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Density dynamics, diet composition and productivity of sparrowhawk *Accipiter nisus* L. population in central Poland

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Abstract. Long-term monitoring of raptor populations can serve as a proxy for the evaluation of whole ecosystem health. The aim of the study was to compare the current abundance of the sparrowhawk *Accipiter nisus* L. with data from past decades. Additionally, we examined the diet of this species in the breeding season and recorded the number of fledglings.

The study area encompassed 105 km^2 of field and forest mosaic, located in the vicinity of the Rogów village (51°49'17,98"N, 19°53'54,5"E). Forests covered approximately 24% of the area and formed eight individual complexes ranging in size from 65 ha to 1000 ha. In the years 2011–2017, an average of 20.1 sparrowhawk pairs were recorded resulting in a population density of 19.1 pairs per 100 km^2 of total area and 8.2/10 km^2 of forested area. This is an increase of 26% compared to the years 2001–2003, when only 16 pairs nested in the same study area. Each successful pair of sparrowhawk produced between one and five fledglings with the average being 3.4.

Larch *Larix* spp. and Scots pine *Pinus sylvestris* L. dominated as nesting trees accounting for 36.9 and 35.9% of nesting sites respectively. The average age of the nesting trees was 31 years and nests were built at an average height of 11.7 m.

The sparrowhawk diet was dominated by birds, which amounted to 81.5% of prey items and over 95% of the consumed biomass. Among the birds identified to the species level, the domestic pigeon *Columba livia* f. *domestica* Gm. constituted the biggest share in biomass. Further important prey items were starling *Sturnus vulgaris* L., with 5.6% of prey items and 9.8% of the total biomass, and hawfinch *Coccothraustes coccothraustes* (L.), with 6.3% of prey items and 7.6% of the total biomass. Sparrowhawks also consumed significant numbers of thrush *Turdus* spp. that formed in total over 11% of the total consumed biomass.

It would appear that the observed population growth was a result of prohibited persecution and the ban on DDT usage in agriculture.

Keywords: field and forest mosaic, pellets, plucking place, fledglings, nests

1. Introduction

A long-term monitoring of birds of prey populations provides information on the health of the total ecosystem. Being at the top of a food web, raptors respond most intensely to unfavourable changes in the environment (Pielowski 1996; Cenian 2009). The latter became spectacular when population numbers of a majority of raptor species in Europe crashed in the 50s and 60s of the 20th century, that coincided with the widespread application of DDT and human attempts to eradicate birds of prey (Pielowski 1996). Our study aimed at determining the abundance of sparrowhawk *Accipiter nisus* population within the permanent study area and comparing the results with data available from the past decades, to evaluate the long-term abundance trend. In order to provide a complete characteristic of the population under study, the diet composition was determined during the sparrowhawk breeding season, nesting trees were described and the number of fledglings was estimated. An attempt was also made to determine factors mediating the long-term population trends.

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2. Methods

The study area embraced 105 km^2 of a field-woodland mosaic, in the vicinity of the village of Rogów, in the Łódź voivodeship (51°49'17, 98''N, 19°53'54, 15'E). Forests, taking around 24% of the surface, occurred there as eight forest complexes sized from 65 to 1,000 ha. The forest area was managed by the Experimental Forest Station of Warsaw University of Life Sciences and the Brzeziny Forest District. Scots pine *Pinus sylvestris* L. was the major forest species, dominating on about half of the surface. Oaks *Quercus* spp. contributed to above 20% and common beech *Fagus sylvatica* L. to nearly 10% of the woodland surface. Mixed fresh- and fresh deciduous forest types were the major forest habitat types (jointly 83% of forest surface). The remaining portion of the study area was occupied by arable land (59%), fruit orchards (5%), permanent meadows and pastures (5%) and scattered settlements (Goszczyński et al. 2005; Gryz et al. 2013). The field study was made in the years 2011–2017. Abundance of the sparrowhawk breeding pop-ulation was estimated based upon the number of occupied nests in a given year (or occasionally, upon the presence of offsprings). To trace nests of sparrowhawks, both forests and woodlands, were surveyed. Firstly, we checked coniferous stands of the I and II age class as well as older stands with a lower canopy layer build by fir trees *Abies* spp. and spruces *Picea abies* (L.) H. Karst. The work was usually done by two persons, equipped with walkie talkie and binoculars (10 × 42), who were walking spaced 30–50 m apart, depending on the stand structure. The nests located were marked on the 1:10,000 forest stand map, and their positions were registered using a GPS receiver. The nest location height was determined using the SILVA Clino Master altimeter. Feathers from plucking posts, pellets and other remains of prey were collected near the nesting place. All the known sparrowhawk territories were searched. Most of the field work was carried out from March to August. The nests were searched in spring. Later in the season, the territories were controlled to collect pellets and food remains (mainly feathers), and to determine the number of fledglings; the search was also conducted in areas where no nest was found, but adults and young birds were seen. In the laboratory, the following keys were used to identify the systematic position of the prey: Ruprecht 1979; Pucek 1984; Engelman et al. 1985; Moreno 1985, 1986; März 1987; Ujhelyi 1992 and Brown et al. 1999, in addition to a comparative collection of feathers and skulls.

Histological hair analysis was performed in selected cases (Dziurdzik 1973; Brunner, Coman 1974; Dziurdzik 1978; Teerink 1991). The average mass of prey was adopted based on the literature (Szczepski, Kozłowski 1953; Pucek 1984; Jędrzejewska, Jędrzejewski 2001; Aulak, Rowiński 2010), the rodent body weight was determined during live-trapping, which was carried out simultaneously with ornithological research (Gryz, Krauze-Gryz non-published). In the case of roe deer *Capreolus capreolus* L. carrion, the value of average daily nutritional requirement (DNR) was assumed to be the biomass consumed. Considering a large difference in size between male and female sparrowhawks (Newton 1986), an average DNR value of 50 g was supposed for both sexes. In the case of insects, a weight of 0.5 g was determined for all species. The food composition was presented as the percent proportion of a given taxon in both total number of prey and total biomass consumed. The pellet analysis was used mainly to identify the invertebrate, amphibian, reptile and mammalian fractions in the diet. The number of birds consumed was determined based generally on feathers found in plucking posts. In order to evaluate the population productivity, the average number of fledglings was determined with the aid of binoculars, mainly in June and July, and then the value was referred to a pair of birds with breeding success. Since the distribution of the numbers of pairs nesting within the study area in the two periods compared deviated from the normal one, non-parametric Mann-Whitney test was used for data analysis.

3. Results

From 18 to 22 sparrowhawk pairs were recorded in the years 2011–2017 (Fig. 1), on average 20.1; SD = 1.3. The population density was 19.1 pairs per 100 km^2 of the total area and 8.2/10 km^2 of the forest area. There was an increase in abundance by 26% (Mann-Whitney test, $Z = -2.32$, $p < 0.05$) as compared to the years 2001–2003, when 16 pairs of the species bred within the study area every year (Gryz et al. 2006; Krauze, Gryz 2007; Gryz, Krauze-Gryz 2014). Sparrowhawks produced from one to five juveniles (Fig. 2), on an average 3.1 (SD = 0.9) per pair with breeding success (N = 42).

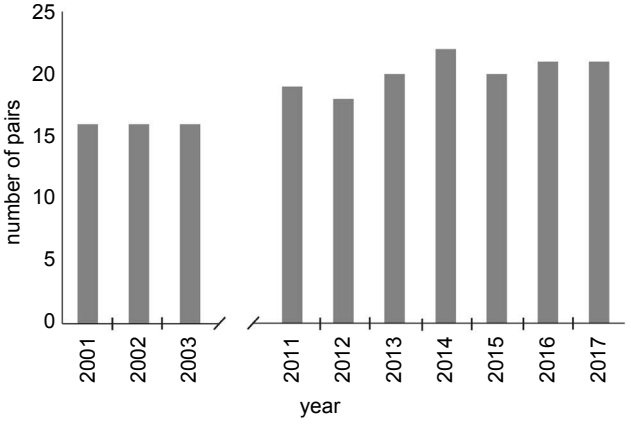

Figure 1. Number of pairs of sparrowhawk in Rogów Forest in the two compared study periods

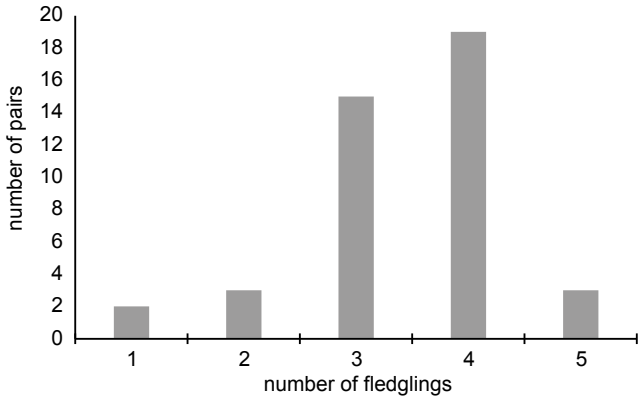

Figure 2. The number of sparrowhawk fledglings leaving nest in the Rogów Forests

European larch *Larix decidua* Mill. (36.9%) dominated among 103 nesting trees, followed by Scots pine (35.9%), and Norway spruce (16.5%). In addition, seven nests were situated on fir trees, three on Douglas firs *Pseudotsuga menziesi* (Mirb.) Franco, and one on silver birch *Betula pendula* Roth. Nests were built on trees aged from 16 to 44 years, an average tree age being 31.5 years (SD = 7.6), and were located at a height from 7 to 17 m, at an average 11.7 m (SD = 1.8). The nests were made near the trunk on coniferous trees, while in the case of birch, the nest was built in the crown fork. Overall, 930 prey items were identified, with a total biomass of over 42 kg. The prey included predominantly birds representing 81.5% of all items, and over 95% of the biomass consumed. Among the birds taken, identified to species, the largest biomass was found for domestic pigeon *Columba livia* f. *domestica* Gm. The following significant prey categories were: common starling *Sturnus vulgaris* L. (5.6% of prey and 9.8% of biomass) and hawfinch *Coccothraustes coccothraustes* L. (6.3% of prey and 7.6% of biomass). Thrushes *Turdus* spp. were also a frequent prey of sparrowhawks, accounting jointly for over 11% of the biomass consumed. Analysis of food also revealed the remains of nine species of mammals (4% biomass in total), one amphibian and one lizard. Insects, mainly cockchafers *Melolontha* spp., accounted for over 10% of the prey, but their total biomass was negligible (Table 1). A review of sparrowhawk prey selection indicated that they hunted in various environments, such as forests, agrocenoses, villages and the neighbourhood of water courses and reservoirs. Apart from one Eurasian woodcock *Scolopax rusticola* L. and carrion of roe deer, no other game was found in the sparrowhawk diet.

4. Discussion

The early findings of sparrowhawks in the vicinity of Rogów have been documented as the following artefacts exhibited in the Museum of Forest and Wood in Rogów and in the Research-Education Collection of the Department of Forest Zoology and Wildlife Management, the Faculty of Forestry, the Warsaw University of Life Sciences: ♂ Józefów, 6.XI.1949, leg. M. Stuglik; ♂ Jasień, 8.III.1950, leg. I. Mozga and ♀ Wilczy Dół, 7.I.1965, leg. R. Dałkowski. Information on sparrowhawk observations at the Arboretum of the Warsaw University of Life Sciences may be found in the papers by Zaborowski (1966) and Guzik (1983). No sparrowhawk was found during an inventory carried out in the Popień complex tract in the 1970s (Bujalska 1977). Sparrowhawks in the area under study were intensively persecuted as 'enemies of game' in the 1950s and 1960s. They were recommended to be shot during the whole year, with particular reference to the breeding season (Szulik 1962). However, in the second half of the 1970s, shooting of birds of prey was a rarity (M. Wasilewski, pers. info). No evidence of sparrowhawk nest shearing by local pigeon breeders was recorded in the years 2001–2017, as the latter directed their efforts to fight common buzzard *Buteo buteo* (L.) and goshawk *Accipiter gentilis* (L.) (Gryz 2003; Krauze 2003).

Sparrowhawk was recorded in some forest complexes during the intensive ecological study on the selected bird species, conducted in the years 1978–92; however, this species was considered to be respectively rare (Goszczyński 1997). The sparrowhawk population was able to basically recover probably in the 1990s. This was possible thanks to the discontinuation of DDT application in Poland and the abandoning of hunting (starting from the year 1976). A study suggested that there was a relationship between the presence of the pesticide in the environment and the decreased thickness of egg shells, which resulted in low reproductive success (Newton 1986).

In the vicinity of Rogów, the first inventory of sparrowhawk was carried out in the years 2001–2003, showing the presence of 16 pairs (Gryz et al. 2006). An increase in the sparrowhawk numbers in recent decades was recorded in many places in Europe (Tomiałojć, Stawarczyk 2003; Burfield, Kovács 2011; Petty 2011, Janiszewski et al. 2012). In contrast, a long-term declining trend was demonstrated for Finland (Saurola, Björklund 2011). Data from the State Environmental Monitoring proved that sparrowhawk populations in Poland were stable in the years 2000–2016 (http://monitoringptakow.gios.gov.pl/baza-danych [accessed 02.09.2017]). The population density found in our research was so far one of the highest in Poland (Tomiałojć, Stawarczyk 2003; Wojciechowski, Janiszewski 2007). Higher sparrowhawk densities were reported only for the Strzeleckie Forests, where 56–62 pairs/100 km^2 were found (Matusiak et al. 2002). However, it should be mentioned, that the latter study area embraced solely woodlands.

The number of fledglings found in our study approximated the numbers reported by the other authors. On an average, 3.6 fledglings were found per pair with breeding success in the Strzeleckie Forests (Matusiak et al. 2002), whereas three

Table 1. Diet composition of sparrowhawk during breeding season in the Rogów Forests

Prey	Mass [g]	Number of prey N	Share of prey [%]	Biomass	Share of biomass [%]
Coturnix coturnix (L.)	100	1	0.1	100	0.2
Columba livia f. *domestica* Gm.	400	19	2.0	7600	17.9
Streptopelia decaocto (Friv.)	225	9	1.0	2025	4.8
Streptopelia turtur (L.)	150	1	0.1	150	0.4
Cuculus conorus L.	100	1	0.1	100	0.2
Apus apus (L.)	40	1	0.1	40	0.1
Scolopax rusticola L.	250	1	0.1	250	0.6
Upupa epops L.	60	1	0.1	60	0.1
Alcedo atthis (L.)	30	1	0.1	30	0.1
Dendrocopos major (L.)	70	24	2.6	1680	4.0
Dendrocopos spp.	70	7	0.8	490	1.2
Jynx torquilla L.	37	1	0.1	37	0.1
Alauda arvensis L.	35	2	0.2	70	0.2
Hirundo rustica L.	18	2	0.2	36	0.1
Anthus spp.	20	6	0.6	120	0.3
Motacilla alba L.	24	3	0.3	72	0.2
Erithacus rubecula (L.)	17	3	0.3	51	0.1
Luscinia sp.	23	1	0.1	23	0.1
Phoenicurus phoenicurus (L.)	16	2	0.2	32	0.1
Turdus philomelos Br.	50	28	3.0	1400	3.3
Turdus viscivorus L.	80	8	0.9	640	1.5
Turdus pilaris L.	70	6	0.6	420	1.0
Turdus merula L.	70	26	2.8	1820	4.3
Turdus spp.	65	8	0.9	520	1.2
Sylvia spp.	12	9	1.0	108	0.3
Miliaria calandra (L.)	20	1	0.1	20	0.0
Acrocephalus sp.	30	1	0.1	30	0.1
Phylloscopus spp.	8	24	2.6	192	0.5
Regulus regulus (L.)	6	2	0.2	12	0.0
Ficedula spp.	15	17	1.8	255	0.6
Parus major L.	18	32	3.4	576	1.4
Cyanistes caeruleus (L.)	10	7	0.8	70	0.2
Paridae indet.	20	19	2.0	380	0.9
Aegithalos caudatus (L.)	8.5	2	0.2	17	0.0

Prey	Mass [g]	Number of prey N	Share of prey [%]	Biomass	Share of biomass [%]
Sitta europaea L.	22	23	2.5	506	1.2
Certia spp.	9	4	0.4	36	0.1
Oriolus oriolus (L.)	73	2	0.2	146	0.3
Lanius spp.	50	3	0.3	150	0.4
Garrulus glandarius (L.)	170	10	1.1	1700	4.0
Sturnus vulgaris L.	80	52	5.6	4160	9.8
Passer domesticus (L.)	29	9	1.0	261	0.6
Passer montanus (L.)	21	12	1.3	252	0.6
Passer spp.	25	22	2.4	550	1.3
Fringilla coelebs L.	20	41	4.4	820	1.9
Fringillidae indet.	20	18	1.9	360	0.8
Chloris chloris (L.)	26.5	2	0.2	53	0.1
Carduelis spinus (L.)	12	4	0.4	48	0.1
Carduelis cannabina (L.)	18	1	0.1	18	0.0
Carduelis sp.	19	2	0.2	38	0.1
Pyrrhula pyrrhula (L.)	25	9	1.0	225	0.5
Coccothraustes coccothraustes (L.)	55	59	6.3	3245	7.6
Loxia sp.	35	3	0.3	105	0.2
Emberiza citrinella L.	30	3	0.3	90	0.2
Small bird indet.	25	136	14.6	3400	8.0
Medium bird indet.	75	67	7.2	5025	11.8
∑ Aves		758	81.5	40614	95.7
Sciurus vulgaris L.	250	1	0.1	250	0.6
Myodes glareolus (Schr.)	17.6	36	3.9	633.6	1.5
Apodemus flavicollis (Mel.)	30.6	1	0.1	30.6	0.1
Apodemus agrarius (Pall.)	24	4	0.4	96	0.2
Apodemus spp.	27	4	0.4	108	0.3
Mus musculus L.	15	1	0.1	15	0.0
Microtus arvalis (Pall.)	19	1	0.1	19	0.0
Microtus spp.	22	3	0.3	66	0.2
Rodentia indet.	22	17	1.8	374	0.9
Sorex araneus L.	8	3	0.3	24	0.1
Sorex sp.	6.5	1	0.1	6.5	0.0
Mustela sp.	45	1	0.1	45	0.1
Capreolus capreolus (L.)	50	1	0.1	50	0.1

Prey	Mass [g]	Number of prey N	Share of prey [%]	Biomass	Share of biomass [%]
∑ Mammalia		74	8.0	1717.7	4.0
Rana sp.	22	1	0.1	22	0.1
Lacertidae indet.	18.5	1	0.1	18.5	0.0
Insecta	0.5	96	10.3	48	0.1
Total		930	100.0	42420.2	100.0

fledglings were found in the Śremska Valley (Kwieciński, Mizera 2006).

Only few works provide data on nesting trees and the height at which nests are built. From the green areas in Łódź, sparrowhawks were reported to build their nests mostly on coniferous trees (81%), while the average height of nest location was 11.1 m (Janiszewski et al., 2012). The majority of nests in the Strzeleckie Forests were located in the coniferous stands, aged 17–44 (Matusiak et al. 2002). In Hungary, nests were mainly built on *Pinus* spp., occasionally on poplars *Populus* spp. and ash trees *Fraxinus excelsior* L. The average nesting height was 16.3 m (Papp 2011).

The results of our research and those provided by other authors indicate that birds are the predominating diet item of sparrowhawks, regardless the landscape type they inhabit. In the Białowieża National Park, sparrowhawks most often preyed on tits Paridae, common chafffinch *Fringilla coelebs* L. and thrushes Turdidae (Jędrzejewska, Jędrzejewski 2001). In the Augustowska Forest, thrushes accounted for 32% of prey and nearly 50% of the biomass consumed (Zawadzka, Zawadzki 2001). Trushes were also the major prey (18.3% of hunted birds) of sparrowhawks nesting in the Carpathians, followed by blackcap *Sylvia atricapilla* L. constituting 7.3% of birds eaten (Bujoczek, Ciach 2009). In the agricultural areas of north-eastern Spain, the most hunted prey was house sparrow *Passer domesticus* L. – 12.3% of prey items and starlings Sturnidae – 8.6% of victims (Mañosa, Oro 1991).

Conflicts of interests

The authors declare no potential conflicts of interests.

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Author contribution

J.G. – conceptualisation, field study, data processing, manuscript writing; D.K-G – field study, data processing, manuscript writing.

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