ADVANCING KNOWLEDGE AND STEWARDSHIP OF FRESH WATER SYSTEMS THROUGH RESEARCH, EDUCATION, AND RESTORATION

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Ecological Significance of Specific Conductance in Streams – Part 2

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EnviroDIY
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Terms Describing Salt in Fresh Water

- **Salinity (ppm)**
- **Total Dissolved Solids (TDS, ppm)**
- **Electrical Conductivity or Specific Conductance (µS/cm)**
- **Salt (mg/L)**
  - (NaCl, KCl, CaCl$_2$, MgCl$_2$)
- **Chloride (mg Cl/L)**
Electrical Conductivity/Specific Conductance measures dissolved salt concentration

SC does not tell you about specific salts (NaCl vs MgCl₂)

SC naturally varies 100 – 200 μS/cm in response to precipitation, and 500 – 1000 μS/cm with a region

Natural spatial variation (geology) may be more important than natural temporal variation (dilution events)
Why is Electrical Conductivity Important to Aquatic Organisms?

- Electrical conductivity is a measure of salt concentration – as ions, cations, anions

- Ambient salt concentration affects water balance & ion inside the aquatic organism
  - Internal ion balance is important to normal physiological processes

- Potential mechanisms for salt toxicity not clear
Osmoregulation
- maintaining salt and water balance -

Cells placed in a hypertonic environment shrink due to loss of water. In a hypotonic environment, cells swell due to intake of water. The blood maintains an isotonic environment so that cells neither shrink nor swell. (credit: Mariana Ruiz Villareal)

Migratory fish must use different physiological mechanisms to survive in (a) freshwater or (b) saltwater environments.
Most freshwater organisms do not have the ability to move from fresh water to salt water. They can tolerate some increase in salinity, but have limited ability to adapt to great increases in salinity.
Why does salt physiology matter?

Streams are becoming saltier.

Sodium Doubled 1973 - 1999

Chloride

Schuylkill River @ Philadelphia

Interlandi & Crockett 2003
Increased salinization of fresh water in the northeastern United States


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Fig. 1. Examples of significant, long-term increases in baseline concentration of chloride for streams and rivers of the northeastern United States. The $R^2$ values are given for linear regressions. All streams and rivers are located in rural areas but contain roads within their watersheds. (A) LMR0015 (Little Morgan Run), MDE0026 (Middle Run), and BEA (Beaver Run) are sampling stations for tributaries to Liberty Reservoir, a drinking water supply for Baltimore. (B) Wappinger Creek and the Mohawk River are tributaries to the Hudson River in the Hudson River Valley. (C) The streams in the White Mountains drain into Mirror Lake; one is located near an interstate highway in the Hubbard Brook Valley, and the forested reference stream is watershed 6 of the Hubbard Brook Experimental Forest (10).
History of Road Salt Use in US

1972 (Claffey) & 1976 (TISA)
Safety and economic benefits of deicing

Winter Travel
- Plowing
- Anti-skid
- Snow tires
- Chains

1993 Marquette U
Germany
Safety studies

Now 23
Salt concentration in urban streams is always elevated.

near West Chester, PA
Sept 22, 2019

Patty Haag
WCU MS Student
Chester Co Master Watershed Steward
Salt concentration in urban streams is always elevated near West Chester, PA Sept 22, 2019 Late Summer Sample
Salt concentration in urban streams is always elevated

near West Chester, PA
Sept 22, 2019

Conductivity (uS/cm) vs. Chloride (mg/L) for various streams:
- Plum Run - GNA
- Plum Run - New
- Blackhorse Cr
- Taylor Run
- Goose Cr trib

Late Summer Sample
WCC at Stroud
Salt concentration in urban streams is always elevated.
Salt concentration always elevated, but highly variable.

Peaks at 20,000 to 40,000 µS/cm

Seawater 55,000 µS/cm
Assessing salt toxicity

Dose Response Curve

LC50
Lethal Concentration that results in 50% mortality

50% mortality
Toxicity decreases with increased hardness

Lethal Concentration (LC50)
30-day exposure

![Graph showing chloride levels in different streams with hardness levels indicated]

- WCC: 600 mg/L
- Dyberry: 400 mg/L
- Spruce: 100 mg/L

Centroptilum triangulifer

- 35% Reduction
- 89% Reduction

Stream:
- Hard
- Moderately Hard
- Soft
Not all species are sensitive

Lethal Concentration (LC50)
2-day exposure

Chloride (mg/L)

Rainbow, Fathead, D. magna, C. triangulifer, ps. frondale, C. dubia, P. rivulare

81% Reduction
Toxicity increases with exposure duration

**Lethal Concentration (LC50)**

- **2 day**: Chloride (mg/L) = 2400
- **30 day**: Chloride (mg/L) = 600

**Centropilum triangulifer**

- 75% Reduction
Toxicity is less in cold water

Lethal Concentration (LC50)
4-day exposure

Neocloeon triangulifer

Toxicity Increases

Cl - (mg/L)

Temperature (°C)

75% reduction
Salt concentration always elevated, and temperature matters

N. triangulifer

2 days

Acute LC50 @ 5°C

21 days

Acute LC50 @ 20°C
Not all salts are equal
Acute toxicity (48 h)

<table>
<thead>
<tr>
<th></th>
<th><em>Ceriodaphnia dubia</em> LC50 (mg Cl/L)</th>
<th><em>Daphnia magna</em> LC50 (mg Cl/L)</th>
<th><em>Pimephales promelas</em> LC50 (mg Cl/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NaCl</strong></td>
<td>1,960</td>
<td>4,770</td>
<td>6,510</td>
</tr>
<tr>
<td><strong>MgCl$_2$</strong></td>
<td>880</td>
<td>1,330</td>
<td>2,840</td>
</tr>
<tr>
<td><strong>CaCl$_2$</strong></td>
<td>1,830</td>
<td>2,770</td>
<td>&gt;6,560</td>
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</tbody>
</table>
Not all salts are equal
Rainbow trout – growth (25 d)

<table>
<thead>
<tr>
<th>Concentration (mg Cl⁻ L⁻¹)</th>
<th>Control</th>
<th>MgCl₂</th>
<th>NaCl</th>
<th>CaCl₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>230</td>
<td><img src="image1" alt="Fish" /></td>
<td><img src="image2" alt="Fish" /></td>
<td><img src="image3" alt="Fish" /></td>
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<tr>
<td>860</td>
<td><img src="image1" alt="Fish" /></td>
<td><img src="image2" alt="Fish" /></td>
<td><img src="image3" alt="Fish" /></td>
<td><img src="image4" alt="Fish" /></td>
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<tr>
<td>1500</td>
<td><img src="image1" alt="Fish" /></td>
<td><img src="image2" alt="Fish" /></td>
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<tr>
<td>3000</td>
<td><img src="image1" alt="Fish" /></td>
<td><img src="image2" alt="Fish" /></td>
<td><img src="image3" alt="Fish" /></td>
<td><img src="image4" alt="Fish" /></td>
</tr>
</tbody>
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Conductivity Correlates with Degradation

157 sites, primarily in Schuylkill River basin

Macroinvertebrate Score vs. Conductivity (< 550 µS/cm)

Chloride (< 85 mg/L)

$r^2 = 0.52$

Good
Fair
Poor

NaCl
Conductivity Correlates with Degradation

157 sites, primarily in Schuylkill River basin

Macroinvertebrate Score

Conductivity (< 550 µS/cm)

Correlation may not equal Causation

Chloride (< 85 mg/L)

r^2 = 0.52

Good
Fair
Poor

NaCl
Salt Illustrates Land/People Connection to Water:

**Toxins:**
- Salt
- Oils
- Metals
- Sealants
- Herbicides
- Insecticides
- Soaps
- Drugs
- Personal Care
- Fertilizers
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<table>
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<th>Storm Drains:</th>
<th>Sewer System:</th>
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</thead>
<tbody>
<tr>
<td>&quot;Chemical Cocktail&quot;</td>
<td>&quot;in storm water&quot;</td>
</tr>
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</table>

**Freshwater Salinization Syndrome**

*Kaushal et al. 2018*
There are new pollutants of concern today

- PAHs in coal tar seal coats (2003)
- 6PPD-quinone from tires (2020)
Salt Levels of Concern

LC 50s for a few mayflies
moderately hard water at 20°C

<table>
<thead>
<tr>
<th></th>
<th>Chloride (mg/L)</th>
<th>Conductivity (uS/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute (96 h)</td>
<td>311-2894</td>
<td>1013-8603</td>
</tr>
<tr>
<td>Chronic (30 d)</td>
<td>151-898</td>
<td>543-2738</td>
</tr>
</tbody>
</table>
Salt in streams is increasing, especially urban streams.

Elevated salt can cause physiological stress or even be toxic for aquatic organisms. Brief salt spikes in winter are not well understood.

Impact of elevated salt depends on concentration, stream hardness, exposure duration, type of salt, water temperature, and species.
Questions?
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