The effects of diluted bitumen (dilbit) exposure during embryonic development on the future swimming performance and metabolic and ionic recovery post-exercise in sockeye salmon (Oncorhynchus nerka)

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The effects of diluted bitumen on the embryonic development and swimming performance of sockeye salmon (*Oncorhynchus nerka*)

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30th Salish Sea Ecosystem Conference, April 4-6, 2018
Background
Knowledge gap about dilbit toxicity

- Dilbit, a non-conventional crude oil
  - ↓ BTEX
  - ↓ Total polycyclic aromatic hydrocarbons (PAHs)
  - ↑ 3~5 ringed PAHs in proportions
    - Most toxic and bioavailable to aquatic life

- Different environmental behaviour when spilled
  - High density and viscosity
  - High potential of sinking
Knowledge gap about dilbit toxicity

- Dilbit toxicity to fish species remains unclear
  - Very few studies on dilbit toxicity
  - Not enough empirical data

- Studies using other crude oil blend or its components (e.g. BTEX, PAHs)
  - Generalization of risk?
Study objectives

- Acute and sublethal toxicity of dilbit on early life stage (ELS) Pacific salmonids
  - Mortality
  - % Deformity
  - Swimming ability
  - Biochemistry
- Latent effect in formally exposed survivors?
- Environmentally relevant exposure method
Exposure apparatus

- Generate water soluble fractions (WSFs) of dilbit
- Initial spike of total PAHs at 3.5, 16.4, 66.7 µg/L
- Beads re-soaked every 21 days
Experiment part 1

- Fertilized sockeye salmon embryos exposed to 3 concentrations of WSFs
  - 3.5, 16.4, 66.7 µg/L total PAHs
  - Control at 0.002 µg/L

- At 50% yolk sac absorption
  - Deformity assessment

- At swim-up stage
  - Burst swimming ability
  - Body biochemistry
Results

Values are means ± s.e.m (n = 960). One-factor ANOVA and Tukey HSD test (p<0.05).

The stacked cumulative mortality (%) of fish across treatments (n = 960 ) at three different developmental stages.
<table>
<thead>
<tr>
<th>Deformity (%)</th>
<th>Control</th>
<th>3.5 µg/L</th>
<th>16.4 µg/L</th>
<th>66.7 µg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yolk sac edema</td>
<td>2.0 ± 1.0 c</td>
<td>6.0 ± 1.0 b</td>
<td>15.0 ± 4.0 a</td>
<td>12.0 ± 2.0 a</td>
</tr>
<tr>
<td>Pericardiac edema</td>
<td>1.0 ± 0</td>
<td>0</td>
<td>4.0 ± 2.0</td>
<td>1.0 ± 0</td>
</tr>
<tr>
<td>Craniofacial</td>
<td>1.0 ± 0</td>
<td>3.0 ± 2.0</td>
<td>3.0 ± 1.0</td>
<td>5.0 ± 2.0</td>
</tr>
<tr>
<td>Skeletal</td>
<td>0</td>
<td>1.0 ± 0</td>
<td>1.0 ± 0</td>
<td>1.0 ± 0</td>
</tr>
<tr>
<td>Finfold</td>
<td>0</td>
<td>1.0 ± 0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fish with at least 1 type of deformity</td>
<td>2.0 ± 1.0 c</td>
<td>8.0 ± 1.0 b</td>
<td>20.0 ± 2.0 a</td>
<td>17.5 ± 0.5 a</td>
</tr>
</tbody>
</table>

Values are means ± s.e.m (n = 200). One-factor ANOVA and Tukey HSD test (p<0.05)
Results

Vals are means ± 95% confidence interval (n = 20). One-factor ANOVA and Tukey HSD test (p<0.05).
Results

Values are means ± 95% confidence interval (n = 20). One-factor ANOVA and Tukey HSD test (p<0.05).

- Unchanged carbohydrate storage
- Increased lipid storage
- Decreased soluble protein
U_{burst} swimming speed --- measure of burst ability

- Involved in food capture and predation avoidance

Loligo swimming tunnel used for U_{burst} test

Values are means ± 95% confidence interval (n = 12). One-factor ANOVA and Tukey HSD test (p<0.05).
Reared in clean water for 8 months. $U_{\text{burst}}$ swimming speed tested at 1, 3, 6, or 8 months in clean water.
Exposed swim-up fry

Yearling parr

Pre-smolt stage

Month(s) reared in clean water

Values are means ± 95% confidence interval (n = 12). Two-factor ANOVA and Tukey HSD test (p<0.05).
Pre- and post-exercise biochemistry

- **Plasma cortisol**
  - Pre-exercise range: 0–20 ng/mL
  - Post-exercise range: 20–60 ng/mL

- **Plasma glucose**
  - Pre-exercise range: 0–5 mM
  - Post-exercise range: 5–15 mM

- **Plasma lactate**
  - Pre-exercise range: 0–5 mM
  - Post-exercise range: 5–15 mM

**Indicators of stress level**
- Spikes in circulating cortisol, [glucose], [lactate] after exhaustive exercise

Values are means ± 95% confidence interval (n = 12). One-factor ANOVA and Tukey HSD test (p<0.05).
Pre- and post- exercise biochemistry

- Indicators of water-ion homeostasis

- Reduction in circulating plasma [Na\(^+\)] and [Cl\(^-\)] after exhaustive exercise

Values are means ± 95% confidence interval (n = 12). One-factor ANOVA and Tukey HSD test (p<0.05).
Conclusions
Exposure to WSFs of dilbit:

- Latent effect
- Signs of recovery after 8M?

- ↑ Mortality
- ↑ % Deformity
- ↓ $U_{burst}$ swimming speed
- Altered biochemistry
Experiment part 2 (ongoing)

- Exposed juvenile sockeye salmon exposed to 3 concentrations of WSFs
  - 3 exposure length: 24h, 96h, or 14d

- $U_{\text{burst}}$ and body biochemistry
  - Exercise recovery ability
  - Stress response
Thank you for listening!

Acknowledgements:

Funding support by the National Contaminant Advisory Group

Supervision by Dr. Chris Kennedy
Animal care staff at SFU for extensive fish care
Water accommodated fractions (WAFs)