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Mercury concentration in feathers of *Prunella modularis* in spruce and dwarf pine forest

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Abstract. Levels of mercury contamination in bird feathers show some dependence of Hg contamination on habitat type or elevation. The aim of this study was to determine the level of Hg in the feathers of *Prunella modularis* from different habitats of the West Carpathians, Slovakia. No significant differences in the amount of mercury found in feathers was detected between spruce and dwarf pine habitats, and the level of Hg in the feathers also did not change with altitude.

Key words: mercury, feathers, *Prunella modularis*, spruce forest, dwarf pine forest

Introduction

Mercury (Hg), in contrast to other heavy metals, can be transported in the atmosphere around the world. European primary emission sources have a significant impact on mercury pollution, and due to the long residence time of gaseous mercury in the atmosphere, outside of Europe as well (Harmens *et al.* 2013). Hg is one of the most toxic environmental contaminants, and enters ecosystems through the air or water (Evers 2018). It is deposited in terrestrial and water surfaces, builds up in soils or sediments and may be persistent in the environment. In aquatic systems the metal is biologically converted into the toxic compound methylmecury (MeHg or CH_3Hg^+). Ingested methylmercury is often completely absorbed by the gastrointestinal tract because Hg is strongly bound with proteins and amino acids (methylmercury-cysteinyl complex) (Kerper *et al.* 1992). Chronic exposure causes a number of adverse effects, such as damage to the central nervous system, kidneys and stomach, and affects the immune system, blood pressure and heart activity (Kampa and Castanas 2008). Birds reduce the load of toxic Hg using several mechanisms, including feather growth. MeHg has a high affinity to the free thiol group (-SH) which is rich in keratin in the feathers (Crewther *et al.* 1965). During their growth, feathers are connected to the body by a blood vessel and circulating Hg can be transported to the feather and incorporated into the keratin structure. When rectrices growth is complete, after fledging in young birds or after each molt in adults, the feather is no longer supplied with blood and the Hg remains physically and chemically stable within the feather (Stettenheim 2000). Higher levels of Hg in circulating blood occurs during the growing period in adult feathers than young feathers (Westermark *et al.* 1975; Hughes *et al.* 1997). The levels of Hg in feathers can indicate the degree of environmental pollution by Hg (Berg *et al.* 1966).

Hg production has decreased in Central Europe over the last few decades (EEA 2016). The current Hg levels in mountainou areas of Slovakia are unknown and current studies are mostly focused on soils (Tóth *et al.* 2009), water environments (Kapustová 2009; Stobiński and Kubica 2016), and vascular plants (Ciriaková 2009).

Subalpine regions in the high mountains of Slovakia can be an indicator of the load of heavy metals for several trophic levels and habitats. To analyze levels of Hg in birds, dunnock (*Prunella modularis*, Linnaeus, 1758) was chosen as an indicator species. This species is particularly widespread in forested mountain areas where spruce predominates, but also in mountain ranges habitated by dwarf pine.

The aim of this study was to investigate the dependence of Hg contamination in feathers of dunnock on the type of forest habitat and altitude in mountain regions in Slovakia.

Material and Methods

Study area

Study areas included characteristic habitats of dunnock in the mountain and submountain zone of the Slovakian part of the Western Carpathians, including: The High Tatras (Veľká studená dolina), Belianske Tatras (Tatranská Javorina, Ždiar, Biele pleso, Kolové pleso), West Tatras (Červenec), Low Tatras and Hornádska kotlina (Chopok, Tri domky, Suchý vrch, Stredná hoľa), Oravské Beskydy (Babia hora, Oravská priehrada) and Chočské vrchy (Veľký Choč). Capture and sampling of birds were conducted between 1999-2017, mostly in the spring and summer periods.

Sampling analysis

Hg levels were analyzed in 39 dunnocks. They were frozen (at -20° C) and stored in the Institute of High Mountain Biology in Tatranská Javorina. From each individual two outer tail feathers (rectrices) were collected. All assembled samples wer dried, weighed and cut into small fragments. A direct

Hg Analyzer (DMA-80; Milestone, USA) was used to measure Hg levels in the feathers.

One way ANOVA and regression analysis was used to compare the levels of Hg at different altitudes and habitats (Statiscica 12 software).

Results

In total the feathers from 39 birds were investigated. Most individuals were collected from the area Belianske Tatry (Ždiar, Podspády, T. Javorina). Average levels of Hg in different months and localities are given in Table 1.

A statistically significant relationship between the amount of Hg in the dunnock feathers and the elevation at which they were collected was not found (Fig. 1). The dunnocks from lower elevation spruce habitats did not differ in the amount of Hg in their tail feathers from dunnocks living in the higher dwarf pine habitats (Fig. 2).

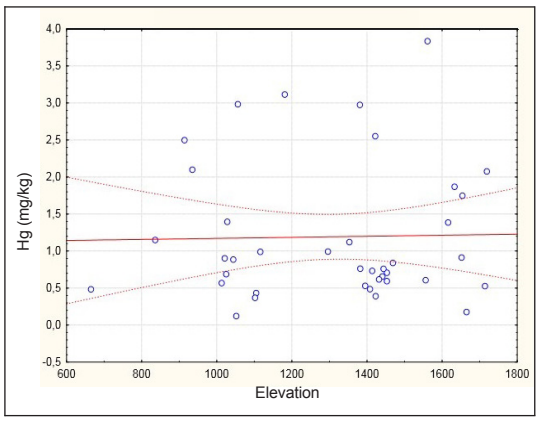

Fig. 1. Amount of mercury in the tail feathers of dunnocks in dependece on elevation in the West Carpathians. (Elevation: Hg (mg/kg): y=1.1004+7.0856 E-5*x; r=0.0209; p=0.8995).

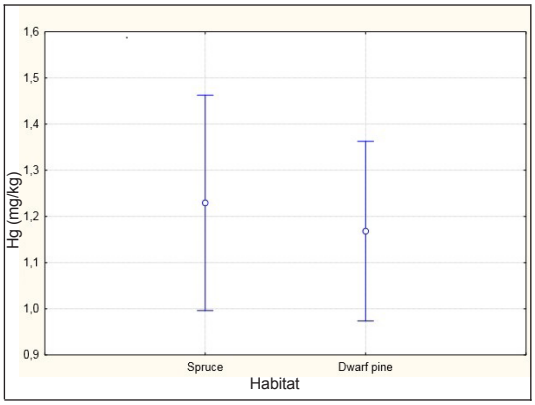

Fig. 2. Current effect levels of Hg between two vegetation lines. (LS Means + standard errors. Current effect: F(1, 37) = 0.04066, p = 0.84130)).

Discussion

Mercury levels are a major environmental burden for remote ecosystems that receive elevated deposition from long-range atmospheric transport (Blackwell and Driscoll 2015). The increased deposition of metals over large mountain areas of Europe is obvious (Janiga 2001). Examination of spatial deviations in Hg exposure of *P. modularis*, did not show any significant differences. Mountain ecosystems are exposed to higher levels of atmospheric Hg deposition as shown by accumulation patterns on the forest floor and associated high-elevation fauna (Townsend *et al.* 2014). Blackwell and Driscoll (2015) reported that total soil Hg concentrations increased with elevation from the deciduous to the alpine zone. Based upon soil characteristics, tree species, precipitation patterns, and expected Hg inputs, ecosystems at higher elevations are thought to receive higher Hg deposition and support greater methylation (Lawson *et al.* 2003; Yu *et al.* 2014). Findings of increased Hg concentrations in invertebrates, salamanders, and birds (Blais *et al.* 2006; Townsend *et al.* 2014), with increases in elevation support this hypothesis. Mercury enters ecosystems via wet or dry deposition, with inputs varying by forest cover type. Non significant differences among spruce and dwarf pine zones are attributed to the fact that both are within the coniferous tree line. Gerson *et al.* (2017) found that soil MeHg concentrations were highest in the mid-elevation coniferous zone (0.39 ± 0.07 ng/g) compared to the alpine tree zone (0.28 ± 0.04 ng/g) and deciduous tree (0.17 ± 0.02 ng/g), while the percent Hg as MeHg in soils decreased linearly with elevation. Higher concentration of Hg in

	Average levels of Hg (mg/kg) in different localities (n – number of individuals)				
	Belianské Tatras	**Central High Tatras**	**Low Tatras; Hornádska kotlina**	**West Tatras**	**Oravské Beskydy; Choč**
April	1.43 (3)				
May	1.43 (2)	0.54 (2)	1.51 (2)	2.97 (1)	0.48 (1)
June	1.04 (2)		1.82 (2)		1.82 (1)
July	1.78 (3)		1.75 (1)	0.59 (8)	1.19 (5)
August	0.56 (2)				
September	1.35 (3)	2.08 (1)			

Table 1. Number of samples divided to the time in months.

soils in coniferous forests compared to deciduous forests have been reported by several studies (Fisher and Wolfe 2012; Graydon *et al.* 2008, Kolka *et al.* 1999).

Birds are often used as bioindicators of environmental contaminants, and their feathers are widely used for the indication of heavy metal contaminantion (Thompson and Furness 1989; Ahmadpour *et al.* 2016). It has been found that Hg binds with the growing feather, which gives a history of contamination at the time that the feather was grown (Thompson and Furness 1989). When molting is completed, the level of Hg in the feather remains stable, even if the bird feeds on contaminated food. The increase of Hg concentrations is then noted in internal organs (Dauwe *et al.* 2003). Results of this study show levels of Hg found in the *P. modularis* of the subalpine region from spring to late summer. Generally Hg levels in the feathers are low, but there are significant individual deviations from the average. This likely reflects the very 'eurytopic' way of life of the species.

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