Dietary Exposure of Mink (*Mustela vison*) to Fish from the Upper Hudson River, New York, USA: Effects on Reproduction, Offspring Growth and Mortality

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Introduction

◆ Hudson River
  ▪ Contaminated with PCBs from Ft. Edward to New York City

◆ Major sources of PCBs
  ▪ Manufacturing facilities at Ft. Edward and Hudson Falls
Introduction

◆ Field studies
  ▪ Wild mink have hepatic PCB concentrations suggesting risk of reproductive impairment
Introduction

◆ Mink (*Mustela vison*) collected from PCB-contaminated sections of the Hudson River between Fort Edward and Troy between 1998 and 2001
  ▪ Hepatic $\sum$PCBs concentrations (\(\mu g/g\) lipid)
    • Within 6 km (1 home range) = 13 (0.54 to 139)
    • Within 1 km of river = 33 (1.4 to 139)

◆ LOAECS for reduced kit survival
  ▪ 45 $\mu g/g$ lipid (Heaton et al., 1995; Saginaw Bay)
  ▪ 29 $\mu g/g$ lipid (Bursian et al., 2006; Housatonic River)
Objective

◆ To evaluate health effects of feeding ranch mink diets containing PCB-contaminated fish from the Hudson River
  ▪ Reproductive performance
  ▪ Offspring survival
  ▪ Organ mass and tissue pathology (WP114)
Methods

- Carp collected from upper Hudson River

- Ground fish incorporated into feed at a rate of 20%
### Dietary Concentrations of $\sum$PCBs and TEQs

<table>
<thead>
<tr>
<th></th>
<th>Targeted dietary concentrations (µg $\sum$PCBs/g feed)</th>
<th>Analyzed dietary concentrations (µg $\sum$PCBs/g feed)</th>
<th>Total TEQs (pg TEQs/g feed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean herring (0.09 µg $\sum$PCBs/g, ww)</td>
<td>0%  2.5%  5%  10%  15%  20%</td>
<td>0.007  0.72  1.5  2.8  4.5  6.1</td>
<td>0.72  5.4  10  20  28  38</td>
</tr>
<tr>
<td>Hudson River carp (36 µg $\sum$PCBs/g, ww)</td>
<td>0%  2.5%  5%  10%  15%  20%</td>
<td>0.007  0.72  1.5  2.8  4.5  6.1</td>
<td>0.72  5.4  10  20  28  38</td>
</tr>
</tbody>
</table>
## Number of Female and Male Mink per Treatment Group

<table>
<thead>
<tr>
<th></th>
<th>μg $\sum$PCBs/g feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.72 1.5 2.8 4.5 6.1</td>
</tr>
<tr>
<td># Females</td>
<td>15 10 10 10 15 15</td>
</tr>
<tr>
<td># Males</td>
<td>5 5 5 5 5 5</td>
</tr>
</tbody>
</table>
Methods

- Animals housed singly in an open-sided pole barn
- Test diets fed from 8 weeks prior to breeding through weaning of kits (≈ 160 days)
- Kits weighed at 24 hr post-partum and at 3 and 6 wk of age
Methods

◆ Adults and a sample of kits were necropsied when kits were ≈ 6 wk old
◆ Liver, brain, heart, kidneys, spleen, thyroid gland, adrenal glands, testes/uterus, mandible/maxilla removed, weighed, fixed for histology
◆ Portion of liver frozen for contaminant analysis
Methods

◆ Remaining kits maintained on dietary treatment until ~ 31 wk old
  ▪ Control - 47 kits
  ▪ 0.72 µg ΣPCBs/g - 24 kits
  ▪ 1.5 µg ΣPCBs/g - 13 kits
  ▪ 2.8 µg ΣPCBs/g - 9 kits
  ▪ 4.5 µg ΣPCBs/g - 12 kits
  ▪ 6.1 µg ΣPCBs/g - 2 kits

◆ Necropsied juveniles (30 controls and 23 in 0.72 µg ΣPCBs/g feed group)
<table>
<thead>
<tr>
<th>Endpoint</th>
<th>Data Type</th>
<th>Statistical Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult body weight</td>
<td>Continuous</td>
<td>Generalized Estimating Equations Regression for Repeated Measures</td>
</tr>
<tr>
<td>Adult feed consumption</td>
<td>Continuous</td>
<td>Generalized Estimating Equations Regression for Repeated Measures</td>
</tr>
<tr>
<td>Number of females mated</td>
<td>Binary</td>
<td>Logistic Regression / Fisher’s Exact Test</td>
</tr>
<tr>
<td>Length of gestation</td>
<td>Continuous</td>
<td>ANOVA / Linear Regression</td>
</tr>
<tr>
<td>Number of females whelping</td>
<td>Binary</td>
<td>Logistic Regression / Fisher’s Exact Test</td>
</tr>
<tr>
<td>Number whelped per female</td>
<td>Count</td>
<td>Negative Binomial Regression</td>
</tr>
<tr>
<td>Number whelped live per female</td>
<td>Count</td>
<td>Negative Binomial Regression</td>
</tr>
<tr>
<td>Average litter weight</td>
<td>Continuous</td>
<td>ANOVA / Linear Regression</td>
</tr>
<tr>
<td>Kit weight at birth, three and six weeks</td>
<td>Continuous</td>
<td>Linear Generalized Estimating Equation Regression</td>
</tr>
<tr>
<td>Kit mortality at three and six weeks</td>
<td>Binary</td>
<td>Beta-Binomial Regression</td>
</tr>
<tr>
<td>Monthly body weights of seven-month-old juveniles</td>
<td>Continuous</td>
<td>Linear Generalized Estimating Equation Regression</td>
</tr>
</tbody>
</table>
### Summary of Study Endpoints, Data Types and Statistical Analysis Methods

<table>
<thead>
<tr>
<th>Endpoint Description</th>
<th>Data Type</th>
<th>Analysis Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult organ weights</td>
<td>Continuous</td>
<td>ANOVA / Linear Regression</td>
</tr>
<tr>
<td>Six-week-old kit organ weight</td>
<td>Continuous</td>
<td>Linear Generalized Estimating Equation Regression</td>
</tr>
<tr>
<td>Seven-month-old juvenile organ weight</td>
<td>Continuous</td>
<td>Linear Generalized Estimating Equation Regression</td>
</tr>
<tr>
<td>Total PCB and Total TEQs in adult livers</td>
<td>Continuous</td>
<td>ANOVA / Linear Regression</td>
</tr>
<tr>
<td>Total PCB and Total TEQs in six-week-old kit livers</td>
<td>Continuous</td>
<td>Linear Generalized Estimating Equation Regression</td>
</tr>
<tr>
<td>Total PCB and Total TEQs in seven-month-old juveniles livers</td>
<td>Continuous</td>
<td>Linear Generalized Estimating Equation Regression</td>
</tr>
<tr>
<td>Histopathology of adult organs and jaws</td>
<td>Binary</td>
<td>Logistic / Fisher’s Exact Test</td>
</tr>
<tr>
<td>Histopathology of six-week-old kit organs and jaws</td>
<td>Binary</td>
<td>Beta-Binomial Regression / Fisher’s Exact Test</td>
</tr>
<tr>
<td>Histopathology of seven-month-old juvenile organ and jaws</td>
<td>Binary</td>
<td>Beta-Binomial Regression / Fisher’s Exact Test</td>
</tr>
</tbody>
</table>

*Organ mass and histopathology: WP114*
Live Kits Per Litter

![Bar chart showing the number of live kits per litter based on dietary PCB concentration (μg ΣPCBs/g feed). The chart includes bars for different PCB concentrations: Control, 0.72, 1.5, 2.8, 4.5, and 6.1. The bars are labeled with letters indicating statistical significance.](image-url)
Percent Survival of Six-Week-Old Kits

Dietary PCB concentration (μg \( \sum \text{PCBs/g feed} \))

- Control
- 0.72
- 1.5
- 2.8
- 4.5
- 6.1

% Kit survival

Legend:
- a
- b
Mass of Six-Week-Old Kits

![Bar chart showing the mass of six-week-old kits by gender and treatment group. The chart includes bars for Males and Females, with different treatment groups labeled as Control, 0.72, 1.5, 2.8, 4.5, and 6.1. The bars are labeled with 'a' and 'b' to indicate statistical significance.]

- **Males**
  - Control: a
  - 0.72: a
  - 1.5: b
  - 2.8: b
  - 4.5: b
  - 6.1: b

- **Females**
  - Control: a
  - 0.72: a
  - 1.5: b
  - 2.8: b
  - 4.5: b
  - 6.1: b
Offspring Mortality Between 6 and 31 Weeks of Age

- **Control**
  - 6 wk (15F)
  - 10 wk
  - 31 wk

- **0.72 µg ∑PCBs/g feed**
  - 6 wk (10F)
  - 10 wk
  - 31 wk

- **1.5 µg ∑PCBs/g feed**
  - 6 wk (10F)
  - 10 wk
  - 31 wk

- **2.8 µg ∑PCBs/g feed**
  - 6 wk (10F)
  - 10 wk
  - 31 wk

- **4.5 µg ∑PCBs/g feed**
  - 6 wk (15F)
  - 10 wk
  - 31 wk

- **6.1 µg ∑PCBs/g feed**
  - 6 wk (15F)
  - 10 wk
  - 31 wk

(Number of live kits)
<table>
<thead>
<tr>
<th></th>
<th>Dietary PCBs (µg ∑PCBs/g feed)</th>
<th>Dietary TEQs (pg TEQs/g feed)</th>
<th>Hepatic PCBs (µg ∑PCBs/g feed)</th>
<th>Hepatic TEQs (pg TEQs/g feed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.007</td>
<td>0.72</td>
<td>0.051</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>0.72</td>
<td>5.4</td>
<td>1.4</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>10</td>
<td>2.8</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>2.8</td>
<td>20</td>
<td>3.3</td>
<td>101</td>
</tr>
<tr>
<td></td>
<td>4.5</td>
<td>28</td>
<td>4.9</td>
<td>181</td>
</tr>
<tr>
<td></td>
<td>6.1</td>
<td>38</td>
<td>6.2</td>
<td>220</td>
</tr>
</tbody>
</table>
Dietary ΣPCBs/TEQs Associated with 20% Mortality of 6-wk-old Kits

Hepatic ΣPCBs/TEQs Associated with 20% Mortality of 6-wk-old Kits
Conclusions

- Reproductive performance of adult female mink and offspring survival and growth were adversely affected by consumption of feed containing PCBs derived from fish collected from the Hudson River.
Conclusions

◆ Reproductive Performance
  ▪ The number of stillborn kits per litter was significantly increased by dietary concentrations of 4.5 µg ∑PCBs/g feed (28 pg TEQs/g feed) and greater

◆ Kit Survivability
  ▪ Dietary LC20 based on kit survivability at 6 wk of age = 0.34 µg ∑PCBs/g feed (2.9 pg TEQs/g feed)
  ▪ Hepatic LC20 based on kit survivability at 6 wk of age = 0.80 µg ∑PCBs/g liver, ww (13 pg TEQs/g liver, ww)

◆ Kit Growth
  ▪ Average body masses in the 1.5, 2.8 and 4.5 µg ∑PCBs/g feed groups (10, 19 and 28 TEQs/g feed, respectively) were less than controls at six weeks of age
Conclusions (WP114)

◆ Organ Mass
  ▪ ↑ thyroid mass of adult females, ↓ heart mass of 6-wk-old kits, ↑ adrenal gland mass of juvenile mink

◆ Tissue histopathology
  ▪ Development of a jaw lesion in adult mink characterized as mandibular and maxillary squamous epithelial proliferation
    • Dietary EC20 = 2.3 µg ∑PCBs/g (15 pg TEQs/g)
    • Dietary EC50 = 3.9 µg ∑PCBs/g (25 pg TEQs/g)
    • Hepatic EC20 = 2.8 µg ∑PCBs/g (89 pg TEQs/g)
    • Hepatic EC50 = 4.4 µg ∑PCBs/g (151 pg TEQs/g)
Conclusions

◆ EC20 based on the jaw lesion is 6-fold greater than LC20 based on kit survivability

◆ EC50 based on the jaw lesion is 1.7-fold greater than LC50 based on kit survivability
The conclusions and opinions presented here are those of the authors, they do not represent the official position of any of the funding agencies, the Hudson River Trustees or the United States. Funding provided by the Hudson River Trustees.
QUESTIONS?

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