Labs

Nov. 14th  Lab 11 – stream invertebrate ID
Nov. 21st  Lab 12 – revisit Dunham pond
Dec. 5th   Project presentations
Nutrients

P, N often limiting
Increases in nutrients increase vegetation
Leads to high BOD, low oxygen
Long-term fertilization of Kuparuk Creek
Long-term fertilization of Kuparuk Creek

Fig. 5. Epilithic total chlorophyll in the reference and fertilized reach riffles of the Kuparuk River during fertilization (July and August). Values for 1987 and 1994 means only include August chlorophyll values. In 1988, fertilized reach values are inflated due to contamination by green algal filaments. Data are means ± 1 SE.

Notes: Chlorophyll data in this figure reflect values that have been recalculated since estimates were published in the following manuscripts: Peterson et al. (1985, 1993a), Miller et al. (1992), Deegan et al. (1997). Due to an error (10×) in the conversion of the fluorometer readings, chlorophyll estimates presented in previously published manuscripts were too high, but the relative differences between reaches are not changed.
Ecological surprises

UNDERSTANDING AND PREDICTING ECOLOGICAL DYNAMICS: ARE MAJOR SURPRISES INEVITABLE?

Long-term fertilization of Kuparuk Creek

Fig. 6. Percentage of total bryophyte coverage (mean ± 1 se) in the Kuparuk River, 1992–1998.
Long-term fertilization of Kuparuk Creek
Long-term fertilization of Kuparuk Creek

Bottom-up effects of nutrient additions on shredders

Fig. 7. Mean July densities of major benthic insect taxa in the reference (open bars) and fertilized (solid bars) reaches of the Kuparuk River, 1984–1998. Data were not available for 1983, the 1994 reference reach, and where “ND” appears.
### Nutrient effects

#### Table 3. Food web response to long- and short-term nutrient enrichment in a variety of streams.

<table>
<thead>
<tr>
<th>Site</th>
<th>Years fertilized</th>
<th>Nutrient added</th>
<th>Periphyton (chlorophyll)</th>
<th>Invertebrate (density/biomass)</th>
<th>Fish (growth/density)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska, USA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kuparuk River</td>
<td>16</td>
<td>P</td>
<td>+</td>
<td>+/-</td>
<td>+</td>
<td>Peterson et al. (1993a)</td>
</tr>
<tr>
<td>Kuparuk River</td>
<td>4</td>
<td>P, N + P</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Harvey et al. (1998)</td>
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<tr>
<td>Oksrukuyik Creek</td>
<td>4</td>
<td>N + P</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Oregon, USA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Lookout Creek</td>
<td>3</td>
<td>N</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Gregory and Lamberti (1993)</td>
</tr>
<tr>
<td>British Columbia, Canada</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Keogh River</td>
<td>4</td>
<td>N + P</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Johnston et al. (1990), Perrin et al. (1987)</td>
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<tr>
<td>Salmon River</td>
<td>3</td>
<td>N + P</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Slaney et al. (1994)</td>
</tr>
<tr>
<td>Adam River</td>
<td>4</td>
<td>N + P</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Toth et al. (1997), Slaney and Ashley (1998)</td>
</tr>
<tr>
<td>Big Silver Creek</td>
<td>2</td>
<td>N + P</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Toth et al. (1996)</td>
</tr>
<tr>
<td>Tennessee, USA</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walker Branch</td>
<td>95 days</td>
<td>P</td>
<td>+</td>
<td>+</td>
<td>NA</td>
<td>Elwood et al. (1981)</td>
</tr>
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</table>
Energy in streams

Limnology
 Lecture 20
Energy Sources

• Autotrophic food webs
  – Rely on living organic matter

• Heterotrophic food webs
  – Rely on non-living organic matter
Energy Sources

- **Autotrophic food webs**
  - Rely on living organic matter
- **Heterotrophic food webs**
  - Rely on non-living organic matter
- **Autochthonous**
  - Organic matter produced in the river system
- **Allochthonous**
  - Organic matter from outside the river system
## Trophic relationships


<table>
<thead>
<tr>
<th>Trophic group</th>
<th>Food</th>
<th>Feeding mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shredders</td>
<td>Leaf detritus, wood, living aquatic plants</td>
<td>Chewing of detritus and macrophytes, mining of macrophytes, and gougers of wood</td>
</tr>
<tr>
<td>Collectors</td>
<td>Fine particulate organic matter</td>
<td>Suspension feeding (filterers), deposit feeding (deposit collectors/gatherers)</td>
</tr>
<tr>
<td>Scrapers</td>
<td>Attached algae and biofilm</td>
<td>Grazing/scraping of mineral and organic surfaces</td>
</tr>
<tr>
<td>Macrophyte piercers</td>
<td>Cell and tissue fluids of living plants</td>
<td>Piercing and fluid sucking</td>
</tr>
<tr>
<td>Predators</td>
<td>Tissue of living animals</td>
<td>Engulfing, piercing</td>
</tr>
<tr>
<td>Parasites</td>
<td>Tissue and fluids of living animals</td>
<td>Internal and external parasitism</td>
</tr>
</tbody>
</table>
River continuum concept

Low-order streams

Lots of CPOM

Autotrophy < Heterotrophy (P/R)

Lots of shredders and collectors
River continuum concept

Mid-order streams
Macrophytes/Periphyton
Lots of FPOM
Autotrophy > Heterotrophy (P/R)
Lots of collectors and grazers
River continuum concept

High-order streams

Phytoplankton

Lots of FPOM

Autotrophy < Heterotrophy (P/R)

Lots of collectors

Lake-like!
Autotrophy in the River Continuum

- Limited periphyton
- Macrophytes/periphyton
- Phytoplankton
Periphyton Examples

- Thin green film of green algae
- Filamentous green algae
- Thick brown film of diatoms
- Thick patches of blue-green algae (cyanobacteria)
Periphyton: Environmental Factors

Factors that can influence periphyton density

1. Light
2. Current
3. Scouring from floods
4. Grazing
5. Substrate
6. Temperature
7. Chemistry
Periphyton: Effects of Current

A rolling stone gathers no moss

FIGURE 4.9 The relationship between periphyton accumulation rate and a flow index in a small stream (Carnation Creek) in the high rainfall environment of the west coast of Vancouver Island. See text for definition of flow index. (From Shortreed and Stockner, 1983.)

FIGURE 4.10 Amount of stone surface covered by the moss *Hygrohypnum* as a function of stone size in a mountain stream. (From McAuliffe, 1983.)
Periphyton: Nutrient Limitation

FIGURE 4.5 Changes in the numbers of the dominant diatom species in troughs enriched with NO$_3$-N, PO$_4$-P, or both in combination. Troughs were placed in Carnation Creek, Vancouver Island, allowed 4 weeks to colonize, and then fertilized for 52 days. Note that periphyton populations peaked after 30–40 days, and then declined sharply, prior to termination of the fertilization experiment. (After Stockner and Shortreed, 1978.)
Periphyton: Light Limitation

FIGURE 4.4 Seasonal change in mean periphyton abundance, measured as chlorophyll $a$, in a small Massachusetts river flowing through mostly agricultural land but with riparian shading. The shaded period extended from 10 May until 20 October. Note the major peak in chlorophyll (3.9 x mean summer values) just prior to leaf-out, and the minor peak (1.7 x mean summer values) just following leaf fall. Water temperatures were highest throughout the summer. $\bullet$ = Chlorophyll $a$; $\times$ = photosynthetically active radiation. (After Sumner and Fisher, 1979.)
Heterotrophy in the River Continuum

Autotrophy

Heterotrophy
Leaf Conditioning

FIGURE 5.2. The processing or ‘conditioning’ sequence for a medium-fast deciduous tree leaf in a temperate stream. Details of the fate of material converted to fine particulate organic matter (FPOM) are unknown. Leached dissolved organic matter (DOM) is thought to be rapidly transferred into the sediment layer, primarily by microbial uptake.
FIGURE 5.1 The breakdown rates for various woody and non-woody plants, based on 596 estimates compiled from field studies in all types of freshwater ecosystems. Means ± 1 standard error are shown, and the variation is due to (at least) effects of site, technique, and numerous environmental variables. The number of individual rate estimates is shown in parentheses. (After Webster and Benfield, 1986.)
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Breakdown Rates: Environmental Factors

- Temperature: ↑
- Acidity: ↓
- Current: ↑↓
Collecting FPOM
Shredders prefer conditioned CPOM

- CPOM with microbial colonization
- Like peanut butter on a cracker
- Microbes more nutritious than leaves
Breakdown Rates: Importance of Microbes

Loss in leaf mass after 28 days at 10°C (Kaushik and Hynes 1971)
Biofilms

Complex of bacteria, algae, fungi on and in sediment or wood

Covers most everything in stream

Higher biomass on wood/leaves
River Continuum Concept

Downstream shifts in:

1) FPOM/CPOM
2) Heterotrophy/Autotrophy
3) Dominance of trophic groups

River Continuum Concept: Does it work?

Prediction: shift from CPOM to FPOM dominated

Predictions:

Ratio of FPOM/CPOM will increase

CPOM will decrease

Verified?

Importance of tributaries

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**Fig. 10.** Trends in benthic organic matter particle sizes expressed in relation to the coarse fraction and mean absolute amounts (AFDM, g/m²) of coarse material; based on mean annual values. The shaded curve shows predictions of the River Continuum Hypothesis.
River Continuum Concept: Does it work?

Prediction:
Heterotrophy in headwaters and lower stations

Verified?
Yes for headwaters

Generally increased autotrophy, in contrast to predictions

River Continuum Concept: Does it work?

Fig. 15. Spatial distribution of benthic invertebrate functional groups, expressed as a percent of the total number of each group collected (given on the figure), at each of the four stations of each site during summer (Su) and autumn (A) or winter (W).
River Continuum Concept: Does it work?

- Strong regional and seasonal effects

- General paradigm, starting point