Studia Ecologiae et Bioethicae
13(2015)4, 117-133

Krassimira ILIEVA-MAKULEC[1]*
Dawid KOZACKI[2]
Grzegorz MAKULEC[1]

The impact of roosting birds on the abundance of two groups of soil mesofauna

Summary

The aim of the study was to assess the influence of corvid urban roosts on the abundance of two groups of soil mesofauna: mites and springtails. Two areas located in the city of Warsaw were taken into consideration, one subjected to winter roosting activity of corvids and the other not influenced by birds. The samples were taken three times, in May, July, and September of 2013. The results show a positive effect of corvid roosts on the density of soil mesofauna, especially in the top 0–5 cm soil layer. On each sampling date, we found more numerous communities of mites and springtails in the soil within the roosting area than in control. The average densities of mites ranged from 30×10^3 ind. m^{-2} to 200×10^3 ind. m^{-2} in the soil within the roost and from 6×10^3 ind. m^{-2} to 40×10^3 ind. m^{-2} in the control. In the case of springtails the average densities ranged from 9×10^3 ind. m^{-2} to 36×10^3 ind. m^{-2} in the roost and from 4×10^3 ind. m^{-2} to 8×10^3 ind. m^{-2} in the control. Among the two groups, mites prevailed over the springtails both in the soil of roost and control area.

We inferred that the corvid roosting activity, involving mainly an excrement deposition on the soil surface, influences soil mesofauna indirectly

---

[1] Institute of Ecology and Bioethics, Cardinal Stefan Wyszyński University, Wóycickiego 1/3, 01-938 Warsaw, Poland, *e-mail: k.makulec@uksw.edu.pl

[2] Institute of Technology and Life Sciences, Al. Hrabska 3, Falenty, 05-090 Raszyn, Poland

through many related changes occurring in soil environment e.g. in nutrient availability, soil acidity, microbial communities.

Key words: corvids, roost, enrichment, mites, springtails

1. Introduction

Corvids winter roosting is a phenomenon occurring all over the world. A roost is a place where birds gather to sleep the night. Usually corvids form large roosts from November to March, later they go back to their home territories to start the nest-building and breeding process. In recent years, roosts are becoming more frequent in the cities. The new food sources of anthropogenic origin and the effect of the so-called urban heat island (felt mainly during the winter), are the reason for the increasing bird colonization of urban areas (Jokimaki, Suhonen 1998, Pinowska *et al*. 2005).

In Poland, corvids (Corvidae, Passeriformes) are perfectly adapted to urban conditions. In the largest cities of the country there are many suitable places (e.g., gardens and parks) used by these birds for roosting and wintering. Very high numbers of birds in roosts (approx. 200 thousand ind.) were observed in the reserve "Las Bielański" in Warsaw (Maksym, Sławska 2011) and even more – 400 thousand ind. in the roost in the vicinity of Wrocław in 1996. Large corvid roosts have also been found in other Polish towns among others in Lublin, Opole, Przemyśl, Poznań, and Szczecin (Mazgajski, Szczepankowski 2005).

At the site where birds regularly occur in large densities a lot of environmental changes take place. The soil as a surface layer of the lithosphere is the most exposed to the impact of bird presence in the roost (Ligęza, Misztal 2000). On the ground under the roost numerous traces of bird activities including feces, bird pellets, and metabolites (e.g. uric acid) can be found. Up to now, the majority of studies have been focused on the changes in physico-chemical properties of soil (Ligęza, Misztal 1999, 2000) and vegetation (Solińska-Górnicka, Namura-Ochalska 1996, Maksym, Sławska 2011) caused by the activity of corvids in the roost. There are a few studies concerning the response of soil fauna to the corvids roosting in the urban areas (Maksym, Sławska 2011). And that is an important issue, because as many studies have been shown the numbers and diversity of soil animal communities usually in a good way reflect the conditions of soil. This is due to the fact that the soil fauna directly and indirectly influence the functioning and productivity of soil environment (Górny 1975, Bednarek *et al*. 2004). Therefore, it should be expected that changes in the community parameters of soil organisms including soil mesofauna (mites and springtails) could be a good indicator of the soil conditions within the corvids roost area.

Our aim was to check whether and how a bird roost affects the numbers in two groups of mesofauna: mites and springtails.

Our research hypothesis assumed, that roosting birds will influence soil mesofauna indirectly – soil animals will respond to the changes in soil environment as a result of guano deposition and decomposition. A higher density of both groups of mesofauna within the roost than in controls was expected.

2. Materials and methods

2.1. Study area

The study area is located in Warsaw (52°17'49 N"–21°2'40"E) about 7–8 km away from the city center and 3.4–3.5 km from the Vistula River. The area has a typical urban character, consisting mainly of blocks of flats with small not very diverse tree plantings and lawns between. The dominant tree species is the horse chestnut (*Aesculus hippocastanum*) and the most trees with a height exceeding 10 m.

Two plots of trees (of about 100 m^2) were chosen for sampling – one where trees have been used as birds roost for several years and the other adjacent to the roosting areas but not subjected to the bird influence.

Several bird species were observed on the roosting area, most belong to corvids (Corvidae) as the rook (*Corvus frugilegus*), western jackdaw (*Coloeus monedula*), the hooded crow (*Corvus cornix*) but some starlings (Sturnidae), mainly the common starling (*Sturnus vulgaris*) also was noticed. It has been observed that the birds would arrive at the roost in groups of a dozen to several dozen individuals.

Counting of birds in the studied roost was performed three times in April, late in the afternoon i.e. at the time of their gathering to the roost (Photo 1). For this purpose, we used videos and photos taken during long exposure times. The number of birds on each date is shown in Table 1. A decrease in the number of birds flying to the roost in April was noticed.

Table 1. Numbers of birds flying to the roosting place.

No	Date in April, 2013	Time period	Number of counted birds
1	3	18:45–19:15	264
2	14	19:55–20:25	258
3	22	20:29–20:49	198

Photo 1. The birds gathering in the treetops.

Photo 2. Chestnut leaf with visible traces of droppings.

Photo 3. Birds excrements on the ground under the the roost.

Within the roosting area a lot of signs (e.g. bones, fruit stones, feathers, and droppings etc.) indicating the activity of birds were found both on the leaves of trees and on the soil surface (Photos 2 and 3).

In the roosting area birds leave many droppings consisting essentially of undigested food residues in admixture with a whitish uric acid as a product of nitrogen metabolism. A layer comprised of a mixture of droppings and metabolites was well visible on the soil surface at the beginning of the study (Photo 3).

2.2. Sampling

Soil samples were collected three times: in spring (May), summer (July) and autumn (September) of 2013. At each habitat (roost and control) 5 soil samples were taken in spring and 10 samples in summer as well and in autumn.

Soil cores were collected using a steel corer of the area of 10 cm^2 to a depth of 10 cm. Samples were divided into two layers: upper (0–5 cm) and lower (5–10 cm). Mites and springtails were extracted from the soil using a high gradient Macfadyen extractor. Animals were stored in 75% ethanol, and counted under a microscope.

2.3. Statistical analysis

To assess the statistical significance of the habitat (roost and control) influence, soil layer and season, a multi-way analysis of variance (ANOVA) followed by Tukey's multiple range test was applied. Differences were considered significant at $p < 0.05$.

3. Results

3.3. Relative abundance of mites (Acari) and springtails (Collembola) in total mesofauna

We found that among the two groups of mesofauna, mites prevailed over the springtails both in the soil of the roost and control area. The percent share of each group in the total mesofauna changes in different way during the study period (Fig. 1).

The share of mites in the total number of mesofauna in the spring was higher in the roost, while in the autumn in the control soil. On the contrary in the case of springtails, their percent share was higher in spring in the control, while in autumn in soil within the roost. Thus, two different trends were observed: during the study period (from spring to autumn) within the roost the prevalence of mites over the springtails decreased, while in the control soil this predominance increased.

Fig. 1. Relative abundance of mites and springtails in the total mesofauna inside and outside the roost in spring, summer and autumn.

3.1. The density of mites

It was found that on each sampling date the average density of mites was higher in soil within the roost than in control soil, but the only significant ($p < 0.05$) difference was in summer (Fig. 2, Table 2).

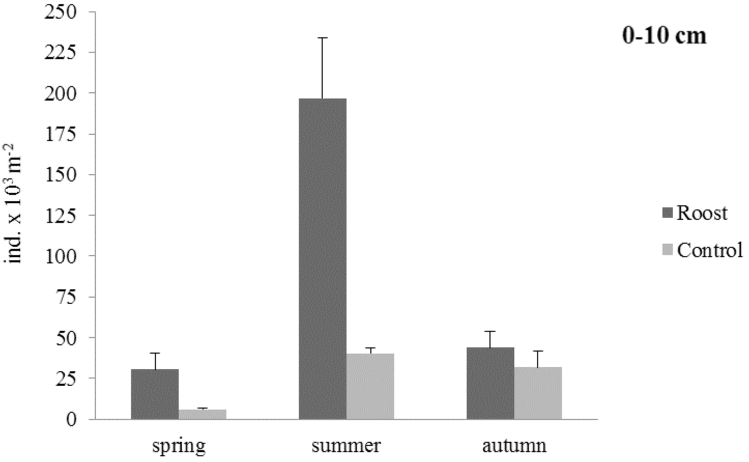

Fig. 2. The density (mean ± SE) of mite communities in the soil inside and outside of the roost.

Table 2. Results of mulivariate ANOVA for the influence of bird roosting activity on the mite density.

Variable	F	p
Habitat (roost, control)	16.092	0.0001
Layer (0–5 cm, 5–10 cm)	20.380	0.0000
Season (spring, summer, autumn)	16.266	0.0000
Habitat × Layer	13.749	0.0004
Habitat × Season	10.248	0.0001
Layer × Season	9.501	0.0002
Habitat × Layer× Season	8.892	0.0003

Statistically significant differences in the density between the habitats were observed especially in the layer of 0–5 cm, where the numbers of mites in the spring and summer, were found to be respectively 6 and 7 times higher in soil within the roost than in the control. In the layer 5–10 cm more mites in the soil under the roost than in the control were observed only in the spring (Fig. 3).

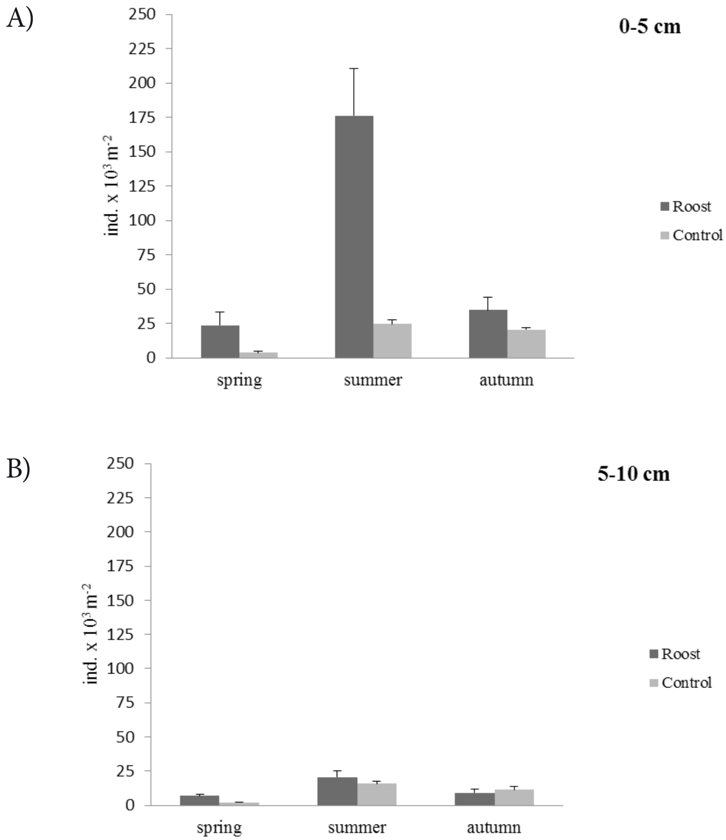

Fig. 3. The density (mean ± SE) of mite communities in the soil inside and outside of roosts in the layer 0–5 cm (A) and 5–10 cm (B).

The dynamics of mite numbers in both habitats was similar. The maximum density of soil mites in both habitats were observed in the summer, except that the peak in the roost was 5 times higher than in control. In the autumn the density of mites in both habitats decreased but it was a drop much larger inside the roost than in the control (Fig. 2).

Within the roost on each sampling date the density of mites was significantly ($p < 0.05$) higher (4–8 times i.e. 80–90% of total number) in the surface layer of 0–5 cm than in a layer 5–10 cm. However, in the control soil the density of mites in the two layers was similar or slightly higher (represented approx. 60% of the total community) in the layer 0–5 cm (Fig. 3).

3.2. The density of springtails

Our results show that the average density of springtails was significantly higher (from 2 to 6 times) in soil within the roost than in the control soil on each sampling date (Fig. 4, Table 3).

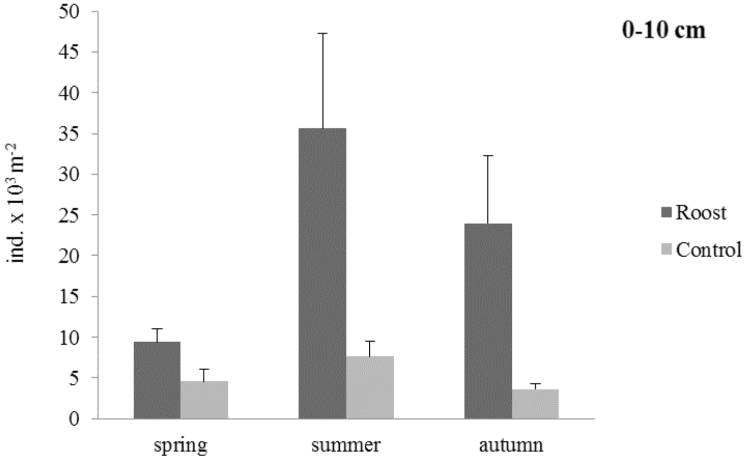

Fig. 4. The density (mean ± SE) of springtails communities in the soil inside and outside of the roost.

We found greater fluctuations in the dynamics of springtails numbers in the roost in comparison to the control. In each habitat springtails were the most numerous in the soil in the summer, but significant differences between the dates were not found (Table 3).

Statistically significant differences in the springtail density between the two habitats were observed in each layer, but it was more very clearly seen in a layer of 0–5 cm, where the density of springtails in the roost in autumn was even 9 times higher than in control (Fig. 5, Table 3).

Table 3. Results of multivariate ANOVA for the influence of bird roosting activity on the springtail density.

Variable	F	p
Habitat (roost, control)	7.999	0.0058
Layer (0–5 cm, 5–10 cm)	8.675	0.0041
Season (spring, summer, autumn)	1.723	0.1844
Habitat × Layer	4.299	0.0411
Habitat × Season	1.014	0.3669
Layer × Season	0.994	0.3741
Habitat × Layer × Season	0.744	0.4784

In each habitat the density of springtails was significantly higher in the surface 0–5 cm layer than in the layer 5–10 cm ($p < 0.05$). The percentage shares of springtails in the upper layer ranged from 75 to 85% in the soil of the roost, and from 64 to 82% in the control.

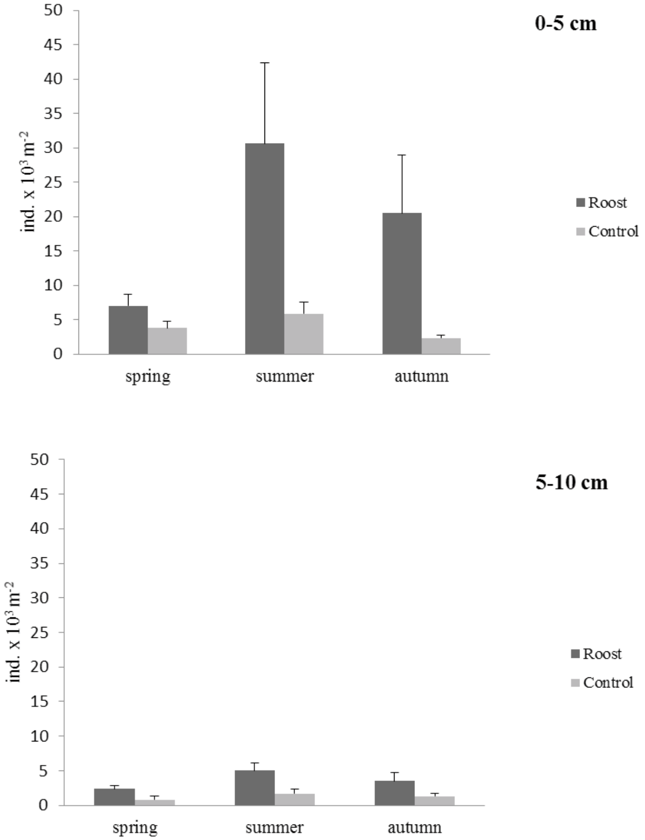

Fig. 5. The density (mean ± SE) of springtail communities in the soil inside and outside of roosts in the layer 0–5 cm (A) and 5–10 cm (B).

4. Discussion

The results of our study show a significant impact of corvid roosting activity on the density of soil mesofauna. We found more numerous communities of mites and springtails in the soil within the roosting area than in the control. These two groups of mesofauna have been also found to be among the most numerous of the all soil invertebrates studied in the area of a former corvid roost in the reserve "Las Bielański" (Maksym, Sławska 2011). To explain this positive response, we should take into consideration all changes and processes occurring in soil due to inflow of nutrients. The level of biogenic enrichment of the soil depends on the number of birds within roost area and the kind and amount of nourishment (Gilmore *et al*. 1984). Counts at roosts usually ranged from 5,000–10,000 birds, but larger roost of more 100 thousand birds were also observed (Mazgajski and Szczepanowski 2005). The roost under this study may be classified as small in terms of area and number of birds.

Most corvids gathering at roosts are known to be omnivorous. In their diet, both plant (e.g., seeds and fruits) and animal (e.g., small invertebrates) food can be find. The diverse diet influences the composition of bird droppings, which are left in high amounts on the plant leaves and on soil surface within the roost area. Biodeposition is known to be an important geochemical process, especially where large numbers of animals gather (Hicks 1979). Bird excrements consist mainly of organic compounds, nitrogen, phosphorus, calcium, and water. These substances when leached from the surface may spread further into the soil horizons (Ligęza, Misztal 2000). As Ligęza and Small (2003) found, the concentrations of mineral nitrogen, available phosphorus, and exchangeable potassium were many times higher in the soil (especially in top horizons) under the influence of birds, in comparison to the control soil.

There are many studies showing that such nutrient supply leads to the changes in the vegetation and in soil physico-chemical characteristics and microbial communities (bacteria and fungi). The nitrogen in bird droppings occurs mostly in the form of uric acid, which quickly decomposes into ammonia (Ligęza, Misztal 2000), one of the substrates used in the nitrification process carried out by the nitrifying bacteria (Weiner 2012). The nitrification process in the soil subjected to bird activity seems to occur very intensively and efficiently (Ligęza *et al*. 2001). Moreover, the high content of micronutrients (e.g. Ca, Fe, Cu, Mg, P) in the soil may also enhance this process (Ligęza, Misztal 1999). It has been proved that in the soil influenced by birds some bacteria of the phylum Actinobacteria and Firmicutes are positively correlated with the content of ammonia in the soil, while certain groups of bacteria respond positively to the high nitrogen content (Teixeira *et al*. 2013).

Moreover, although guano itself is typically alkaline, the process of its decomposition in the soil often results in increased soil acidity (Zwolicki *et al*. 2013). We found that the soil within the roost in our study was characterized by a lower pH value both in the 0–5 cm (pH=5.47) and 5–10 cm layer (pH=6.25) in comparison to soil originating from the control area – 7.13 and 7.23, respectively in upper and lower layer. Similarly, a higher acidity of the soil subjected to bird influence has been detected in other studies (Julin 1986, Ligęza, Misztal 1999, Stempniewicz *et al*. 2007).

An indicator of the enhanced microbial development in our study could be the observed increase of the density of bacterial and fungal feeding nematodes (unpubl. data from this study) which in turn are a component of mesofauna diet mainly to mites with a group of Gamasida, commonly found in soils (Górny 1975).

It is also well known that the input of nutrients such as phosphorus and nitrogen is essential to the plant growth, but in some cases it leads to a reduction of plant species diversity in eutrophied terrestrial communities presumably because of ammonium poisoning (Kolb *et al.* 2010). Some transformations of vegetation due to bird roosting activity were also visible in our study. In comparison to the control area, a lack of vegetation in the herb layer within the roost was noticed (Photo 3). Our observations are in agreement with the finding of Maksym and Sławska (2011) who observed larger vegetation changes in the ground layer than in the layer of tree and bushes in a former roost.

In conclusion, in our study the corvid roosting activity involving mainly excrement deposition seems to influence soil mesofauna indirectly through changes occurring in soil environment (e.g. in nutrient availability, soil acidity, microbial, and nematode communities).

Our results differ from the results of Kolb *et al.* (2010) which found that despite nutrient enriched detritus, collembolan densities decreased on active cormorant islands. According to Kolb *et al.* (2010) such response may be attribute to direct (through soil acidification) and indirect (through changes in soil microbial communities) negative effects of high N inputs. Furthermore, they also stated that decreased vegetation cover might alter soil moisture and micro-climate which could negatively affect collembolans. The most probable cause for that disagreement could be the differences in the quantity and durability of the deposited guano (and all changes related to that) between the permanent breeding colonies under investigation in Kolb *et al.* (2010) and corvid winter roosts formed periodically, as it was in our study.

Our study shows that urban roosts as "hot spots" which have been proved to play an important role in nutrition of urban plants and in the microbial processes occurring in urban areas are also likely to influence the dynamics of soil animal communities. Further studies are needed to clarify the effects of such biogenic enrichment within roost area on the diversity of soil mesofauna.

Summing up, studies of the role of soil animals in nutrient cycles in cities seem to be in an early stage, but in the future the results from such studies may contribute to the development of ecologically sustainable urban environments.

References

Bednarek R., Dziadowiec H., Pokojska U., Prusinkiewicz Z., 2004, *Badania ekologiczno-gleboznawcze*, Wydawnictwo Naukowe PWN, Warszawa.

Gilmore A.R., Gertner G.Z., Rolfe, G.L., 1984, *Soil chemical changes associated with roosting birds*, Soil Sci. 138 (2), 158–163.

Górny M., 1975, *Zooekologia gleb leśnych,* PWRiL, Warszawa.

Hicks R.E., 1979, *Guano deposition in an Oklahoma crow roost*, Condor, 81, 247–250

Jokimaki J., Suhonen J., 1998, *Distribution and habitat selection of wintering birds in urban environments,* Landscape and Urban Planning, 39, 253–263.

Julin K., 1986, *Decline of second-growth Douglas-fir in relation to Great Blue Heron nesting*, College of Forest Resources University of Washington Seattle, Northwest Science, 60, 4, 201–205.

Kolb G.S., Jerling L., Hambäck P.A., 2010, *The impact of cormorants on plant-arthropod food webs on their nesting islands*, Ecosystems, 13, 353–366

Ligęza S., Misztal M., 1999, *Zmiany właściwości gleb na obszarze noclegowiska gawronów,* Zesz. Probl. Post.Nauk Roln. 467, 379–385.

Ligęza S., Misztal M., 2000, *Zbiorowiska ptaków jako czynnik modyfikujący środowisko przyrodnicze*, Instytut Gleboznawstwa i Kształtowania Środowiska Przyrodniczego, Akademia Rolnicza, Lublin, 293–299.

Ligęza S., Small H., Misztal M., Ciesielczuk P., Piliszczuk G., 2001, *Zmiany wybranych właściwości środowiska glebowego na terenie kolonii kormoranów w Kątach Rybackich*, Acta Agrophysica, 56, 155-164.

Ligeza S., Smal H., 2003, *Accumulation of nutrients in soils affected by perennial colonies of piscivorous birds with reference to biogeochemical cycles of elements*, Chemosphere, 52, 595–602.

Maksym T., Sławska M., 2011, *Wpływ ptaków krukowatych na roślinność i faunę glebową rezerwatu Las Bielański*, Studia i Materiały CEPL w Rogowie, R. 13. Zeszyt 2 (27), 126–135.

Mazgajski T., Szczepanowski R., 2005, *Liczebność zgrupowania ptaków krukowatych zimujących w Warszawie*, in: Jerzak L., Kavanagh B.P., Tryjanowski P. (eds) „Ptaki krukowate Polski" [Corvids of Poland], Bogucki Wyd. Nauk., Poznań, 428–434.

Pinowska B., Pinowski J., Kosicki J., 2005, *Zmiany liczebności gawrona Corvus frugilegus i wrony siwej Cormis comix pod wpływem urbanizacji w strefie podmiejskiej*, in: Jerzak L., Kavanagh B., Tryjanowski P. (eds) "Ptaki krukowate Polski" [Corvids of Poland], Bogucki Wyd. Nauk., Poznań, 473–480.

Solińska-Górnicka B., Namura-Ochalska A., Symonides E., 1996, *Stan i dynamika szaty roślinnej rezerwatu przyrody „Las Bielański”*. Ekspertyza wykonana na zlecenie Departamentu Ochrony Przyrody MOŚZNiL, Warszawa, 1–5.

Stempniewicz L., Zmudczyńska K., Zwolicki A., Wojtuń B., Matuła J., Iliszko L., 2004–2007, *Wpływ dużych kolonii ptaków morskich na strukturę i funkcjonowanie lądowej części ekosystemu arktycznego na Spitsbergenie*, Projekt Zamawiany: PBZ–KBN–108/PO4, 25–27.

Teixeira L., Yeargeau E., Balieiro F., Piccolo M., Peixoto R., Greer Ch., Rosado A., 2013, *Plant and bird presence strongly influences the microbial communities in soils of Admiralty Bay*, Maritime Antarctica, 8, (6) 1–10.

Weiner J., 2012, *Życie i ewolucja biosfery. Podręcznik ekologii ogólnej*, Wydawnictwo Naukowe PWN, Warszawa, 89–91.

Zwolicki A., Zmudczyńska-Skarbek K.M., Iliszko L., Stempniewicz L. 2013, *Guano deposition and nutrient enrichment in the vicinity of planktivorous and piscivorous seabird colonies in Spitsbergen*, Polar Biol. 36, 363–372