No effect of heavy metal content on the external morphology of first-year wintering Willow Tits *Poecile montanus*

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Abstract. Previous studies have shown that elevated levels of heavy metals may give reduced growth and shorter wings, whereas other studies gave no detectable effects. I examined the possible effects of exposure to the heavy metals, cadmium (Cd), copper (Cu) and zinc (Zn), on the morphology (lengths of wing, tail and tarsus, and body mass) of first-year wintering sedentary Willow Tits *Poecile montanus* near a refuse power plant in Trondheim, central Norway, in 1993-2000. The concentrations of Cd and Zn in the liver of the birds varied insignificantly from one year to another, whereas Cu varied significantly, suggesting that the Willow Tits were exposed to metal pollution. No significant correlations were found between the concentration of the metals and the lengths of the wing, tail and tarsus, or the body mass of the birds. Morphological measurements of the Willow Tits living near the power plant were compared with those of Willow Tits wintering at two other sites 3 and 90 km, respectively, from the power plant. Wing length, tail length, tarsus length and body mass did not differ significantly in the study sites, indicating that pollution by the heavy metals investigated did not affect the morphology of the Willow Tits.

Key words: heavy metal; cadmium; copper; zinc; contamination; *Poecile montanus*; morphology

INTRODUCTION

Heavy metal pollution may affect the health and growth pattern in birds (Janssens et al. 2003, Dauwe et al. 2005, Dauwe et al. 2006, Talloen et al. 2008) as well as their behaviour (Pedersen & Sæther 1999, Janssens et al. 2003, Hogstad & Pedersen 2007).

Cadmium (Cd) is one of the highly toxic heavy metals that accumulate in the liver and kidneys. Previous studies have shown that elevated levels of Cd may give reduced growth (e.g. Cain et al. 1983, Scheuhammer 1991). High levels of Cd and zinc (Zn) may affect the intake of copper (Cu), which is an essential metal for birds and mammals and is also a cofactor in several enzymes (Aarseth & Norseth 1986).

In the present paper I compare morphological measurements (wing length, tail length, tarsus length and body mass) of juvenile Willow Tits *Poecile montanus* collected in winter close to a municipal refuse power plant with that of wintering juvenile Willow Tits living in rural areas. The effluent gas from the refuse plant may be a source of heavy metals, and the concentrations of Cd, Cu and Zn in the liver of some passerine species living near the plant have been found to vary from one year to another (see Hogstad 1996). Sedentary Willow Tits feed on food items collected within a limited area near the refuse plant, so any heavy metals in these birds are derived from the local source. Previous studies have shown that elevated levels of heavy metals may give reduced growth and shorter wings (Cain et al. 1983, Dauwe et al. 2006, Talloen et al. 2008), whereas other studies gave no detectable morphological effects of metal pollution (Janssens et al. 2003, Norte et al. 2010).

The aim of this study was to examine whether any heavy metals in the highly sedentary Willow Tits may be detected through morphological measurements of the birds.

MATERIAL AND METHODS

The Willow Tit is a small non-migratory passerine living in non-kin winter flocks consisting most often of an adult pair and two to four juveniles. These flocks live within their territories outside the breeding season, and the food items collected are found within a limited area (Ekman 1979, Hogstad 1987).

The tits were caught at three sites in central Norway in 1993-2000. The Tiller forest, situated in Trondheim about 1.5 km east of the refuse power plant, consists mainly of Norway spruce *Picea abies*, Scots pine *Pinus sylvestris*, downy birch *Betula odorata* and grey alder *Alnus incana*. The Klæbu forest, situated 3 km south-east of the refuse plant, is similar to the Tiller forest. The Budal forest is 90 km south of the refuse plant, and is a subalpine (600 m a.s.l.) mixed forest of pines and birches.

Seven male and eight female Willow Tits were collected at Tiller (mainly during November-December)

Table 1. Mean concentrations (in mg kg^{-1} dry weight) of the heavy metals cadmium (Cd), copper (Cu) and zinc (Zn) in the liver tissues of juvenile Willow Tits collected at Tiller, 1.5 km from a refuse plant.

	Males (n=7) mean ± sd	Females (n=8) mean ± sd	Total (n=15) mean ± sd
Cd	0.39 ± 0.09	0.45 ± 0.15	0.42 ± 0.13
Zn	76.00 ± 11.84	74.94 ± 13.29	75.43 ± 12.20
Cu	19.94 ± 6.76	20.04 ± 9.23	20.00 ± 7.89

under a licence from the Directorate for Nature Management. The birds were kept frozen until analysed for Cd, Cu and Zn. The liver was digested in concentrated HNO_3 and then evaporated. The concentration of metals was determined by atomic absorption spectrometry. Standard reference materials were analysed concurrently with the samples. All values were within certified limits. All metal values are given as ppm (mg kg^{-1}) dry weight.

The tits studied at Budal and Klæbu were caught in October-November and individually colour-ringed, sexed (Haftorn 1982, Hogstad 1987) and aged (first-year vs. older birds; see Laaksonen & Lehikoinen 1976).

The birds were weighed with a Pesola spring balance, generally with an accuracy of 0.2 g, and the lengths of their wings and tails were measured to the nearest 0.5 mm. Only weight values made between 1100 and 1300 hours were recorded, since body weight varies appreciably through the day (Haftorn 1992, Ekman & Lilliendahl 1993, Koivula et al. 1988). The folded wing was flattened against a ruler and the primaries were straightened to give the maximum length. The tail length was measured from the base of the central tail feathers to the tip of the longest feather. The wings and tails were measured on birds after they had moulted. Yearling Willow Tits do not moult their primaries or secondaries until the postnuptial moult the following summer (Orell 1983, Svensson 1992). The tarsus length was measured to the nearest 0.05 mm using the standard method described by Svensson (1992).

Since metal concentrations in the liver are generally higher in adults than juveniles (Hogstad 1996), and adult Willow Tits are generally larger than juveniles (Hogstad 1987), only juvenile birds were analysed. Birds were collected at Tiller in midwinter because a previous study had found that concentrations of Cd and Cu may increase during a few winter months (Hogstad 1996). Statistical tests are two-tailed.

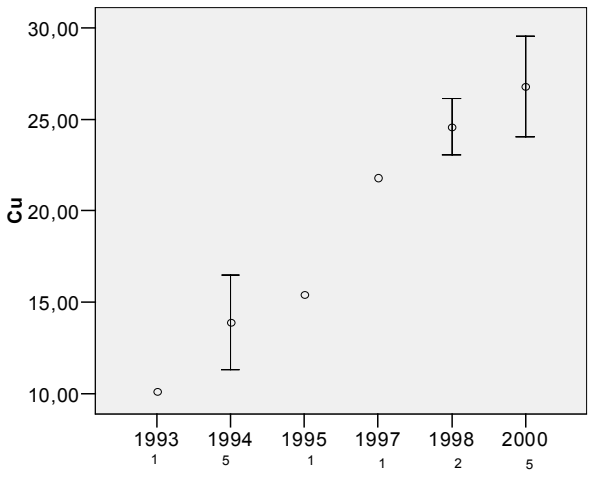

Figure 1. Concentrations (ppm) of Cu (mean ± 1se) in the liver of juvenile Willow Tits collected in mid-winter in the vicinity of a refuse plant. Figures below years denote sample size.

RESULTS

Metal concentrations

The metal levels (in ppm dry weight) of Cd, Cu and Zn in the liver of the Willow Tits revealed no differences between the sexes (t=0.02-0.04, p=0.36-0.88, df=13). The concentration values have therefore been pooled for each of the metals (Table 1).

The concentrations of Cd and Zn did not vary significantly from one year to another, possibly due to low sample size (One-way ANOVA; Cd: F=2.18, df=13, p=0.15; Zn: F=1.16, p=0.40), whereas Cu varied significantly (F=3.62, df=5, p=0.045). The mean yearly Cu concentration increased significantly during the study period (r=0.986, p<0.001, n=6; Figure 1). The concentration of Cd tended to decrease during the study period (r=-0.667, p=0.148), whereas Zn tended to increase (r=0.665, p=0.149).

The relatively great change in the metal levels in the liver of the birds, especially that of Cu, suggests that the birds were contaminated during the study period.

The correlation coefficients between the metal content in the birds showed a significant value for Zn-Cu (r=0.827, p<0.001, n=15) but not for Zn-Cd (r=-0.09, n=15) and Cd-Cu (r=-0.46, p=0.08, n=15).

Correlations between metal concentrations and morphology

No significant correlations were found between the

Table 2. Relationships (Pearson correlation) between morphometric measurements and metal concentrations (in mg kg^{-1} dry weight) in the liver of juvenile Willow Tits collected at Tiller.

	Males			Females		
	Cd	Cu	Zn	Cd	Cu	Zn
Wing length	0.30	0.43	0.71	-0.02	-0.10	0.09
Tail length	0.05	0.40	0.27	0.33	-0.32	-0.07
Tarsus length	-0.23	0.19	0.09	-0.24	0.16	0.35
Body mass	-0.27	0.33	-0.16	-0.18	0.31	0.16

concentrations of the three metals and the lengths of the wings, tails and tarsus, or the body mass, in the juvenile Willow Tits (Table 2).

Morphological measurements

There was no variation in the mean values for the wings, tails, tarsus and body mass at the three localities (Table 3).

DISCUSSION

The concentrations (ppm) of the metals in the liver of the wintering Willow Tits at Tiller were substantially higher for Cu (20.00) and Zn (75.43), but lower for Cd (0.42), than in breeding female Great Tits Parus major near a heavy-metal smelter near Antwerp, Belgium (Cu: 10.75, Zn: 36.0, Cd: 2.72; Dauwe et al. 2005). Nyholm (1996) also found lower amounts of Cu in passerines.

Whereas the concentrations of Cd and Zn in the Willow Tits varied insignificantly from year to year, the concentration of Cu increased significantly, indicating a change in the food content during the study period. This change in the Cu level in the liver of the birds suggests that they were contaminated.

Several studies have reported negative effects of Cu on small passerine birds. Eeva & Lehikoinen (1995) found that the Pied Flycatcher *Ficedula hypoleuca* was more susceptible to pollutants near a copper smelter than the Great Tit; egg shells were thinner, eggs smaller, clutch size smaller and hatching success lower. The local survival of adult females near a Cu smelter was also about 50% lower than in other areas, whereas males survived relatively well (Eeva et al. 2009). Eens et al. (1999) found that the Cu level in outer tail feathers of Great and Blue Tits *Cyanistes caeruleus* was significantly higher at a polluted site than at a reference site. On the other hand, Dauwe et al. (2005) found that Blue Tit reproduction was not affected by heavy metal pollution from a metallurgic smelter, although significantly positive correlations were found between Cd and lead (Pb), and egg contents and egg shells. Eeva et al. (2010) found that the total snail shell mass increased towards the pollution source, but declined abruptly in the vicinity of the smelter, and concluded that the pollution affected the diversity, abundance and quality of land snails, posing reproductive problems for birds that rely on snails as a calcium source during breeding.

However, even though the Willow Tits at Tiller probably were polluted by Cu, morphological measurements of the birds revealed no significant effects of the pollutant. Dauwe et al. (2006) did not find any effect of heavy metal pollution on the morphological measurements of Great Tits either, although their wings were somewhat longer furthest away from the smelter. Nam & Lee (2006), on the other hand, reported that the body

Table 3. Mean morphometric measurements (mm) and body mass (g) of juvenile male (M) and juvenile female (F) Willow Tits caught at Tiller, Budal and Klæbu. A One-way ANOVA test showed no variations between the three sites.

		Tiller (n)	Budal (n)	Klæbu (n)	One-way ANOVA
Wing	M	66.2 (13)	65.9 (131)	66.3 (3)	F=0.86, p=0.423
	F	62.2 (14)	62.6 (109)	62.2 (10)	F=2.85, p=0.062
Tail	M	58.3 (13)	57.4 (21)	59.0 (3)	F=3.26, p=0.051
	F	54.2 (14)	54.9 (13)	55.3 (10)	F=1.72, p=0.194
Tarsus	M	16.9 (13)	16.6 (20)	16.9 (3)	F=2.26, p=0.120
	F	16.5 (14)	16.4 (9)	16.6 (10)	F=0.51, p=0.604
Body mass	M	11.8 (13)	11.8 (21)	12.1 (3)	F=0.33, p=0.724
	F	11.3 (14)	10.8 (9)	11.3 (10)	F=2.42, p=0.106

weight, and the lengths of the wings, tarsus and bills of nestlings from a polluted area (Cd, Zn) were less than those from a less polluted area, and Dauwe et al. (2006) that found that the wings of Great Tits were longer at sites further from a non-ferrous smelter, whereas tail lengths and body mass did not differ between the pollution site and reference areas. Talloen et al. (2008), using ptilochronology, also found that exposure to lead caused the growth rates of tail feathers to decrease and resulted in shorter tail feathers. Furthermore, Cain et al. (1983) and Scheuhammer (1991) showed that elevated levels of Cd may give reduced growth.

The findings of Eeva & Lehikoinen (1995), however, showed that Pied Flycatchers were more susceptible to pollutants than Great Tits, suggesting that species may react differently to Cu pollution. Thus, the results found for Willow Tits in the present study may not be applied to other species.

Sammendrag. **Kontaminering av tungmetaller påvirker trolig ikke størrelse og vekt av unge granmeiser.** I forbrenningsprosessen ved Trondheim Energiverk's anlegg slippes det ut røykgass. Mulige miljøvirkninger av røykgassen ble undersøkt ved å måle konsentrasjonen av tungmetallene kadmium (Cd), kobber (Cu) og sink (Zn) i lever hos stedfaste unge granmeiser som holdt til nær (1.5 km) anlegget i løpet av 1993-2000. Konsentrasjonen av Cd og Zn varierte ikke statistisk gjennom årene, mens Cu økte signifikant.

Det ble ikke funnet signifikante korrelasjoner mellom tungmetallene og lengden av vinge, stjert og tars eller kroppsvekt av fuglene nær anlegget. Tilsvarende morfometriske mål ble tatt av unge granmeiser henholdsvis 3 km og 90 km fra anlegget i samme tidsrom. Det ble ikke funnet signifikante forskjeller mellom områdene, og det antas at en eventuell kontaminering av de tre tungmetallene ikke påvirker størrelse eller vekt av unge granmeiser.

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