How Marine-Derived Nutrients Benefit Both Natural and Model Stream Systems

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Marine-derived Nutrients: Ecosystem Needs

Many stream ecosystems throughout northeastern North America are nutrient limited
Marine-derived Nutrients: Ecosystem Needs

Many stream ecosystems throughout northeastern North America are nutrient limited.

Migrating fish move essential materials across ecosystem boundaries.
Many stream ecosystems throughout northeastern North America are nutrient limited. Allochthonous nutrient and carbon inputs can be the primary driver of stream productivity.
The Majority of MDN studies have focused on Pacific northwest ecosystems.
Pacific salmon (*Oncorhynchus* spp.) in western North America

- Chinook
- Coho
- Sockeye
- Pink
- Chum
- Steelhead

*Semelparous (except steelhead)*

- Carcasses
- Excretory Products
- Eggs

*Spring, late summer and fall runs*

U.S. Fish & Wildlife Service, NOAA, Georgia Strait Alliance
Anadromous fish in the Atlantic

Atlantic salmon

Shortnose sturgeon

Atlantic sturgeon

Rainbow smelt

Brook Trout

Iteroparous (except sea lamprey)

Excretory Products
Eggs

Diverse life histories and spawning event timing

Diverse freshwater habitats

Alewife

Blueback herring

American shad

Striped bass

Sea lamprey

U.S. Fish & Wildlife Service, NOAA
Marine-derived Nutrients Impact Freshwater Productivity
# Change in Marine Nutrient Loading

Adult salmon returns in the St. John River at the Mactaquac Dam

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<tr>
<td>* Total N</td>
<td>610 Kg</td>
<td>57 Kg</td>
</tr>
<tr>
<td>* Total P</td>
<td>8 Kg</td>
<td>0.5 Kg</td>
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* Calculations are based on excretory products and gametes only, **no mortality**
# Change in Marine Nutrient Loading

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<tr>
<td>Cows</td>
<td>915</td>
<td>85</td>
</tr>
<tr>
<td>Manure</td>
<td>62.25 tonnes</td>
<td>5.75 tonnes</td>
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Number of cows/amount of manure to produce the equivalent amount of nutrients
Objective

Compare effects of marine-derived nutrient inputs from natural and supplemental sources on stream productivity
Study Areas – Natural Anadromous Populations

Anadromous Species
- Smelt
- Alewife
- Lamprey
- Salmon

Study Areas
- New Brunswick
  - Indiantown Brook
  - Rocky Brook
  - Cross Creek
- Prince Edward Island
  - Doctor’s Brook
  - Knoydart Brook
- Nova Scotia
  - Oromocto River

Map showing various study areas in New Brunswick and Nova Scotia with marked locations for Indiantown Brook, Rocky Brook, Cross Creek, Doctor’s Brook, and Knoydart Brook.

Legend:
- New Brunswick
- Prince Edward Island
- Nova Scotia
- 100 km scale
- North orientation
Kingsbury Plantation Piscataquis County Maine

Study Area – Nutrient Addition Study

- 4 Streams
- Carcass Analog
  - BioOregon Product
  - Fall Chinook salmon (hatchery)
  - ~10%N, 2.2%P
  - Free of pathogens
- Density
  - 0.10 kg/m²
- Timing
  - “Lamprey”: July
Stable Isotopes as Ecological Tracers

\( \delta^{15}N \) vs. \( \delta^{13}C \)

- Marine
  - High \( \delta^{15}N \)
  - High \( \delta^{13}C \)
- Freshwater
  - Low \( \delta^{15}N \)
  - Low \( \delta^{13}C \)
Stable Isotopes as Ecological Tracers

- **δ15N**: High to Low
- **δ13C**: Low to High

Legend:
- **Marine**: Yellow circle
- **Freshwater**: Various shapes
- **MDN Incorporation Through Time**: Red arrow

The diagram illustrates the relationship between δ15N and δ13C in freshwater and marine environments, showing how isotopic ratios change over time.
Incorporation of MDN into the Freshwater Food Web by Macroinvertebrates

**Natural System**

- **Control Sites**
- **May 6**
- **May 14**
- **May 24**
- **June 16**

**Model System**

- **Carcass Analog**
- **Smelt eggs**
- **June 23**
- **July 13**
- **July 27**
- **August 24**

Graph showing changes in δ^{13}C and δ^{15}N values from May 6 to June 16.
Productivity Responses to Marine-Derived Nutrients

Primary Productivity (Biofilm)

Invertebrates

Fish Growth/Health
Differences in Invertebrate Abundance – Natural System

Smelt River

Area With MDN

Alewife River

Area Without MDN
Differences in Invertebrate Abundance – Model System
Changes in Body Condition of Atlantic Salmon Parr in the Presence of MDN

Natural System

Condition Factor (g·cm⁻³ × 100)

Model System

Fish Mass (g)

- MDN Inputs
- Control
- Lamprey Spawning

<table>
<thead>
<tr>
<th>Month</th>
<th>Treatment</th>
<th>Control</th>
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<tbody>
<tr>
<td>June</td>
<td></td>
<td></td>
</tr>
<tr>
<td>July</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sept</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct</td>
<td></td>
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(0+ Parr)
Total Lipid Composition in Salmon Parr

Natural System

Model System

Spawning Period

Carcass Analog Addition
Omega 6 Fatty Acids – Natural System

- **Brain**

- **Gonad**

- **Muscle**

**MDN Inputs**

**Control**

**Spawning Period**
Changes in Productivity - Biofilm Abundance with Anadromous Fish Spawning

Atlantic Salmon Spawning

Rainbow Smelt Spawning

Total Chlorophyll Abundance (μg cm⁻²)

Sept                     Oct                      Nov                      Dec

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Total Chlorophyll Abundance (μg cm⁻²)

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Changes in Productivity - Biofilm Abundance with Anadromous Fish Spawning Model System
Nutrient Subsidies Are Good **YES**
Strategy Is Simple **NO**
Dump In Fertilizer **NO, NO**
Fertilizer Additions Do Not have the Same Ecological Effects as Carcasses

Wipfli et. al 2010 (Trans. Am. Fish. Soc. 139)
Point Source vs. Pulsed Nutrient Inputs

Point Source Nutrient Addition

Pulsed Nutrient Addition
What is the Research Question?

- To restore rivers to their natural state
- Recovery of a single species (i.e. salmon)
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Nutrient Subsidies Have a Relatively Small Effect Range

500m Affected Range

water flow
11 km Section of the Little Southwest Miramichi

Otter Brook (~4.2 km Long)

Catamaran Brook site

Israelite site

Otter Brook site

Otter Brook (~4.2 km Long)
What is the Research Question?

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Summary

• Anadromous fish bring nutrients and other constituents to freshwater ecosystems

• MDN/nutrient subsidies inputs result in increased productivity at various trophic levels

• Increased productivity is better “quality” with the incorporation of essential fatty acids

• Nutrient additions need to be strategic based on specific restoration goals

• Nutrient additions are designed to be used in concert with other restoration techniques
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Cunjak Lab

Photo credit R. Cunjak