Reproduction in Aquatic & Terrestrial Wildlife Following Remediation of the TVA Coal Ash Spill in Kingston, TN

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Effects of Coal Combustion Byproducts on Wildlife Physiology, Behavior, and Reproduction

Dec 22, 2008

54 million cubic yards of ash ingested by Bullfrog

Ingested Bullfrog
Timeline of events

- **December 2008**: Winter/Spring 09 Dredging starts
- **Summer 2010**: Dredging complete
- **April 2011**: Begin sampling post-remediation
Overarching Objectives

1. Following remediation, are wildlife exposed to trace elements?

2. Following remediation, do wildlife maternally transfer trace elements to their eggs?

3. Do trace elements affect physiology, behavior, or *reproductive success of wildlife post-remediation?
Why tree swallows?

1. Well studied in the wild
2. Large sample sizes are possible
3. Link between aquatic and terrestrial ecosystems
   - Feed heavily on emerging aquatic insects
4. Used in other ecotoxicological studies
Tree swallow study area
Methods for 2011 & 2012

- Monitored ≈ 500 nest boxes daily
- Mist-net adults or trap in nest box
- Basic reproductive parameters-clutch size, hatching & fledging success
- Measured, banded and bled adults & nestlings
- Collected 1 fresh egg from each clutch, blood and diet samples-quantified concentrations of 20 elements
- Focus today on As, Hg, Se, & Sr
Tree swallows sampling effort 2011 & 2012

Monitored 1121 nests
Banded 3699 tree swallows
Collected 473 food samples
Collected 881 fresh eggs
Questions
1. After remediation, are trace elements being transferred to eggs? Does maternal transfer of trace elements affect tree swallow reproductive success?

2. After remediation, are nestling tree swallows being exposed to elevated concentrations of trace elements in their diet?

3. After remediation, does trace element exposure affect nestling growth and fledging success?
Post-remediation trace elements in tree swallow egg samples (2011)

As was below detection limit

Hg mg/kg dm

F = 28.17
p < 0.001

Sr mg/kg dm

F = 22.83
p < 0.001
Post-remediation hatching success among colonies (2011 & 2012)

Hatching success near the spill area is similar to reference colonies post-remediation.

Proportion hatch
\[ F_{8, 694} = 1.013 \]
\[ p = 0.425 \]
Questions

1. After remediation, are trace elements being transferred to eggs? Does maternal transfer of trace elements affect tree swallow reproductive success?

2. After remediation, are nestling tree swallows being exposed to elevated concentrations of trace elements in their diet?

3. After remediation, does trace element exposure affect nestling growth and fledging success?
Tree swallow dietary exposure

- Adults retain food in their bill
- Many insects can be identified to order or family
Post-remediation trace elements in tree swallow bolus samples (2011)

Hg was below detection limit

As mg/kg dm

F = 1.37
p = 0.23

Se mg/kg dm

F = 6.34
p < 0.001

Sr mg/kg dm

F = 3.35
p = 0.003

Colony
Diet is related to post-remediation trace element exposure (2011)

$r^2 = 0.190, p < 0.001$

PC1: As, Ba, Cd, Cu, Fe, Mn, Se, Sr, Zn

$r^2 = 0.338, p < 0.001$

- Proportion aquatic insects
- Proportion Chironomidae
Questions

1. After remediation, are trace elements being transferred to eggs? Does maternal transfer of trace elements affect tree swallow reproductive success?

2. After remediation, are nestling tree swallows being exposed to elevated concentrations of trace elements in their diet?

3. After remediation, does trace element exposure affect nestling growth and fledging success?
Post-remediation fledging success among colonies (2011&2012)

Fledging success near the spill area is similar to reference colonies post-remediation.

Proportion fledge

\[
F_{8,570} = 2.540, \quad p = 0.010
\]
Tree swallow summary

Following remediation, trace element exposure still occurs (eggs, diet, blood) but at relatively low levels.

Detected no significant effects on reproduction post-remediation.
Tree swallow current research directions

- Examine physiological endpoints
  - Stress and immune response
- Effects of multiple stressors
- Relate 2012 trace element data to effects
Why turtles?

- Abundant
- Site fidelity
- Long lived
- Diverse feeding strategies
- Egg production occurs over several months
- Clutches easily incubated/hatchlings easily maintained
Trap nights:
Emory 2,861
Clinch 2,666
Tennessee 2,921

Turtle captures:
2011 5,077
2012 4,319
Egg collection results (2011 & 2012)

- 132 musk (Sternotherus) turtle clutches (431 eggs)
- 127 slider (Trachemys) clutches (1197 eggs)
Post-remediation arsenic concentrations in hatchlings (2011)

**Trachemys**
- $F_{2,48} = 8.76$
- $p < 0.01$

**Sternotherus**
- $F_{2,23} = 3.06$
- $p = 0.07$

<table>
<thead>
<tr>
<th>Location</th>
<th>Trachemys</th>
<th>Sternotherus</th>
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<tbody>
<tr>
<td>Emory</td>
<td>18</td>
<td>10</td>
</tr>
<tr>
<td>Clinch</td>
<td>22</td>
<td>5</td>
</tr>
<tr>
<td>Tennessee</td>
<td>11</td>
<td>11</td>
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</tbody>
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Post-remediation selenium concentrations in hatchlings (2011)

*Trachemys*

\[ F_{2,48} = 16.17, \ p < 0.01 \]

*Sternotherus*

\[ F_{2,23} = 26.88, \ p < 0.01 \]
Turtle clutch size (2011 & 2012)

- **Trachemys**: $F_{2,110} = 0.620$, $p = 0.54$
- **Sternotherus**: $F_{2,107} = 4.36$, $p = 0.02$

- **Emory**: Trachemys 37, Sternotherus 45
- **Clinch**: Trachemys 35, Sternotherus 48
- **Tennessee**: Trachemys 55, Sternotherus 39
Turtle hatching success (2011 & 2012)

Trachemys
\[ F_{2,113} = 1.12 \]
\[ p = 0.33 \]

Sternotherus
\[ F_{2,110} = 1.10 \]
\[ p = 0.34 \]
Turtles summary

• Post-remediation, As and Se concentrations higher in Clinch and Emory Rivers than Tennessee River
  – Overall concentrations low

• No observed adverse effects on hatching success or clutch size at spill site post-remediation

• Ongoing analyses of offspring quality; 2012 data forthcoming and will yield final conclusions
Preliminary Take-Home Messages

1. Remediation efforts coupled with the large dilution factor likely limited exposure to trace elements $\approx 2.5$ years following the spill
   - Elevated concentrations of trace elements (but often below levels of likely concern) in all species post-remediation

2. No signs of reproductive impairment post-remediation
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