Excessive lead burden among Golden Eagles and the search for the source of lead

Cooperation:
- Swiss Ornithological Institute Sempach
- Cantonal Fish and Game Departments of GR, BE, LU, GL, SG
- Institut of Pharmacology Veterinary and Toxicology, University of Zurich
- Department of Forensic Pharmacology & Toxicology, University of Zurich
- Foundation Pro Bartgeier
- Parco Nazionale dello Stelvio

vogelwarte.ch

Amt für Jagd und Fischerei Graubünden
Ufficio per la caccia e la pesca dei Grigioni
Uffizi da chatscha e pestga dal Grischun

Universität Zürich
Excessive lead burden among Golden Eagles and the search for the source of lead

Questions and hypothesis
- Are GE and BV impacted by lead?
- Which organs are impacted by lead?
- What are the sources of lead for GE and BV?

→ hypothesis: if ammunition is the source of lead, scavengers should be significantly more affected than non-scavengers
section of bodies / analysis
### Amount of acute poisoning
(with symptoms of poisoning and/or very high lead concentration in blood or liver/kidney)

<table>
<thead>
<tr>
<th>Golden Eagles:</th>
<th>Bearded Vultures:</th>
<th>Eagle Owl:</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 (6) out of 41</td>
<td>(3 out of 6)</td>
<td>0 out of 20</td>
</tr>
<tr>
<td>≥ 7.3%</td>
<td>50.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

9.5.2011 Scuol Clínica Alpina
10.11.2009 Bisistal, Ikarus
results

lead in bones golden eagles eagle owl bearded vulture µg/g

[Graph showing lead concentrations in bones of different scavengers]
Golden eagles – lead concentration in feathers (n = 18)

Lead concentration in segments of the shaft of individual flight feathers (n = 18). Each flight feather is from a different individual golden eagle. Note the logarithmic y axis.
lead-isotopes analysis: first results

**isotope ratio** $^{207}\text{Pb}/^{208}\text{Pb}$

**Golden eagle and eagle owl: bones**

Caliber of ammunition Grisons: 10,3(!) x 60 mm

Ammunition: 5 samples of commonly used projectiles (bullets and shot) and 2 shot which were found incapsulated in the bones.

The isotope ratio $^{207}\text{Pb}/^{208}\text{Pb}$ differs significantly between ammunition and eagle owl and between golden eagle and eagle owl. No difference was found between ammunition and golden eagle.
The evidences point to ammunition as the source of lead in the bodies of golden eagles. But alternative lead sources can’t be totally excluded (bio-accumulation, soil).

Additional samples were analysed:
- prey of golden eagles (ibex carcasses, marmots)
- prey of eagle owl (small mammals, birds)
- soil
analysis of the prey of golden eagles: lead concentrations in bones

Mean bone lead concentration of golden eagles and eagle owls compared with their prey. Lines are 95% confidence intervals (if not shown they are smaller than the symbol). Means not sharing the same symbol are significantly different from each other at the p < 0.001 level. Numbers in parentheses are sample sizes.
Mean ratio of $^{207}\text{Pb}/^{208}\text{Pb}$ and $^{206}\text{Pb}/^{208}\text{Pb}$ found in bones of golden eagles, eagle owls, their prey and in Alpine ibex, as well as in ammunition and soil. Ellipses are 95% confidence intervals. A sample is significantly different from another sample if the mean is not included within the 95% confidence ellipse of the other sample.
Are offals - left in the field by hunters - sources of lead?

Offal of a deer, deposited by a hunter during the hunting season 2013

Shot-channel of a lead bullet in a soap block.

The bullet was 34% lighter after the shot (Einstein 25.2.14)

> 60% of the offals contained lead fragments (n = 146; Bassi and Ferloni 2012; Sondrio)

Lateral-view radiograph of the mid-thorax of an adult female white-tailed deer killed by a standard copper-jacketed lead-core soft-point hunting bullet in northern Wyoming in 2004. The fragment array surrounding the bullet path was approximately 12 cm in diameter excluding outliers. (Hunt et al. 2006).
ibex - hunting  september 2014, Engadin
Golden eagles consuming offals of ibex
Open questions:
- What impact have the high lead concentrations on the vitality of golden eagles?
- Are feathers of bearded vultures appropriate for isotope studies?
Lead signatures and feathers  Pb207/Pb208 and Pb206/Pb208 (golden eagles n = 15, feathers n = 80)
Lead signatures and feathers  Pb207/Pb208 and Pb206/Pb208
(golden eagles n = 18, feathers n = 80)
Mean feathers µg/g Pb

### Pb 207:208 all (n=81)

**ANOVA**

<table>
<thead>
<tr>
<th>Model</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>0.001</td>
<td>1</td>
<td>0.001</td>
<td></td>
<td>2.329</td>
</tr>
<tr>
<td>Residual</td>
<td>0.028</td>
<td>79</td>
<td>0.000</td>
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<tr>
<td>Total</td>
<td>0.028</td>
<td>80</td>
<td></td>
<td></td>
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</tbody>
</table>

Predictors: (Constant), masse
Dependent Variable: alle

**Regression**

\[
\text{alle} = 0.42 + 0.00 \times \text{masse}
\]

R. Square = 0.83

---

### Pb 207:208 > 0.5 µg/g Pb (n=15)

**ANOVA**

<table>
<thead>
<tr>
<th>Model</th>
<th>Sum of Squares</th>
<th>df</th>
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<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
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<td>Regression</td>
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<td>0.000</td>
<td></td>
<td>0.000</td>
</tr>
<tr>
<td>Residual</td>
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<td>1</td>
<td>0.000</td>
<td></td>
<td>0.000</td>
</tr>
<tr>
<td>Total</td>
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<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Predictors: (Constant), masse
Dependent Variable: gr0.5

**Regression**

\[
\text{gr0.5} = 0.42 + 0.00 \times \text{masse}
\]

R. Square = 0.23

---

### Pb 207:208 > 1.0 µg/g Pb (n=5)

**ANOVA**

<table>
<thead>
<tr>
<th>Model</th>
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<td>3</td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td>0.000</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Predictors: (Constant), masse
Dependent Variable: gr1.0

**Regression**

\[
\text{gr1.0} = 0.43 + 0.00 \times \text{masse}
\]

R. Square = 0.01

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Mean feathers µg/g Pb

Not significant: p > 0.05

Only feathers with slightly elevated lead conc.

Only feathers with elevated lead conc.

Not significant: p > 0.05

Significant: p < 0.05
Conclusion

- All evidences point to ammunition as a source of lead in golden eagles’ tissues
- Some findings indicate an even higher lead burden in bearded vultures
- Feather analysis on lead isotopes ratio are less purposeful than the analysis of bones

For statistical evidence, a sufficient sample size is crucial (lead concentrations and isotope ratios)

A multilateral approach is required to clarify the origin of the lead in BV tissues (blood, bones, liver, feathers)
Consequences?

In all **Swiss Cantons**:
- Hunting on waterfowl: lead shot ammunition is banned since 2014
- Bullet ammunition:
  - in three Cantons (SG, GR and SZ):
    Gamekeepers changed to lead-free ammunition.
  - 30’000 hunters are still hunting with lead ammunition

Thank You!