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Beata DULISZ, Jacek J. NOWAKOWSKI

The species diversity of the avifauna in built-up areas in the city of Olsztyn (NE Poland)

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Abstract. From 1991 to 1993 the breeding birds were censused in five types of built-up areas in the city of Olsztyn (NE Poland). The bird communities were characterized by Margalef's index of species diversity and Simpson's index of dominance structure. Areas of new construction had the lowest species diversity (d = 3.23), with a clear dominance of one species — *Columba livia domestica* (c = 0.44). The breeding communities of the industrial area had high species diversity (d = 10.13), but the lowest population density. The most diverse communities occurred in suburban developments of the "villa" type (d = 11.53), and in a housing estate district with older buildings and urban green space (ground cover and shrubs) (d = 9.55). Analysis of differences in indices of species diversity showed that the factors influencing diversity were the percentage cover of urban green space, the percentage cover of built-up areas and the presence of small bodies of water.

Key words: urban environment, bird communities, urban built up area, Olsztyn

Dept. of Biology Didactic, Teachers Training College, Żołnierska 14, 10–561 Olsztyn, POLAND

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INTRODUCTION

Research on the communities of breeding birds in urban environments has concentrated mainly on the avifauna of urban green space and suburban woodlands (Luniak 1977, 1983). In contrast, and particularly in Eastern Poland, much less work has been done on the avifauna of built-up areas, and especially in the way that this varies with the type and age of development (Luniak & Głażewska 1987).

The aim of this work was to compare the communities of breeding birds inhabiting built-up areas of Olsztyn. These areas vary in the type and age of buildings, in spatial structure and in the role of green space. We also sought to determine the factors that influence the diversity of communities of breeding birds in the environments under discussion.

STUDY AREA

Olsztyn lies in northeast Poland, in the center of the Warmian and Mazurian geographical areas. The administrative boundaries of the city include an area of about 88 km^2 (166 000), of which only about half is built-up. Nowakowski (1995) provided a map of Olsztyn's habitats.

The built-up urban area is very diverse (Fig. 1). About half consists of residential areas of the "villa" type, while the center of the city (the Old Town) has the typical dense development of such areas. The remaining areas are variously-aged housing estates of the "tower block" type as well as industrial built-up areas. Green space associated with housing estates or places of work, or else existing independently, covers a total of about 370 ha (Stypiński & Ciecierska 1988).

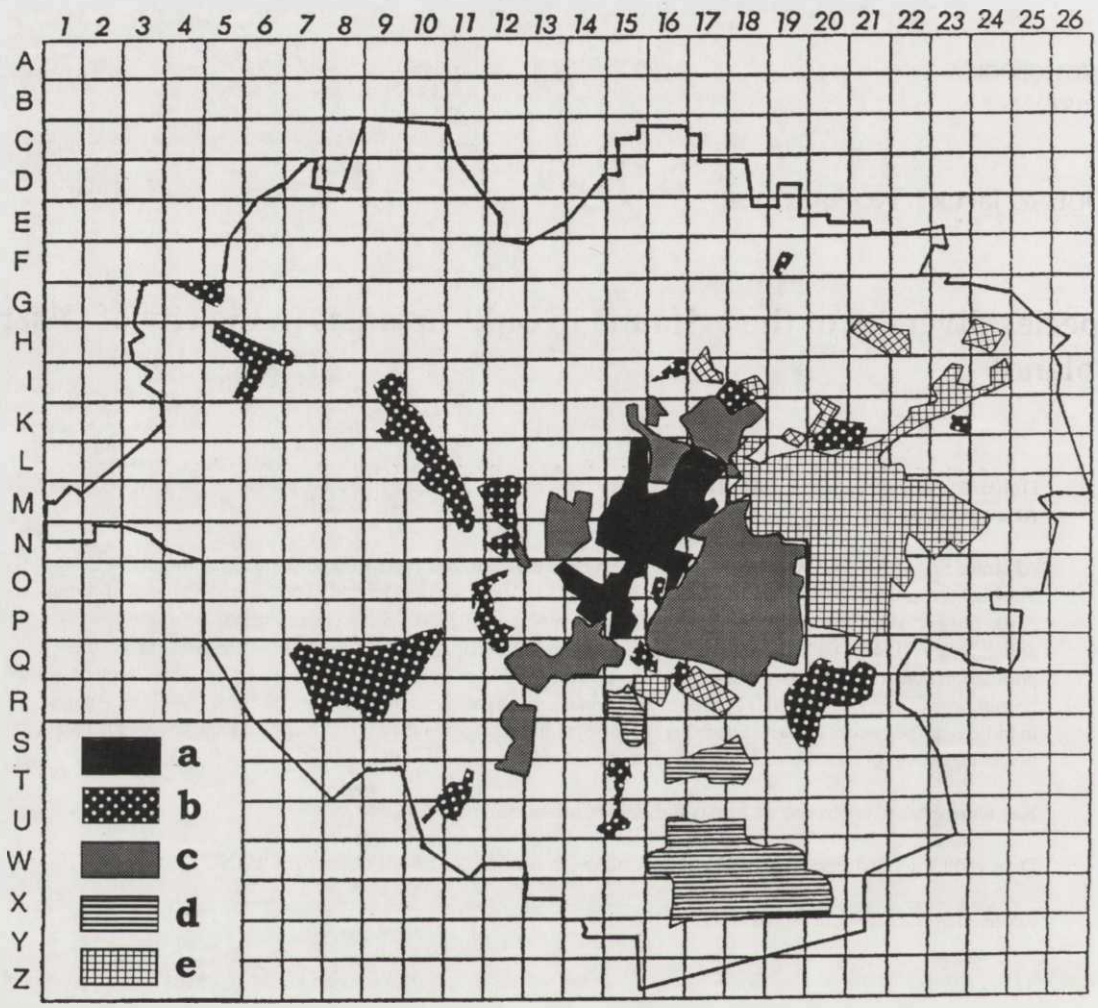

Fig. 1. Distribution of habitats studied within the municipal area of Olsztyn: a — Old Town, b — residential quarters, c — Old Housing estates, d — New Housing estates, e — industrial district.

[Ryc. 1. Rozmieszczenie biotopów na obszarze administracyjnym Olsztyna: a — Stare Miasto, b — zabudowa willowa, c — starsze osiedla mieszkaniowe, d — nowe osiedla mieszkaniowe, e — tereny przemysłowe.]

We established sampling areas in the five types of built-up environment in Olsztyn. These habitat types differ in the form and age of construction, as well as in the extent, and degree of development of green space (Tab. 1).

METHODS

We conducted our research during 1991–1993. We made counts in the early morning using a modified version of the mapping method developed by Tomiałojć (1968). The 6–9 census visits made annually were carried out between March 15th and the beginning of July. Areas I, III and IV were censused in the years 1991–1993, and areas II and V in 1993 only.

Margalef's index of species richness was used to characterize the breeding communities. The formula is as follows:

$$d = S-1/\log N$$

where: S = number of species in an assemblage, and N = total number of individuals in an assemblage (Margalef 1958).

Table 1. Characteristics of the five types of built-up areas studied.

[Tabela 1. Charakterystyka pięciu wyróżnionych typów zabudowy miejskiej w Olsztynie.]

Study plot	Age of buildings (years)	Type of built-up area	Vegetation	
			percentage cover	degree of development
I	>30	close-in three storey tenement buildings	low	
II	20–30	block-type building	high	advanced
III	1–5	block-type building	very low	very limited
IV	10–15	built-up area od the "villa" type	high	advanced
V	5–10	industrial built-up area	quite high	advanced

The dominance structure of the community was described by Simpson's index:

$$C = \Sigma(n_i/N)^2$$

where ni = number of individuals of the i-th species, and N = number of individuals of all species combined (Simpson 1949).

We used cluster analysis to define the similarity of the breeding communities in the selected areas (Norusis 1990). Ward's method was used to determine the distance between communities characterized by the number of species, the total density and the values of the Margalef and Simpson indexes. The means for all the variables in a given cluster were calculated, and the Euclidean distance to the mean of the cluster was then determined in each case (Norusis 1990).

We used correlation analysis to determine which factors in the urban environment of Olsztyn influenced the species diversity of communities. In these analyses we related values for the Margalef coefficient (d) with the cover for urban green space (0 to 100 per cent), the proportion of the area completely built-up (0 to 100 per cent), and an index of 1–8 for the degree to which the environment was mosaic-like in character. We used our data from 1993 to calculate this index and the other statistics. The 1993 data were based on 100 randomly-selected areas of 500 x 500 m within a mapping network covering the city.

RESULTS

Species composition and dominance structure

We found a total of 41 breeding species in the 5 habitat types we identified in Olsztyn. However, only 10 of these species accounted for more than 5 per cent of the total number of birds (Tab. 2). The group of

Table 2. Dominant and subdominant species in the breeding bird communities of the five types of built-up habitat in Olsztyn.

[Tabela 2. Dominujące i subdominujące gatunki lęgowych zespołów ptaków pięciu typów obszarów zabudowanych miasta Olsztyna.]

Area	Dominant and subdominant species in community
I	*S. decaocto* (23.3%), *P. domesticus* (22.3%), *C. monedula* (14.1%), *A. apus* (13.1%), *C. livia f. domestica* (9.3%), *D. urbica* (5.4%), *S. vulgaris* (3.0%), *P. major* (1.7%), *H. rustica* (1.5%), *M. alba* (1.4%)
II	*P. domesticus* (32.9%), *S. decaocto* (15.6%), *C. monedula* (12.0%), *C. livia f. domestica* (9.1%), *A. apus* (6.2%), *S. vulgaris* (2.9%), *D. urbica* (2.6%), *P. major* (2.4%), *P. caeruleus* (1.9%), *A. palustris* (1.9%), *F. coelebs* (1.4%), *S. curruca* (1.5%), *M. alba* (1.5%), *Pass. montanus* (1.4%), *P. pica* (1.2%)
III	*C. livia f. domestica* (63.2%), *P. domesticus* (15.1%), *D. urbica* (12.9%), *C. monedula* (2.7%), *M. alba* (2.0%), *P. ochruros* (1.5%), *O. oenanthe* (1.2%)
IV	*P. domesticus* (28.8%), *S. vulgaris* (10.4%), *Pass. montanus* (6.5%), *P. major* (6.5%), *P. ochruros* (5.9%), *S. curruca* (4.7%), *C. chloris* (4.7%), *M. alba* (3.4%), *P. pica* (3.2%), *A. apus* (3.2%), *F. coelebs* (3.2%), *P. caeruleus* (3.1%), *S. decaocto* (2.5%), *S. communis* (1.7%), *C. carduelis* (1.4%), *A. palustris* (1.4%), *C. monedula* (1.4%) *P. phoenicurus* (1.2%)
V	*P. domesticus* (39.2%), *Pass. montanus* (12.8%), *S. decaocto* (5.7%), *S. vulgaris* (4.9%), *A. apus* (3.8%), *P. major* (3.8%), *A. palustris* (2.7%), *P. pica* (2.2%), *P. ochruros* (2.2%), *S. curruca* (2.2%), *M. alba* (2.2%), *E. citrinella* (1.9%), *H. rustica* (1.9%), *F. coelebs* (1.9%), *P. caeruleus* (1.6%), *D. urbica* (1.4%), *C. livia f. domestica* (1.4%), *O. oenanthe* (1.4%), *C. carduelis* (1.1%), *C. chloris* (1.1%), *S. communis* (1.1%), *T. pilaris* (1.1%)

subdominants (each accounting for 1–5 per cent of the total number of birds) included an additional 14 species, with the remainder breeding at only a few sites and accounting for less than one per cent of the total number of birds.

The largest number of breeding species occurred in the "villa" type (plot IV). This breeding community also had the highest index of species richness (d = 11.53), as well as a moderately-high value for overall density (39.0 pairs per 10 ha) (Tab. 3).

Table 3. Characteristics of the breeding bird communities in various types of built-up areas in Olsztyn.

[Tabela 3. Charakterystyki lęgowych zespołów ptaków różnych obszarów zabudowanych miasta Olsztyna.]

Plot	Number of sp.	p/10ha	index d	index C
I	19	80.8	6.12	0.16
II	26	56.8	9.55	0.16
III	10	64.6	3.23	0.44
IV	33	39.0	11.53	0.12
V	26	28.3	10.13	0.18

Plots I and II (Old Town type and housing estates of the tower block type between 20 and 30 years old, respectively) each had from 19–26 breeding species. The breeding communities of both habitat types were similar in species composition and dominance structure (Tab. 2 and 3). The Old Town (with closed cover of buildings) community differed from the community in the housing estate type in having a higher overall bird density, as well as a lower value for species richness.

The area of industrial construction was inhabited by species nesting on or in buildings, as well as species that used the abundant greenery in the area (Tab. 2). This area had the lowest overall bird density (28.3 pairs per 10 ha), yet a relatively high value for species richness (d = 10.13).

Differentiation of the breeding communities

We distinguished two avifaunal groups based on the similarity of the avian communities (Fig. 2). The first included the three groupings from the built-up area: older tower blocks, the "villa" type construction and industrial construction (plots II, IV and V respectively). The second group included breeding birds in the new housing estate (plot III) and in the Old Town (plot I).

Correlation analysis showed that differences in species richness among the breeding bird communities were related to three factors: the proportion of green space ($r = 0.67$, $n = 100$, $p << 0.05$), the degree to which the environment had a mosaic-like character ($r = 0.47$, $n = 100$, $p << 0.05$) and the percentage of the area that was built-up ($r = -0.66$, $n = 100$, $p << 0.05$). The Margalef index of species richness was positively

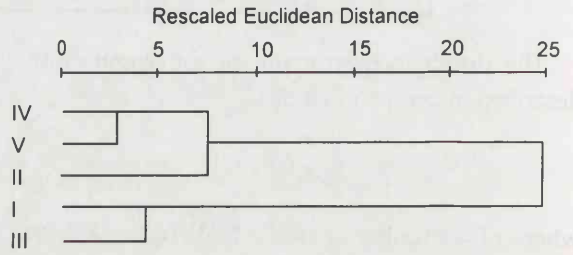

Fig. 2. The hierarchical cluster analysis of similarity between the breeding bird communities of the five build-up habitats we studied in Olsztyn.

[Ryc. 2. Hierarchiczna analiza podobieństw miedzy zespołami lęgowymi ptaków badanych terenów zabudowy miejskiej Olsztyna.]

related to both the percentage cover of green space and the diversity of the urban environment (Fig. 3, 4). In contrast, the amount of built-up area was inversely related to the species richness of the breeding community (Fig. 5). In addition, there was significant positive relationship between the Margalef index and the presence of water bodies in the environment (correlation coefficient $r = 56$, $n = 100$, $p << 0.05$).

CONCLUSIONS

There were fewer species in the built-up areas of Olsztyn than in either the city as a whole (comparison using the authors' data) or in the areas of urban green space studied in other towns and cities (Luniak 1974, Luniak 1983). Only 10 species from the breeding community fulfilled the criterion for 5% dominance. The majority of these were species nesting in or on buildings. The species compositions of the communities were similar to those in the built-up areas

of other Polish towns and cities (Luniak & Głażewska 1987).

The research indicated significant differentiation among in the avian communities from the different types of built-up areas.

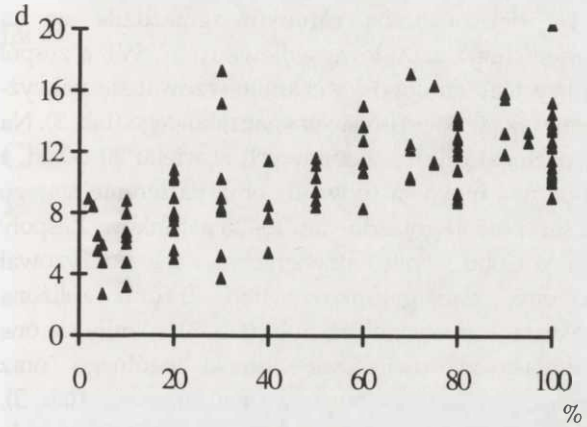

Fig. 3. Relationship between Margalef's index (d) and share of urban green areas (%).

[Ryc. 3. Udział miejskich terenów zieleni (%) w stosunku do wskaźnika Margalefa (d).]

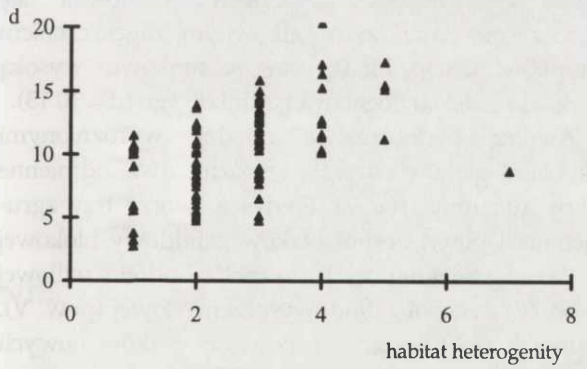

Fig. 4. Relationship between Margalef's index (d) and the index of habitat heterogeneity (1–7).

[Ryc. 4. Wskaźnik mozaikowatości środowiska (1–7) w stosunku do wskaźnika Margalefa (d).]

The communities that were richest in species were the "villa" and the industrial built-up habitat types. The richness of breeding species in these two areas was related to the relatively high levels of habitat diversity. The "villa" areas of Olsztyn are rich in shrubs, trees and gardens. A similar situation occurs in the area of industrial construction. These areas are on the periphery of the city where low density and dispersed development provides large tracts of undeveloped land where the vegetation is left to develop naturally. The resulting high levels of habitat diversity is important in providing for the large number of breeding species present in these areas.

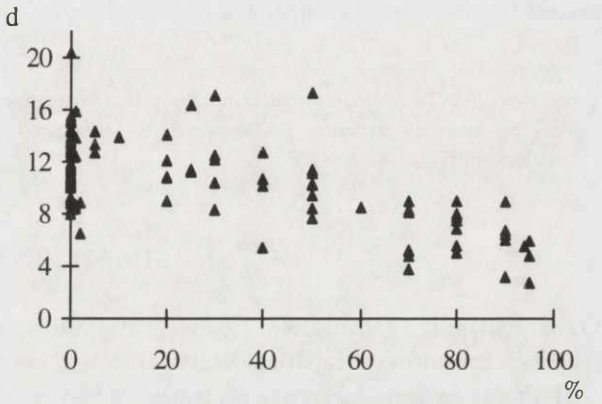

Fig. 5. Relationship between Margalef's index (d) and the share of built-up areas (%).

[Ryc. 5. Udział terenów zabudowanych (%) w stosunku do wskaźnika Margalefa (d).]

In contrast, communities with the smallest number of breeding species occurred in the areas of new housing estates. The community was dominated by one species, the feral pigeon, *Columba livia f. domestica*. Such simple community structure is characteristic of early successional stages in the development of breeding bird communities in urban environments. It occurs because few species can tolerate the significant changes wrought in the environment during the construction of the estates. Following are the factors we identified as those most likely to influence the species richness of breeding communities in the urban environment: the proportion of an area that is built up, the degree to which the vegetation has developed, the presence of bodies of water and the degree of environmental complexity.

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STRESZCZENIE

[Zróżnicowanie gatunkowe lęgowej awifauny na terenach zabudowy miejskiej Olsztyna]

Badania prowadzone były w latach 1991–1993 na powierzchniach próbnych położonych w pięciu wyróżnionych typach środowisk zabudowy miejskiej Olsztyna (ryc. 1), różniących się typem zabudowy, wiekiem zabudowy, stopniem pokrycia powierzchni zielenią miejską oraz stopniem jej wyrośnięcia (tab. 1). Liczenia prowadzone były przy użyciu zmodyfikowanej metody kartograficznej. Różnorodność gatunkowa zespołów lęgowych opisana została indeksem bogactwa gatunkowego Margalefa, a struktura dominacji indeksem Simpsona. Podobieństwo między zespołami lęgowymi wybranych terenów określono przy pomocy metody analizy skupień (cluster analysis). Celem określenia jakie czynniki środowiska miejskiego Olsztyna wpływają na zróżnicowanie gatunkowe zespołów wartość współczynnika Margalefa (d) była korelowana z udziałem powierzchni zieleni miejskiej (0–100%), udziałem powierzchni pokrytych zabudową (0–100%), indeksem mozaikowatości środowiska (1–8). Współczynnik ten i pozostałe dane obliczone zostały dla 100 losowo wybranych powierzchni (500x500m) siatki kartograficznej pokrywającej obszar miasta na podstawie materiałów zebranych podczas prac terenowych w roku 1993.

Przeprowadzone badania wykazały występowanie na badanych terenach zabudowanych 41 gatunków ptaków lęgowych, z których tylko 10 występowało z częstością większą niż 5% (tab.2).

Największa liczba gatunków gnieździła się na powierzchni z zabudową willową (pow. IV), a zespół lęgowy tego środowiska charakteryzował się najwyższym wskaźnikiem bogactwa gatunkowego (tab. 3). Na terenach osiedli mieszkaniowych w wieku 20–30 lat, z zabudową blokową (pow. II) oraz na terenie starego miasta (pow. I) gniazdowało 19–26 gatunków. Zespoły lęgowe obu tych powierzchni charakteryzował podobny skład gatunkowy (tab. 2) oraz zbliżona struktura dominacyjna zespołu (tab. 3), różniły się one natomiast wartością zagęszczenia ogólnego oraz wartością wskaźnika bogactwa gatunkowego (tab. 3). Obszar zabudowy przemysłowej zasiedlały przede wszystkim ptaki gniazdujące na budynkach oraz wśród zieleni, która w tym środowisku miała dość wysoki udział powierzchniowy i stwarzała dogodne warunki gniazdowania dla wielu z nich (tab. 2), przy czym zgrupowanie tego obszaru cechowało się jednocześnie najniższym całkowitym zagęszczeniem gatunków (28.3p/10ha) oraz stosunkowo wysoką wartością indeksu bogactwa gatunkowego (d = 10.13).

Analiza podobieństwa między wyróżnionymi zespołami ptaków pozwala wyróżnić dwie odmienne grupy awifauny (ryc. 2). Pierwszą tworzą trzy zgrupowania lęgowe: zespół ptaków zabudowy blokowej w starszym wieku (pow. II), zespół zabudowy willowej (pow. IV) i zespół zabudowy przemysłowej (pow. V). Grupę drugą tworzą: zgrupowanie ptaków nowych osiedli mieszkaniowych (pow. III) i starego miasta (pow. I).

Zmiany bogactwa gatunkowego zespołu ptaków lęgowych wiązały się z trzema czynnikami: udziałem powierzchni zieleni, stopniem mozaikowatości środowiska i udziałem powierzchni zabudowanej (ryc. 1–3).