EFFECTS OF ENVIRONMENTAL POLLUTION ON BREEDING POPULATIONS OF BIRDS IN SOUTHERN POLAND

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Abstract. Breeding performance of Great tit (*Parus major*) was studied in two forests in southern Poland, in the districts of Cracow and Katowice, and in a Swedish reference area. Concentrations of Cd, Cu, Fe, Pb, Zn, methyl Hg, ΣDDT, and ΣPCB in tissues of nestlings, were monitored. The birds' tissue concentrations of the non-essential elements, Cd and Pb, were elevated at the Polish localities, and reflected the degree of environmental contamination. ΣDDT levels were higher in the Polish birds than in the Swedish. Breeding results of the birds were severely affected in southern Poland, and high frequencies of the fledged young showed low Hb.

Key words: Birds, *Parus major*, heavy metals, persistent organic substances, breeding, nestling development, Hb

1. Introduction

Studies in Swedish heavy metal polluted forests, in the pollution gradient from a sulphide ore smelter plant, showed that adults and nestlings of insectivorous passerine birds accumulated toxic elements and exhibited biological effects, reflecting the amounts of metals in aerial deposition (Nyholm, 1987, 1989, 1994). The methods of those studies were considered relevant for monitoring chemical and biological effects of toxic pollutants in the natural environment. That was the incitement to this study, which was incorporated in a joint Polish-Swedish research programme* in the field of effects of air pollution on forests.

Sawicka-Kapusta *et al.*(1986) showed increased heavy metal contamination of wintering Tits (*Parus* sp.) in forests of southern Poland. The present study, which emphasizes on biological (health) effects related to reproduction of Great tit, was partly carried out in the same forests. Its aim was to characterize the health state of naturally breeding birds in differently polluted forests in southern Poland. The results of the first study year was presented by Nyholm et al. (1994).

2. Material and methods

The study was performed 1990-1992, with nest box breeding populations of Great tit (*Parus major* L.).

The Polish study areas were situated in Nieplomice Forest at Stanislawice (habitat:

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Pino-Quercetum), in District of Krakow, and in Olkusz Forest (habitat: Dicrano-Pinion) at Hutki and Klucze, at four and seven km north-east of Bukowno Zn-Cd smelter plant, respectively, in District of Katowice. Ödsmål, about 50 km north of Gothenburg, a locality with background level of pollution in Sweden, was used as reference.

The heavy metal contamination of the study areas due to aerial deposition was estimated by means of lichen (*Hypogymnia physodes*) (Puckett, 1988; Tyler, 1989).

Breeding course of the birds, clutch size, hatching frequency, and nestling development and survival, were registered. Breeding losses due to depredation, by e.g. mustelids (*Mustela, Martes*) or cat (*Felis*), could be significant, but are not futher considered.

Nestlings were collected when 14 day old 1990 and 1991, and 17 day old 1991 and 1992. Organs were dissected (e.g. liver, brain, spleen, pectoral muscle), weighed and stored frozen in acid washed containers. Blood samples were analysed for hemoglobin concentration (Hb) (Hemocue Hb-photometer), immediately after sampling.

At sampling, excrements of nestlings were let directly into acid washed containers. Excrements and lichen were oven-dried at 60°C until constant weight.

Heavy metal analyses of lichen, bird tissues, and excrements were performed by means of AAS (Perkin Elmer 503); lead (Pb) and cadmium (Cd) (graphite furnace), copper (Cu), iron (Fe), zinc (Zn) (flame), after digestion with HNO_3:$HClO_4$, 4:1. Methyl-mercury (Met-Hg) and organic pollutants in pectoral muscle were analysed by means of cryogenic GC-atomic fluorescence, and GC-MS, respectively. Concentrations are based on wet weight, if not otherwise stated.

3. Results and discussion

The degree of pollution by Cd, Pb, Cu, Zn and Fe varied between study areas (Table I). Depositions of the the non-essential elements, Cd and Pb, at Hutki and Klucze, were about twice those at Stanislawice. This was consistent with the former localities being situated rather close to the Bukowno Zn-Cd smelter. The interannual variation of heavy metal deposition at these localities was insignificant.

Cd deposition at Stanislawice was about twice that at the reference site, but Pb depositions were similar. Pb and Cd depositions at Hutki and Klucze were about two to four times higher than at the reference site, respectively.

Depositions of Cu and Fe were rather similar at the Polish localities, while Zn deposition varied, being higher at Hutki and Klucze than at Stanislawice. At Ödsmål, depositions were lower than at the Polish localities, especially those of Zn and Fe.

The main route of environmental pollutants to the birds is via the food web. Excrements from nestlings were analysed to monitor the heavy metal content in the food (mainly insects) supplied by their parents (Table II). Pb and Cd levels in the excrements varied among sites, in agreement with amounts of these elements deposited in the birds' environment. The variation of Zn level in excrements was insignificant, however. This indicated that Zn exposure to the nestlings in Hutki and Klucze was similar to that in Stanislawice, though the degree of Zn contamination was higher at the former localities. This was consistent with the transfer of "essential" elements, as Zn, in the

TABLE I

Heavy metal concentrations in lichen *Hypogymnia physodes* from Stanislawice, Hutki and Klucze, and Swedish reference localities (mg/ kg; d.w).

Element	Year	Locality			
		Stanislawice	Hutki	Klucze	Ödsmål
Pb	1990	32±7	60±22	76±9	
	1991	25±9	72±22	73±16	
	1992	24±5	54±18	79±21	30
Cd	1990	1.22±0.25	2.45±0.24	2.46±0.22	
	1991	1.29±0.47	2.50±0.64	2.67±0.66	
	1992	1.03±0.29	2.41±0.35	2.58±0.74	0.55
Cu	1990	9.1±1.3	11.3±1.7	11.0±1.7	
	1991	10.7±1.3	12.8±1.4	13.0±1.1	
	1992	9.9±1.9	11.7±2.0	12.0±1.6	6.9
Zn	1990	167±24	287±38	292±30	
	1991	156±17	293±51	283±26	
	1992	126±23	201±16	213±15	104
Fe	1990	4332± 861	4213±1267	4102±923	
	1991	4123± 238	5082±1563	4552±668	
	1992	4387±1770	3697± 950	3560±835	757

Mean ± SD

TABLE II

Concentrations of lead, cadmium and zinc (mg/kg; d.w.) in excrements of Great tit nestlings.

Element	Year	Locality		
		Stanislawice	Hutki	Klucze
Pb	1991	2.0±1.6; (9)	4.9±2.0; (8)	3.4±1.6; (7)
	1992	7.9±5.6; (6)	19±1.8; (2)	24±12.2; (8)
Cd	1991	5.4±2.7; (9)	9.4±4.2; (8)	6.7±4.2; (7)
	1992	2.6±2.4; (6)	8.0±5.1; (2)	4.5±1.4; (8)
Zn	1991	462±218; (9)	525±181; (8)	509±225; (7)
	1992	269± 59; (6)	401± 49; (2)	373± 73; (8)

Mean±SD; (number of clutches)

food web being modified by homeostatic mechanisms in organisms, which strive to keep tissue levels physiologically adequate (Clarkson, 1986).

The Pb and Cd concentrations in liver tissue of nestlings varied according to the deposited amounts. In fourteen and seventeen day old nestlings, liver levels were significantly lower at Stanislawice than at Hutki and Klucze, but similar at the two latter localities. Lowest Pb and Cd levels occurred at Ödsmål (Table III).

The interannual variation of liver concentration over the three years could not be properly studied because the sampled birds had different age in 1990, 14 days. Pb concentration in liver of the specimens from Klucze, however, was significantly higher in 1992 than in 1991 ($p<0.03$; Mann-Witney U-test, 2-tailed). A similar tendency was shown by the birds from Hutki ($p<0.07$). Higher concentrations of Pb in liver in 1992 coin-

TABLE III

Concentrations of lead and cadmium (mg/kg) in liver tissue of Great tit.

				Lead			Cadmium		
Locality	Year	Age	N	Mean ± SD	Range	Geom. mean	Mean ± SD	Range	Geom. mean
Stanisla-	1990	14	5	0.07±0.034	0.04-0.13	0.07	0.09±0.070	0.04-0.21	0.08
wice	1991	14	7	0.09±0.105	0.02-0.27	0.05	0.05±0.020	0.03-0.08	0.04
	1991	17	7	0.19±0.086	0.11-0.32	0.18	0.09±0.048	0.04-0.17	0.08
	1992	17	3	0.17±0.139	0.09-0.33	0.14	0.05±0.059	0.02-0.12	0.03
Hutki	1990	14	8	0.50±0.160	0.31-0.85	0.48	0.24±0.071	0.15-0.35	0.23
	1991	14	7	0.53±0.172	0.29-0.81	0.50	0.22±0.096	0.10-0.34	0.21
	1991	17	6	0.57±0.135	0.42-0.77	0.55	0.46±0.393	0.10-1.16	0.34
	1992	17	6	1.04±0.551	0.58-1.76	0.93	0.14±0.063	0.05-0.22	0.12
Klucze	1990	14	6	0.51±0.314	0.23-1.09	0.44	0.29±0.183	0.17-0.65	0.26
	1991	14	6	0.34±0.164	0.18-0.59	0.31	0.25±0.126	0.09-0.45	0.22
	1991	17	5	0.48±0.149	0.22-0.58	0.46	0.38±0.282	0.17-0.87	0.32
	1992	17	9	1.45±0.906	0.35-3.18	1.21	0.24±0.111	0.11-0.48	0.22
Ödsmål	1990	17	8	0.06±0.016	0.04-0.08	0.06	0.02±0.001	0.01-0.02	0.02

Statistics: Stanislawice - Hutki, Klucze; 1990, 14d; Pb: $p<0.002$; Cd: $p<0.007$; Mann-Whitney, U-test, 2-t.
- " - ; 1991, 14d; " $p<0.002$; " $p<0.001$; - " -
- " - ; 1991, 17d; " $p<0.002$; " $p<0.003$; - " -
- " - ; 1992, 17d; " $p<0.01$; " $p<0.03$; - " -
Ödsmål 1990 - Stanislawice; 1991,1992; " $p<0.001$; " $p<0.003$; - " -

cided with higher levels in excrements that year. Nyholm (1992, 1994) showed that the amounts of Pb, Cd, and total Hg in aerial deposition were sensitively reflected by the tissue concentrations in Pied flycatcher nestlings. This was also true for methyl-Hg in brain (Nyholm, unpubl.). Concentrations of methyl-Hg in brain of Great tit from the Polish localities, 1990, were similar to those of specimens from Ödsmål (Table IV), which indicated low degree of Hg pollution at the Polish localities.

In contrast to nestling tissue concentrations of non-essential elements, those of essential elements, Cu, Fe, and Zn, did not differ between localities. Thus, the concentrations of Zn did not reflect the degree of environmental pollution. This was probably due to the homeostatic control mechanisms, mentioned above, being efficiently capable to

TABLE IV

Concentration of methyl-Hg (mg/kg) in brain of 14 day old nestlings 1990 (cf Nyholm et al. 1994).

Locality	N	
Stanislawice	3	0.004±0.001
Hutki	3	0.025±0.008
Klucze	3	0.011±0.002
Ödsmål	3	0.010±0.004 (17 d.)

Mean±SD

TABLE V

Concentrations of ΣPCB and ΣDDT (mg/kg) in pectoral muscle fat of 14 day nestlings (cf Nyholm et al. 1994).

	N		
Stanislawice	3	0.19±0.06	0.35±0.14
Hutki	3	0.73±0.16	1.89±0.56
Klucze	3	0.59±0.08	0.79±0.25
Ödsmål	3	0.47±0.25	0.06±0.02

Mean±SD

keep normal levels of these elements in the birds and their food items, at the actual Zn deposition. Nyholm, (1992) observed that even at six times increased aerial Zn deposition, Zn level in liver in Pied flycatcher nestlings was kept normal. At that deposition level, the content of Zn in the excrements of nestlings was increased about three times.

Contents of organic pollutants, PCBs and pesticides (ΣDDT and HCH) were analysed in nestlings 1990. HCH levels were below detection limit. PCB concentrations in the birds were lowest at Stanislawice (Table V). ΣDDT was considerably higher in the nestlings from the Polish localities than in those from Ödsmål.

Environmental heavy metal contamination may affect breeding performance in passerine birds. Reduction of clutch size, embryonal and nestling survival, and of impact on health of surviving Pied flycatcher nestlings, reflected increased levels of heavy metal pollution (Nyholm, 1994). In this study, breeding results of Great tit were especially reduced at Hutki and Klucze (Tables VI), the sites most polluted by toxic heavy metals and organic toxicants . The reduction was in the first place due to abnormal nestling mortality. The extraordinary mortality rates at Klucze 1990 and Ödsmål 1991 (Table VI) were associated with heavy rain spells during the nestling period, i.e. natural factors. The climatic conditions were especially favourable at the Polish localities in 1992. That year, total losses of eggs and nestlings were low at Stanislawice. At Hutki and Klucze, however, nestling mortality was still high, indicating that toxic pollutants were significant factors limiting breeding results. To be recruit to the breeding population, fledged young must survive to their first breeding opportunity. To judge condition of the fledglings, weight and hemoglobin concentration (Hb) were measured in seventeen day old nestlings (Table VII). Weight development of nestlings at the Polish localities were similar to that of the reference locality. This indicates that the birds´ food supply was sufficient to admit normal growth, and that growth at the Polish localities was not affected at the actual doses of toxic substances in the nestlings.

At Swedish "clean" localities hemoglobin concentration exceeded 115 g/l in 95 percent of fully grown Pied flycatcher nestlings. That Hb level was considered the lower limit of normal Hb-range in Pied flycatcher at fledging (Nyholm, 1995). The Hb in

TABLE VI
Breeding results of Great tit, 1990-1992.

Locality	Year	Clutch size[a)]	Eggs hatched[a)]	Youngs fledged[a)]	Unhatched eggs (%)	Nestlings dead (%)	Total loss (%)
Stanislawice	1990	9.6±1.2 (10)	8.3±1.7 (10)	7.0±2.1 (9)	14	15	28
	1991	9.5±1.3 (19)	7.6±1.9 (17)	5.5±2.5 (11)	21	29	43
	1992	9.8±1.5 (6)	9.8±1.8 (6)	10.0±1.0 (3)	1.7	6.3	6.3
Hutki	1990	9.5±0.9 (8)	8.6±0.9 (8)	5.0±1.8 (8)	9.2	42	47
	1991	8.6±1.5 (17)	7.8±2.1 (15)	4.8±1.0 (15)	9.3	37	44
	1992	10.3±1.5 (12)	9.8±1.4 (12)	6.3±1.4 (12)	4.9	36	39
Klucze	1990	9.0±1.3 (14)	7.8±2.6 (13)	2.5±0.9 (13)	14	67	72
	1991	8.5±1.2 (14)	7.3±1.6 (10)	4.7±2.2 (9)	14	36	46
	1992	10.2±1.2 (13)	9.7±1.4 (13)	5.7±1.4 (13)	5.3	41	44
Ödsmål	1990	8.8±1.6 (28)	8.0±2.1 (28)	7.7±2.2 (27)	8.2	3.2	12
	1991	7.8±1.1 (16)	7.1±1.2 (15)	4.2±3.0 (13)	9.6	40	47
	1992	8.7±1.3 (15)	7.6±2.2 (11)	7.6±2.4 (9)	13	0	13

a) Mean±SD (number of clutches)

TABLE VII

Body weight and frequency of nestlings with hemoglobin concentration (Hb) less than 115 g/l in Great tit.

Locality	Year	Age (days)	N[a)]	Body weight (g) (Mean ± SD)	Hb<115 g/l (%)
Stanislawice	1991	17	7 (7)	17.3 ± 1.5	43
	1992	17	9 (3)	17.4 ± 1.6	44
Hutki	1991	17	11 (11)	16.9 ± 1.2	9
	1992	17	4 (4)	17.6 ± 2.6	50
Klucze	1991	17	5 (5)	17.3 ± 1.4	20
	1992	17	9 (9)	18.1 ± 0.7	22
Ödsmål	1991-92	17	20 (10)	17.4 ± 1.5	5

a) Numbers of nestlings (Numbers of clutches represented).

Great tit at Ödsmål indicated that similar "lower limit" was adequate for that species. High incidences of the Great tit nestlings at the Polish localities showed Hb lower than normal, anaemia (Table VII), which may have contributed to the high incidences of nestling mortality, and which also should affect survival after fledging. Individual Hb levels were only weakly correlated with body weight (r^2=0.02; N=58), indicating that Hb-status was not significantly related to general condition of the nestlings.

In conclusion, concentrations of toxic heavy metals, cadmium and lead, and persistent organic substancies in tissues of Great tit varied in accordance with the degree of environmental contamination. Breeding results were severely reduced at the localities in southern Poland, in the first place due to abnormal incidence of nestling mortality. Also, an enhanced frequency of the fledged young showed an inferior health state.

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