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The role of nutritional status on tissue contaminant concentrations

ABSTRACT: We investigate how nutritional state can affect the magnitude of liver contaminant residues in predatory and fish-eating birds and demonstrate that the effects of starvation vary markedly with compound.

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Introduction

The liver accumulates high levels of many contaminants and is often the target organ. It is therefore often the organ of choice in biomonitoring studies. However, it is also physiologically dynamic and total liver mass varies with body condition - for example, starvation induces liver wastage. This can affect the measurable contaminant concentration and potentially obscure temporal and spatial trends in accumulation.

Here, we examine the extent to which nutritional status affects bioaccumulation of various legacy and current contaminants in sentinel predatory bird species.

We compared concentrations of polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), total mercury (Hg) and second generation anticoagulant rodenticides (SGARs) in livers collected from the carcasses of starved and non-starved predatory birds. A semi-quantitative categorical fat score was assigned to each bird based on the fat deposits evident in the carcass. Starved and non-starved birds have a fat score of 0 or 1, and 2 to 5, respectively. All carcasses were from the Predatory Bird Monitoring Scheme (PBMS; http://pbms.ceh.ac.uk).

PCBs and PBDEs

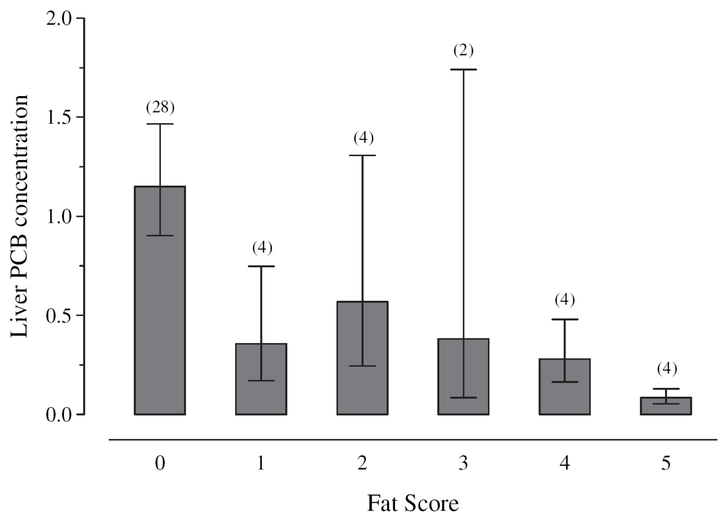

Figure 1.
Geometric mean (and GSE) liver sum PCBs (µg/g wet wt.) in herons (*Ardea cinerea*) with different body fat scores. Data are from Wienburg & Shore (2004); data for first-year, adult, male and female birds are combined. Sample sizes are in parenthesis.

Fat score accounted for 38% of the variation in liver PCBs in herons ($F_{(1,39)}$ =2. 99, P=0.02); liver PCBs were an order of magnitude higher in starved than non-starved birds (Figure 1). Similarly, liver PBDEs in sparrowhawks (*Accipiter nisus*) were some 15-fold higher in starved than non-starved adults [but only two-fold higher in first-years; $F_{(1,21)}$ =5.28, P<0.05 for both age and fat score; Figure. 2].

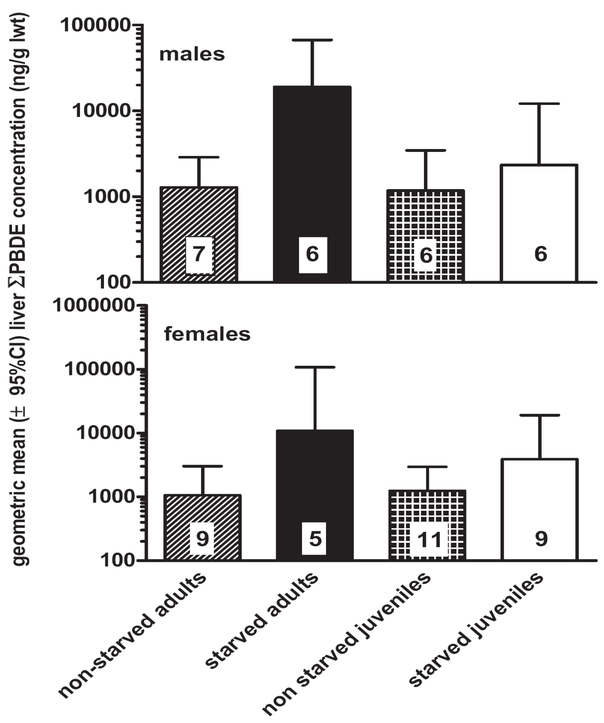

Figure 2.
Geometric mean (95% confidence interval) liver ΣPBDE concentrations (ng/glwt) in male (upper graph) and female (lower graph) sparrowhawks characterised by age and body condition.
Numbers in columns indicate number of birds in each group. Data are from Crosse et al. (2013).

Total mercury (Hg)

Annual median total liver Hg concentrations in sparrowhawks collected by the PBMS were consistently and significantly greater in starved than non-starved birds (Wilcoxon signed rank test, P=0.0016; Figure 3). However, the difference on average was only 1.7 fold, much less than that for PCBs or PBDEs.

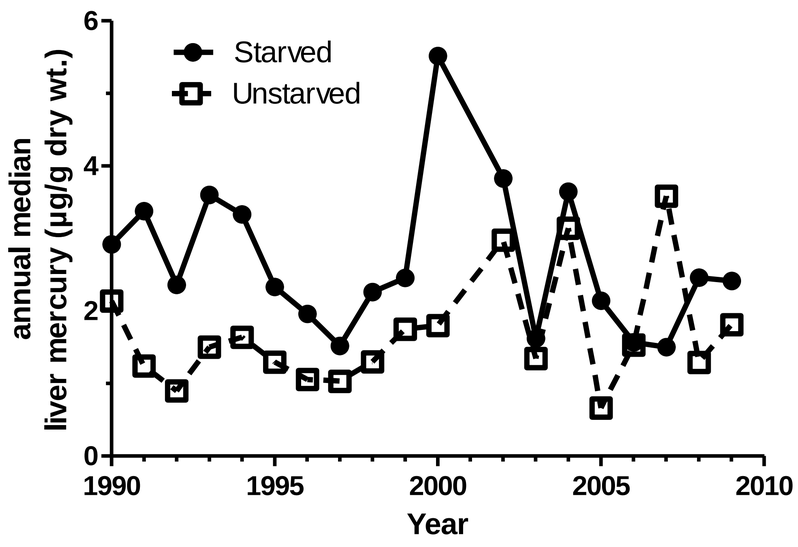

Figure 3.
Annual median total liver Hg concentrations in starved and non-starved sparrowhawks between 1990 and 2010

Summed second generation anticoagulant rodenticides (ΣSGARs)

Unlike with the other contaminants, mean liver ΣSGARs in barn owls (*Tyto alba*) collected by the PBMS between 2007 and 2012 were greater (on average by 45%) in non-starved than starved birds ($F_{(1,203)}$ = 4.74, P=0.031-Figure 4); there was also a significant effect of age.

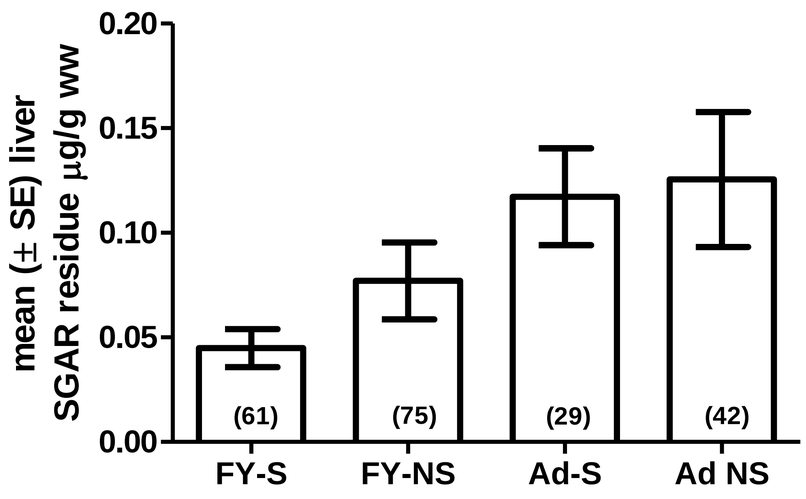

Figure 4.
ΣSGAR residues (µg/g dry wt.) in starved (S) and non-starved (NS) first-year (FY) and adult (Ad) barn owls that died between 2007 and 2012 and had detected SGAR residues.
Numbers in parenthesis indicate sample size.

Conclusions

- Starvation can result in remobilization of lipophilic compounds (such as PCBs and PBDEs) from fat and other lipid-rich tissues, resulting in subsequent sequestration [and order of magnitude elevation of residues] in the liver
- Starvation-induced elevation of liver Hg is broadly in proportion to the extent of liver wastage
- The opposite trend of higher liver SGAR residues in non-starved barn owls suggests there is little or no elevation of SGAR residues with starvation and/or that better nutrition is associated with greater SGAR exposure and accumulation

Understanding how liver residues are affected by starvation is important for: (i) disentangling the "physiological noise" that may obscure temporal and spatial trends in bioaccumulation, and (ii) determining the impact of starvation on contaminant toxicity.

References: Crosse, J. D. et al. 2013. Key factors affecting liver PBDE concentrations in sparrowhawks (*Accipiter nisus*). Environ. Pollut. **177** 171-176; Wienburg, C. L. & Shore, R. F. 2004. Factors influencing PCB concentrations in the livers of predatory birds in Britain. Environ. Pollut. **132** 41-50.

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