and adult individuals, while in *M. glareolus* it was in juveniles, with only a few characters for adults and no differences found in subadult voles.

The largest skull characters of *M. glareolus* were recorded mostly in zone III (the long lasting and strongest influence by the colony), while for subadult *A. flavicollis* it was in zone III, and for adult *A. flavicollis* in both zone III and the ecotone zone between the zones of strongest influence of the colony and surrounding forest.

These differences accompany other differences already known at the level of the small mammal community (Balčiauskienė et al. 2014), population level and individual level (Balčiauskas et al. 2015). Among these, the most intensively used zones of the colony were associated with negative impacts such as reduced
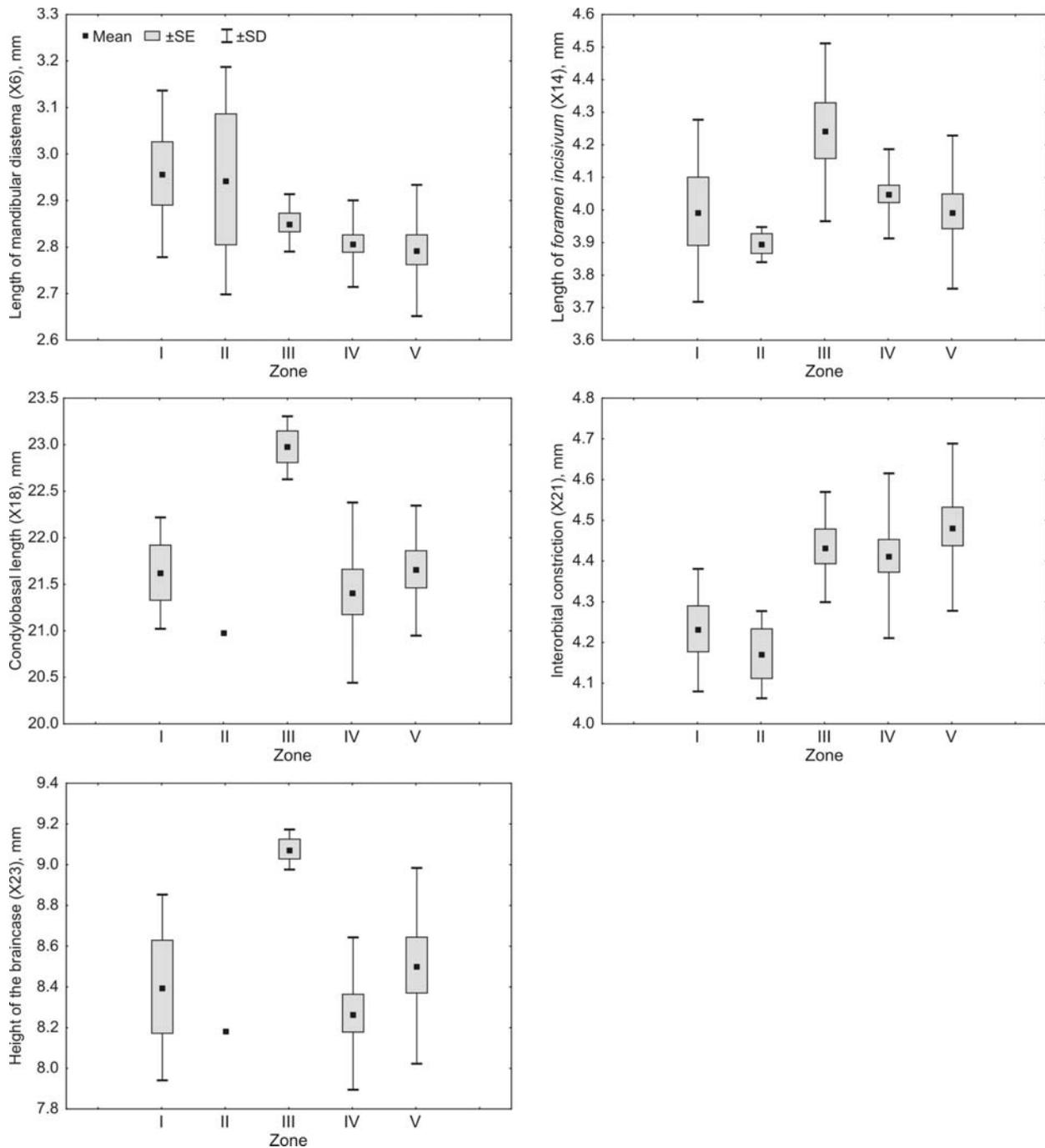
Fig. 5. Differences in skull characters of juvenile *Myodes glareolus* in the zones of the great cormorant colony. I – control zone, II – zone of initial influence, III – zone of the longest-lasting and strongest influence, IV – zone of strong former influence, V – zone of ecotone.

species diversity, changes in sex and age composition of the *A. flavicollis* population, a smaller body mass and poorer body condition.

It is known that in polluted areas animals are subjected to the influence of contaminants at spatial, temporal and media scales (Talmage & Walton 1991; Fritsch et al. 2011). Differences in the size of the animal or the size of skull morphometry may manifest themselves in very short spans (Schlanbusch et al. 2011). Host factors (sex, age, body size) also may influence observed differences (Veličković 2004; Fritsch et al. 2010; Rautio et al. 2010). For the body size of adults, it is

important how long the individual had access to high quality food while growing (Yom-Tov et al. 2003). The trophic level (diet) (Jakimska et al. 2011) and feeding strategy (Johnson et al. 1996; Dayan & Simberloff 2005; van den Brink et al. 2010) could also be of high importance.

Food resources and differences in food availability in the various zones of the cormorant colony are among the expected drivers of the observed differences. The diet of *M. glareolus* is more variable between season and habitat, and more herbivorous than that of *A. flavicollis* (Bergstedt 1965; Heroldová 1994; Abt & Bock

1998). Thus it is possible that limited food resources in the territory of the cormorant colony are not sufficient to maintain high numbers of these voles. The diet of *A. flavicollis* is more stable across habitats (Abt & Bock 1998), more calorific and based on seeds and invertebrates (Gliwicz & Taylor 2002). In addition, *Apodemus* is a very environmentally tolerant species (Renaud et al. 2005). Thus, the dominance of *A. flavicollis* in all zones of the cormorant colony may be explained by the environmental tolerance of the species and its diet. However, the observed differences in skull size between zones may have other drivers.

By their influence on the environment, cormorant colonies may be considered as heavily polluted (Klimaszyk & Joniak 2011; Klimaszyk et al. 2015). As such, zones in the colony can be differentiated according to their influence and load of additional biogens (Adamonytė et al. 2013; Motiejūnaitė et al. 2014). Body and skull size differences may be driven by the gradient of pollution (Nunes 2001; Fritsch et al. 2010; Tête et al. 2013) and also reflect the disturbance of the habitat or the influence of the stress level (Oleksyk et al. 2004; Velickovic 2007; Hopton et al. 2009).

It is known that "environmental stress can increase phenotypic variation in populations by affecting developmental stability of individuals"; for example, vegetation removal influenced fluctuating asymmetry in shrews, and their mandible traits differed in sensitivity (Badyaev et al. 2000). Developmental instability was different in disturbed and undisturbed habitats (Hopton et al. 2009) and at different stress levels (Mooney et al. 1985). In our case, from early spring and through the breeding period, small mammals experience various stressors – among them, the presence and noise of cormorants, their constant droppings, the reduced amount of shelter due to forest and grass cover damage, reduced food choices and the presence of predators visiting the colony for other items of food (nestlings, fish remains, etc.; Jasiulionis unpubl.).

In conclusion, we confirm that the colony of great cormorant colony has an influence on the skull morphometrics of *A. flavicollis* and *M. glareolus* and hypothesize that these differences enhance the ability of survival in the local conditions. Furthermore, we suggest further investigations to discover whether these differences depend on the bioaccumulations or on peculiarities of feeding in the specific habitats in the colony.

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