

HEPATIC OXIDATIVE STRESS IN YOUNG AND ADULT WATERFOWL SPECIES EXPOSED TO LEAD-CONTAMINATED SEDIMENT

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Abstract

Lead (Pb) exposure can result in lipid peroxidation of cell membranes and variations in glutathione (GSH) concentration, accounting for some of the adverse effects of Pb on vertebrate tissues. The toxicity of Pb-contaminated sediment, related to mining activity in the Coeur d'Alene River Basin (CDARB) in Idaho, was studied with respect to hepatic oxidative stress in two species of waterfowl. The relationship among liver Pb, thiobarbituric acid-reactive substances (TBARS), and GSH in growing young of Canada geese (*Branta canadensis*) and mallards (*Anas platyrhynchos*), and in adult mallards was examined. Day-old goslings and ducklings received control diets, or CDARB sediment (3449 µg/g lead) in diets at 12% or 24% (414 and 828 µg Pb/g of final diet) for the first six weeks post-hatching. Adult mallards received similar diets over a ten week exposure period. When goslings and ducklings were compared: Liver Pb concentrations increased more in mallard ducklings than in goslings; the highest lead exposure caused a greater and more significant increase in TBARS in goslings (86%) than in ducklings (20%). Hepatic TBARS concentration was correlated with liver Pb concentration in goslings ($r=0.78$). Although both species showed an increase in hepatic GSH concentration with Pb exposure, GSH levels at the highest exposure level were higher in ducklings than in goslings. Within treatment groups, hepatic GSH concentrations were inversely related to liver Pb concentration in both species, which may correspond to the role of GSH in Pb excretion. A negative relationship between hepatic GSH and TBARS was observed in ducklings, but not in goslings. In adult mallards an increase in hepatic TBARS concentration similar to that in ducklings occurred with an increase in GSH, which was half of that found in ducklings. The apparent lower resistance to lipid peroxidation of Canada geese may explain why geese found dead in the field by Pb shot ingestion often have a lower number of shot in the gizzard and lower liver Pb concentrations than mallards.

Introduction

Lead (Pb) poisoning is common in wild birds by the ingestion of shot pellets and contaminated sediment [1]. Pb exposure causes increases in lipid peroxides, and variations in glutathione (GSH) concentration, which can explain adverse effects of Pb such as hemolytic anemia, immunosuppression, increased blood pressure and inhibition of membrane enzymes [2,3].

Differences in the resistance to oxidative stress and lipid peroxidation could explain differences in the susceptibility to Pb poisoning between species, such as may be the case for Canada geese *Branta canadensis* and mallards *Anas platyrhynchos*. Field studies of Pb poisoned waterfowl have shown lower liver Pb concentrations and number of ingested shot in geese than in mallards [1].

Material and Methods

We studied the relationship among liver Pb, and thiobarbituric acid-reactive substances (TBARS), and GSH in growing young of Canada geese and mallards, exposed to Pb-contaminated sediment incorporated into the diet for the first six weeks post-hatching [4,5]. Diets contained 12 and 24% of Pb-contaminated sediment from the Coeur d'Alene River Basin, Idaho, USA, with, 3,449 µg Pb/g DW (1.7, 414, and 828 µg Pb/g of diet). Liver Pb, GSH and TBARS were determined as described by Hoffman et al. [4, 5]. Differences between species or treatments were studied with ANOVAs and their relationships with linear correlations or ANCOVAs.

Table 1. Mean \pm SE values from groups of 9 Canada goslings (G) or mallard ducklings (D)

Parameter	Treatment			ANOVA			p^b
	Sp	Control	12%	24%	Sp	Treat	
Pb (µg/g WW)	G ^a	0.02 ± 0.01	2.59 ± 0.32	4.63 ± 0.42	***	***	**
	D	0.03 ± 0.02	4.89 ± 0.44	8.41 ± 1.01			
TBARS (nmol/g)	G	15.3 ± 1.5	23.3 ± 2.0	28.4 ± 3.6	***	***	*
	D	12.5 ± 0.9	11.1 ± 0.7	15.0 ± 0.2			
GSH (µmol/g)	G	3.7 ± 0.3	4.2 ± 0.2	4.5 ± 0.4	*	**	ns
	D	3.8 ± 0.5	4.9 ± 0.5	5.7 ± 0.3			

^an=8; ^bns: $p>0.05$; * $p\leq0.05$, ** $p\leq0.01$, *** $p\leq0.001$.

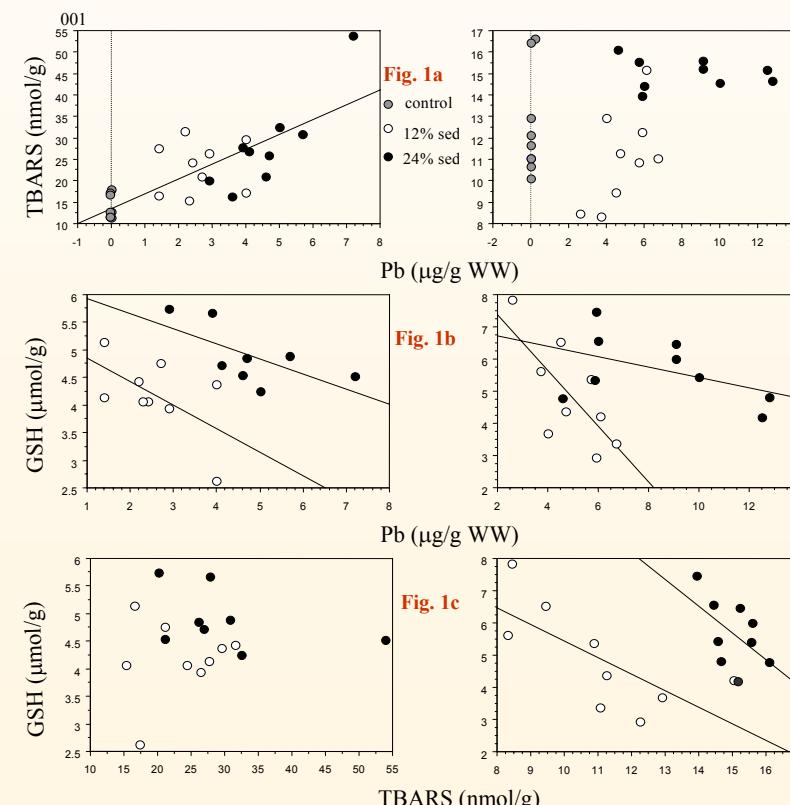


Fig. 1. Relationships among liver parameters in goslings (left) and ducklings (right)

Table 2. Mean \pm SD values from groups of 10 adult mallards.

Treatment	Control	24%
Pb (µg/g WW)	0.08 ± 0.02	9.1 ± 0.61 ^a
TBARS (nmol/g)	27.7 ± 4.2	31.4 ± 4.5 ^a
GSH (µmol/g)	5.5 ± 1.1	6.8 ± 1.4 ^a

^a significant differences ($p<0.5$) between nutrient levels.



Results and Discussion

Liver Pb increased in both species with the percentage of sediment in the diet, but about 82% more in ducklings than in goslings (Table 1). Liver TBARS also increased with the content of sediment in the diet, but more in the goslings (86%) than in the ducklings (20%). Liver TBARS was correlated with liver Pb in goslings ($r=0.78$, $p<0.001$), but not in ducklings (Fig. 1a). Liver GSH was higher in ducklings, but increased at a similar rate in both species. A negative relationship between liver GSH and liver Pb was found among birds within Pb exposed groups in both species ($p=0.005$, Fig. 1b). Liver TBARS showed an inverse relationship with liver GSH in ducklings ($p=0.021$), but not in goslings (Fig. 1c). In adult mallards an increase in hepatic TBARS concentration similar to that in ducklings occurred with an increase in GSH, which was half of that found in ducklings. GSH may have a role in biliary excretion of liver Pb in both species [2], but its protective effect as antioxidant may be higher in mallards, since Canada geese appear more sensitive to lipid peroxidation by Pb exposure. Differences in the resistance to oxidative stress may explain susceptibility to Pb poisoning within and among species.

References

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