

Fauna of the Big City – Estimating Species Richness and Abundance in Warsaw, Poland

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Introduction

While we know much about the diversity of some animal groups in cities - e.g. birds of European cities [Kelcey & Rheinwald 2005], Lepidoptera of London (Plant 1987, 1993), bats of Vienna (Spitzenberger 1990), insects of Rome (Zapparoli 1997), nowhere has there been made an integrated assessment of all wild, multicellular animals living within the administrative boundaries of a city. Therefore, I summarize here the extensive work carried out by the Institute of Zoology of the Polish Academy of Sciences in Warsaw to document the urban fauna of Warsaw, Poland.

Warsaw is a city of 1.7 million people covering an area of 517 km² in central Poland. Vegetated habitats (vegetation in housing estates, parks, allotment gardens, cemeteries, periphery forest parks, green open areas) comprise ~28% of this area, and there are still (rapidly decreasing) wide patches of farmland. The river Vistula, with its 28 km-long green belt, crosses the city. The fauna of Warsaw has been studied extensively (Czechowski 1990, Luniak & Pisarski 1994). From 1974–1990 a research project was carried out by the Institute of Zoology into terrestrial invertebrates of Warsaw and the invertebrate fauna of the Warsaw region (specifically Mazowsze, Central Poland). More than 90 families and orders of animals were studied by about 36 specialists. Invertebrate communities were studied in tree canopies, shrubs, herbaceous ground cover, and in the soil of urban and semi-natural green habitats using standard methods (Czechowski & Pisarski 1981). Major results were summarized by Pisarski (1982, 1990) and in five volumes: “Species composition and origin of the fauna of Warsaw” – Part 1 (Czechowski & Pisarski 1981), Parts 2 and 3 (Czechowski et al. 1982a, 1982b), and “Structure of the fauna of Warsaw; effects of the urban pressure on animal communities” (Czechowski & Pisarski 1986, 1987). In addition to these invertebrate surveys, Luniak et al. (2001) and Nowicki (2001) developed an atlas of Warsaw’s birds based on field studies carried out by their team of 50 observers in 1986–1990 and 1999–2000. Mammals of Warsaw were described in the review by Luniak & Nowicki (1990), as were bats (Lesinski & Fuszera, 2001), and amphibians (Mazgajska, 1996, 1998).

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How many species live in a big city?

These studies identified ~ 3800 species of terrestrial invertebrates (Chudzicka & Skibinska 1994) and ~ 320 species of vertebrates as living in the administration area of Warsaw during the past few decades. This estimate for vertebrates is likely accurate. But the list of invertebrate fauna is fairly incomplete and it is constantly being increased by new investigations, e.g. recent studies on butterflies and moths (Winiarska 2002, 2003, 2004) added several tens of species to the list. Aquatic invertebrates, invertebrates living in house interiors and other structures (e.g., sewer systems), and parasites of wild animals have not yet been assessed and cannot be included. Considering these omissions, the diversity of multicellular animals living in Warsaw likely approaches 6–7 thousand species.

In the European literature there are very few data which could be compared with this estimate. In Lodz (city of 800,000 people in Central Poland), 3059 animal species (including the group described by these authors as “Protozoa”) have been recorded since the 1920s, and the total number of species is estimated at 10–14,000 (Markowski et al. 2004). In Rome, 5151 insect species have been recorded from about 650 urban sites “. . . from the first half of 19th century up to 1996” (Zapparoli 1997). Klausnitzer (1988, 1993) made an extensive ecological and taxonomical review of urban fauna and estimated (1988) that cities of Central Europe (together) could be inhabited by about 18,000 animal species.

Even if these estimates are exaggerated, or my calculation for Warsaw is low, these results suggest that richness of the invertebrate fauna in big European cities exceeds several thousand species and that the knowledge concerning this important component of urban wildlife is poor.

Our knowledge concerning vertebrates of cities is much better. Among about 320 species of this group which have been recently recorded from Warsaw there are about 40 species of mammals, ~247 species of birds (~187 regularly occurring, ~131 – breeding), 5 reptiles, 11 amphibians, and ~30 fishes. Data from cities like Berlin (Sukopp 1990, Otto & Witt 2002), Moscow (Risn 1998), and Lodz (Markowski et al. 2004) indicate that each city contains 35–46 species of mammals, 75–160 species of birds (Kelcey & Rheinwald 2005), 3–5 species of reptiles, 11 species of amphibians, and 30–42 species of fishes. (in Łodz.14 species as the city has no large water bodies). Thus Warsaw seems to be similar to these cities.

Relative species richness

The total number of about 4100 species in Warsaw is about 12% of all “wild” animal species (~ 35, 400 species) which have been recently identified for all of Poland (Chudzicka & Skibinska 2003). For Łodz (Markowski et al. 2004), 3059 animal species were recorded since the 1920s, or about 9% of the total fauna of Poland. If we use the above sources and compare only vertebrates (a relatively well recognized group for both cities), we find that Warsaw has ~ 320 spp, and Lodz ~ 206 spp: all of Poland has 659–690 spp, so the proportions are 48–50% for Warsaw and 30–31% for Lodz.

Urban animal communities usually have only a small proportion of the species found in natural habitats in nearby non-urban areas (Luniak 2004, Marzluff 2005). This is the case for Warsaw’s birds. The entire city includes 65% of the region’s avifaunal species, but only 37% of them are found within the most developed parts of the city (Luniak et al. 2001, Nowicki 2001). The invertebrate fauna of Warsaw relative to the regional fauna is increasingly impoverished as one moves along a gradient of increasing urbanization. Pisarski (1982, 1990) documented 3534 species in the region, but the sources above only found 2005 species (57% of the regional pool) in green suburbs of Warsaw, 31% (1109 spp) in urban parks, and 14% (489 spp) in small green patches in the city center. This general decrease in species richness with increasing urbanization is pronounced in almost all taxonomic groups in Warsaw (Table 1).

Table 1 Species richness along Warsaw’s gradient of urbanization. Regional data are from the semi-natural habitats in the Mazowsze region where Warsaw is situated. “Warsaw” includes various habitats in the city and suburbs of Warsaw. “Parks” are urban parks. “City” includes the green areas in the city center such as courtyards, lawns, and street trees

Animal taxa	Region	Warsaw	Parks	City
Terrestrial snails Gastropoda (terrestra)	55	32	25	5
Earthworms Lumbricidae	12	15	8	8
Spiders Aranei	424	254	134	43
Carabids Carabidae	323	276	96	44
Ladybirds Coccinellidae	58	51	28	14
Neuropterids Neuropterida	56	43	35	14
Flies Diptera, Tabanomorpha	131	95	29	10
Ants Formicidae	43	37	21	11
Wasps Vespidae and Eumenidae	42	14	10	10
Leafhoppers Auchenorrhyncha	270	171	97	43
Noctuid moths Noctuidae	309	270	49	90
Mosquitos Culicidae	35	26	13	7
Springtails Collembola*	61	75	57	55
Percentage spp of 13 taxa above	100%	75%	33%	19%
Total spp of all taxa studied in Warsaw	3534	2005	1109	489
Percentage of all taxa studied in Warsaw	100%	57%	31%	14%

* Data from Sterzynska (1990).

Invisible urban fauna

A significant, but poorly known aspect of the urban fauna is the invertebrates of the soil and litter. Investigations described above demonstrated that 1 m² of soil from Warsaw park lawns hold an average of several thousand (in some cases even 40,000) individual invertebrates. Among the most numerous animal groups recorded were soil mites Acari (~20,000), enchytreids Enchytreidae (5–25,000), springtails Collembola (2–7,500), ants Formicoidea (~500), earthworms Lumbricidae (60–160), click beetles Elateridae (40–100), and many (above one hundred) insect larvae, particularly aphids Aphidodea, beetles Staphylinidae and flies Diptera, also spiders Aranei and snails Gastropoda. This incredible biomass does not include many thousand/m² of nematodes (Nematoda) which live “free” in the soil or inside plant roots. Density was lower in 1 m² of ground and leaf litter, but included several hundred invertebrates. Among them were mainly ants Formicoidea (~200), various groups of beetles Coleoptera (~70), snails Gastropoda, and spiders *Aranei* (some tens of each group).

Shrubs and tree canopies also harbored significant invertebrate communities. Shrub invertebrates were dominated by insects (flies Diptera, leafhoppers Homoptera Auchenorrhyncha, and aphids Aphidodea). In 1 m³ of urban park tree canopy live 2–3 thousand of invertebrate animals. Most numerous among them were aphids Aphidodea, flies Diptera and leafhoppers Homoptera, Auchenorrhyncha, and Hymenoptera.

The ecological role of this “unnoticeable” and uncountable part of the urban fauna should be very significant by their “volume” and also by their variety (Table 1). These animals live inside the soil, on the ground in grass and in leaf litter, in all strata of vegetation, inside tree trunks, in water bodies, even inside technical structures like interiors of buildings and sanitary installations. They are indispensable for all functions and for all links of the energy/matter flow in the ecosystem. They stimulate soil processes, they are consumers of plants and they are predators limiting these consumers. They are the basic food of many vertebrates, but in general they are poorly known (e.g., Whiteley 1994).

The studies above revealed that the abundance of invertebrate communities in urban areas could be relatively high, and – surprisingly perhaps – in many cases it exceeds that in rural habitats. This

often results because of very abundant species that sometimes occur en masse – super-dominants. For example, among groups which usually show much higher urban (vs rural) dominance are ants Formicoidea, wasps Vespidae, and leafhoppers Auchenorrhyncha and Sphecidae (Chudzicka & Skibinska 1994). In the soil, however dominance by single species in urban environments is usually lower than in semi-natural ones. For example, the density of springtails *Collembola* on 1 m² of urban lawn averaged ~ 4000 individuals, but abundance in agricultural meadows was ~ 9000 (Sterzynska 1990).

Avian abundance in the city

Among vertebrates, the most abundant and exact data is for the birds. The total population of the breeding avifauna of Warsaw was estimated to be 150–350,000 breeding territories. This translates into about 300–700 pairs/km² in the overall municipal area of the city. This density is similar to comparable data from Berlin (360–670,000 territories, ~400–700 pairs/km², Otto & Witt 2002) and Hamburg (410, 000 territories, ~540 pairs/km²; Mitschke & Baumung 2001). The mean population density of birds in the highly urbanized areas of inner Warsaw (from a sample of 52 km²) was estimated at 830–1590 pairs (~435 kg of biomass) per km² in the breeding season and 2.5–4.5 thousand individuals (~964 kg) per km² in winter (Nowicki 2001). Such high concentrations of birds in urban areas occurs throughout Europe (e.g. Nourteva 1971, Tomialojc & Profus 1977, Bezzel 1982, Sasvari 1990, Tomialojc 1998), but not in rural habitats of the European temperate zone.

General statements

1. Total number of species of the fauna of Warsaw, in all habitats within its municipal area, is estimated to be 6–7 thousand, including ~320 species of vertebrates. This is typical for big European cities, whose fauna ranges between 5–10 thousand species including 300–400 vertebrates.
2. Species richness of a big city's fauna decreases considerably along the gradient of urbanization from rural areas in the region towards the city center.
3. The population density of the urban fauna is considerable and often reflects superabundant single species. In some groups (e.g. birds, wasps, ants) that density is much higher than in rural areas.
4. Only a very small part of this rich animal world, mainly the few terrestrial vertebrates, is noticeable to city dwellers.

References

- Bezzel E. 1982. *Vögel in der Kulturlandschaft*. Verlag Eugen Ulmer, Stuttgart, pp. 173–255.
- Chudzicka E., Skibinska E. 1994. An evaluation of an urban environment on the basis of faunistic data. *Memorabilia Zoologica*. 49: 176–185.
- Chudzicka E., Skibinska E. 2003. Species diversity – animals. In: Andrzejewski R., Weigle A. (eds.). *Biological diversity of Poland*. Narodowy Fundusz Ochrony Srodowiska, Warszawa, pp. 93–138. [in Polish]
- Cignini B., Zapparoli M. (eds.) 1996. *Atlas of breeding birds of Rome*. Fratelli Palombi Editori, Roma, 126 pp. [in Italian]
- Chojnacki J., Sudnik-Wojcikowska B. 1994. Effect of urbanization on the plant cover of Warsaw. In: Barker G.M., Luniak M., Trojan P. (eds.) *Proc. II European Meeting of the International Network for Urban Ecology*. *Memorabilia Zoologica* 49: 115–127.
- Czechowski W. 1990. Bibliography of the publications of the Institute of Zoology, PAS, in Warsaw on urban ecology (until 1988). In: Luniak M. (ed.). *Urban ecology studies in Central and Eastern Europe*. Ossolineum, Wroclaw, pp. 206–235.

- Czechowski W., Mikolajczyk W. 1981. Methods for the study of urban fauna. In: Czechowski W., Pisarski B. (eds.) Species composition and origin of the fauna of Warsaw. Part I. *Memorabilia Zoologica* 34: 49–58.
- Czechowski, W., Pisarski B. (eds). 1981. Species composition and origin of the fauna of Warsaw. Part 1. *Memorabilia Zoologica* 34: 258 pp.
- Czechowski, W., Garbarczyk H., Pisarski B., Sawoniewicz J. (eds). 1982a. Species composition and origin of the fauna of Warsaw. Part 2. *Memorabilia Zoologica* 35: 168 pp.
- Czechowski, W., Garbarczyk H., Pisarski B., Sawoniewicz J. (eds). 1982b. Species composition and origin of the fauna of Warsaw. Part 3. *Memorabilia Zoologica* 36: 262 pp.
- Czechowski, W., Pisarski, B. (eds). 1986. Structure of the fauna of Warsaw; effects of the urban pressure on animal communities. Part 1. *Memorabilia Zoologica* 41: 230 pp.
- Czechowski, W., Pisarski, B. (eds). 1987. Structure of the fauna of Warsaw; effects of the urban pressure on animal communities. Part 2. *Memorabilia Zoologica* 42: 149 pp.
- Fuchs R., Skopek J., Formanek J., Exnerova A. 2002. Atlas of breeding birds of Prague. Consult Praha, Praha, 320 pp. [in Czech]
- Hewlett J. (ed.) 2002. The breeding birds of the London area. London.
- Khrabriy, V. M. 1991. Birds of Sankt Petersburg – fauna, distribution, conservation. Zoological Institute, USSR Academy of Sciences, St. Petersburg, 273 pp. [in Russian]
- Kelcey, J. G., G. Rheinwald. 2005. (editors). Birds in European Cities. Ginster Verlag, St. Katharinen, Germany.
- Klausnitzer, B. 1988. Verstaedterung von Tieren.. A. Ziemsen Verlag. Wittenberg Lutherstadt. 315 pp
- Klausnitzer, B. 1993. Oekologie der Grossstadtfaua. Gustav Fischer Verlag, Stuttgart, Jena.
- Lesinski, G., Fuszera E. 2001. Characteristics of urban community of bats of Warsaw.. *Nietoperze (Poland)* 2: 3–17. [in Polish]
- Luniak, M., Kozłowski, P., Nowicki, W., Plit, J. 2001. Birds of Warsaw 1962–2000. IGiPZ PAN, Warszawa, 179 pp. [in Polish]
- Luniak, M. 2004. Synurbization – adaptation of animal wildlife to urban development. In: Shaw W.W, Harris K. L., VanDruff L. (eds). Urban wildlife conservation. Proc. of the 4th Intern. Symp., Univ. of Arizona, Tucson, pp. 50–55 .
- Luniak, M., Nowicki W. 1990. Mammals in Warsaw. In: Zimny H. (ed.). Functioning of ecological systems in urban conditions. Wydawnictwo SGGW-AR, No 58, Warszawa, pp. 230–243. [in Polish].
- Luniak, M., Pisarski B. 1994. State of research into fauna of Warsaw (up to 1990). In: Barker G.M., Luniak M., Trojan P., Zimny H. (eds.). Proc. II European Meeting of the Intern. Network for Urban Ecology. *Memorabilia Zoologica* 49: 155–165.
- Markowski J., Kowalczyk J. K., Janiszewski T., Wojciechowski Z., Szczepko K., Domanski J. 2004. Fauna of Lodz – the state of knowledge, changes, protected and threatened species. In: Indykiewicz P., Barczak T. (eds.). Urban fauna of Central Europe in the 21st century. Wydawnictwo Logo, Bydgoszcz (Poland), 19–36 pp. [in Polish]
- Marzluff, J.M. 2005. Island biogeography for an urbanizing world: how extinction and colonization may determine biological diversity in human-dominated landscapes. *Urban Ecosystems* 8: 155–175.
- Mazgajska, J. 1996. Distribution of amphibians in urban water bodies (Warsaw agglomeration, Poland). *Ekologia Polska* 44: 245–257.
- Mazgajska, J. 1998. Inventory of Amphibians of Warsaw in 1992–1994. In: Barczak T., Indykiewicz P. (eds.) Urban Fauna.. Wydawnictwo ATR Bydgoszcz (Poland), pp. 227–236. [in Polish]
- Mitschke, A., Baumung, S. 2001. Atlas of breeding birds of Hamburg. *Hamburger Avifaunistische Beitrage* (hab) 31, 344 pp.
- Montier D. 1977. Atlas of breeding birds of the London area. B. T. Batsford Ltd., London, 288 pp.
- Nourteva, P. 1971. The synanthropy of birds as an expression of the ecological cycle disorder caused by urbanization. *Annales Zoologici Fennici* 8: 547–553.
- Nowicki, W. 2001. Birds of inner Warsaw. MiIZ PAN, Warszawa, 136 pp. [in Polish]
- Otto W., Witt K. 2002. Verbreitung und Bestand Berliner Brutvoegel. *Berliner Ornithol. Bericht*. 12, Sondeheft, 256 pp.
- Pisarski, B. 1982. La faune de la varsovie sa composition et son origine. In: Luniak M., Pisarski B. (eds.). Animals in urban environment. Ossolineum, Wroclaw, pp. 103–113.
- Pisarski, B. 1990. The invertebrate fauna of urbanized areas of Warsaw. In: Luniak M. (ed.). Urban ecological studies in Central and Eastern Europe. Ossolineum, Wroclaw, pp. 98–111.
- Plant, C. 1987. The butterflies of the London area. London Natural History Society, London.
- Plant C., 1993. Larger moths of the London area. London Natural. History Society, London.
- Plant, C. 1994. Lepidoptera of the London area and the use of local naturalists in gathering data. *Memorabilia Zoologica* 34: 221–234.
- Rabosee D. 1995. Atlas des oiseaux nicheurs de Bruxelles 1989–1991. Soc. d'Etudes Ornithol. Aves. Liege, 304 pp.
- Risin, L. P. (ed.) 1998. Nature of Moscow. Bioinformservis, Moskva, 255 pp. [in Russian]
- Sasvari, L. 1990. Structure of bird communities in urban and suburban habitats. In: Luniak M. (ed.). Urban ecological studies in Central and Eastern Europe. Ossolineum, Wroclaw, pp. 155–166.

- Spitzenberger F. 1990. Fledermause Wiens. J & V Edition Wien, Wien, 71 pp.
- Sterzynska M. 1990. Communities of Collembola in natural and transformed soils of the linden-oak-hornbeam sites of the Mazovian Lowland. *Fragmenta Faunistica* 34: 165–262.
- Sukopp H. 1990. Stadtoekologie – das Beispiel Berlin. D. Reimer Verlag, Berlin. 455 pp
- Sukopp H. 1998. Urban ecology – scientific and practical aspects. In: Breuste J., Feldmann H., Uhlmann O. (eds.). *Urban ecology*, Springer Verl., Berlin, pp. 3–16.
- Tomialojc, L. 1998. Breeding densities in some urban versus non-urban habitats; the Dijon case. *Acta Ornithologica* 33: 159–171.
- Tomialojc, L., Profus P. 1977. Comparative analysis of breeding bird communities in two parks of Wroclaw and in adjacent *Quercus-Carpinetum* forest. *Acta Ornithologica* 26: 117–177.
- Whiteley, D. 1994. The state of knowledge of the invertebrates in urban areas in Britain with examples taken from the city of Sheffield. In: Barker G.M., Luniak M., Trojan P., Zimny H. (eds.). *Proc. II European Meeting of the Inter. Network for Urban Ecology. Memorabilia Zoologica* 49: 207–220.
- Winiarska G. 2002. Butterflies and moths (Lepidoptera) in urban habitats: the moths of Warsaw. I. Noctuidae, Pantheidae, Nolidae. *Fragmenta Faunistica* 45: 131–145.
- Winiarska G. 2003. Butterflies and moths (Lepidoptera) in urban habitats: II The butterflies (Rhopalocera) of Warsaw. *Fragmenta Faunistica* 46: 69–91.
- Winiarska G. 2004. Butterflies and moths (Lepidoptera) in urban habitats: the moths of Warsaw. III. Noctuidea (second part): Notodontidae, Arctidae, Lymantridae. *Fragmenta Faunistica* 47: 121–126.
- Zapparoli M. (ed.) 1997. *Insects of Rome Fratelli Palombi Editori, Roma*, 360 pp. [in Italian]
- Zimny H. (ed.). 1994. *Proc. II European Meeting of the Inter. Network for Urban Ecology. Memorabilia Zoologica* 49: 207–220.