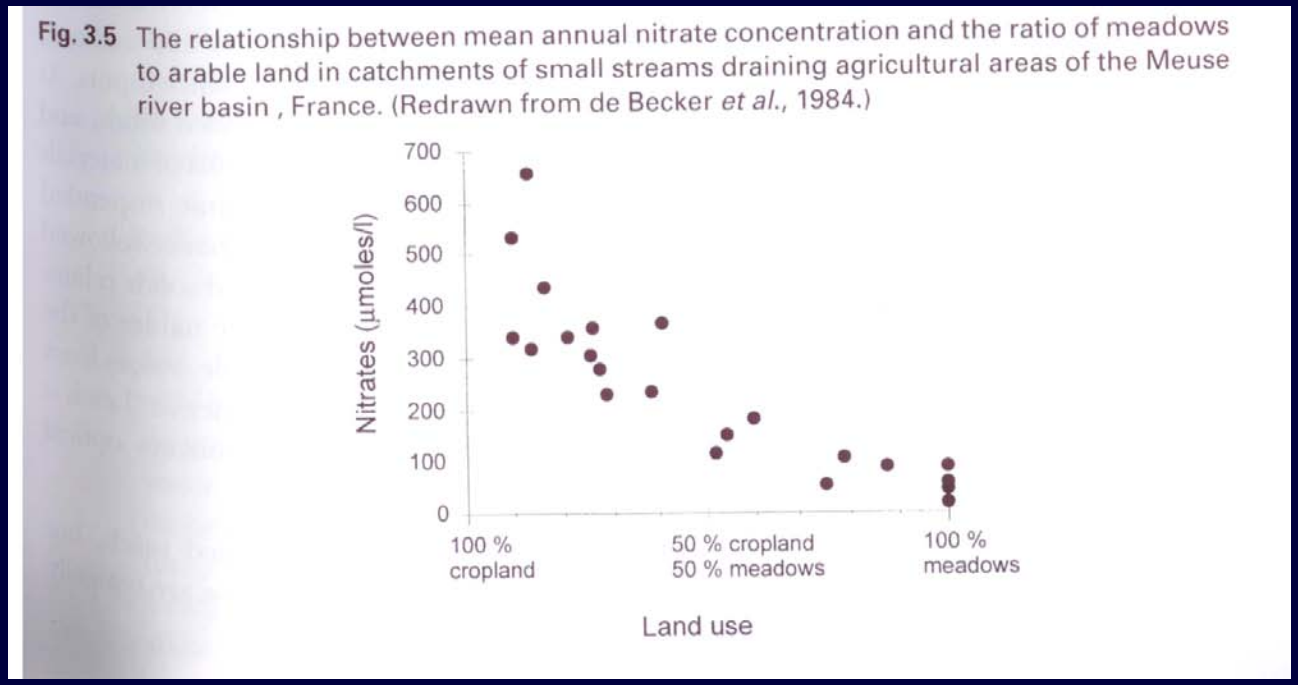
Labs

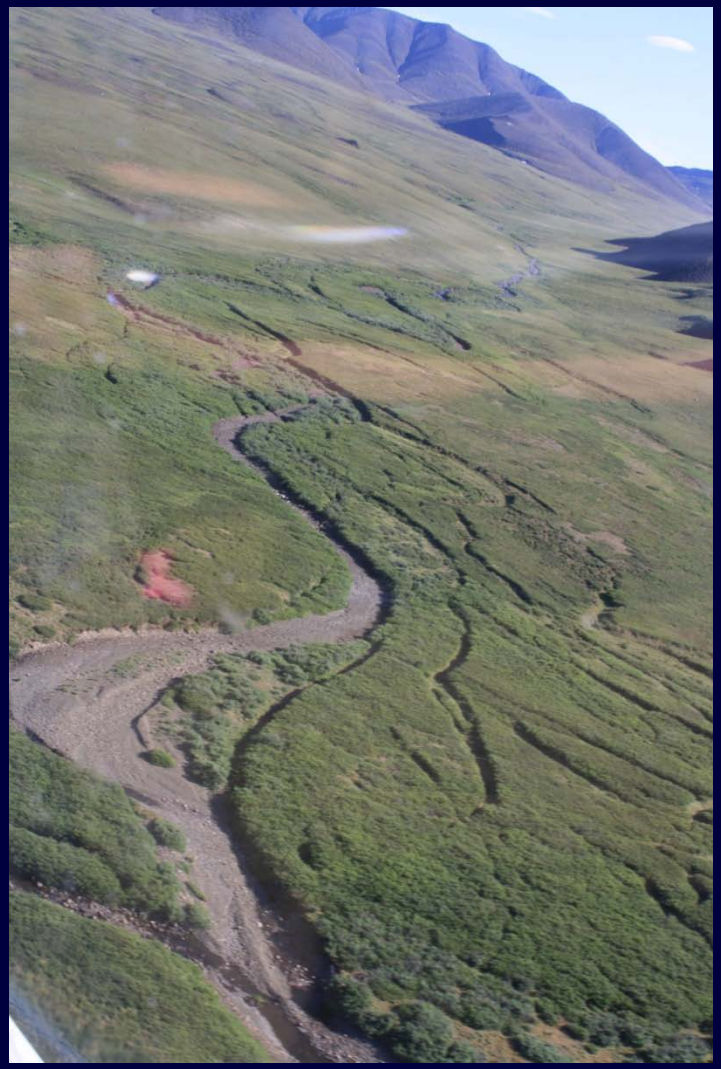
Nov. 14th	Lab 11 – stream invertebrate ID
Nov. 21st	Lab 12 – revisit Dunham pond
Dec. 5th	Project presentations

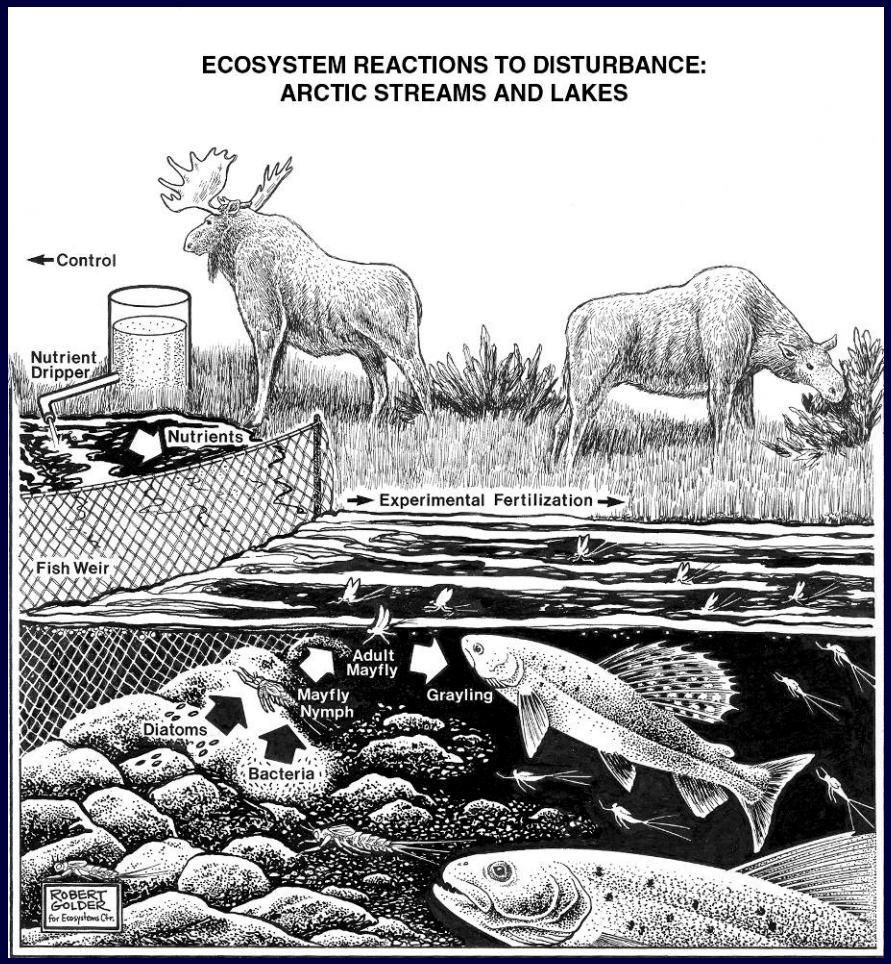
Nutrients



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

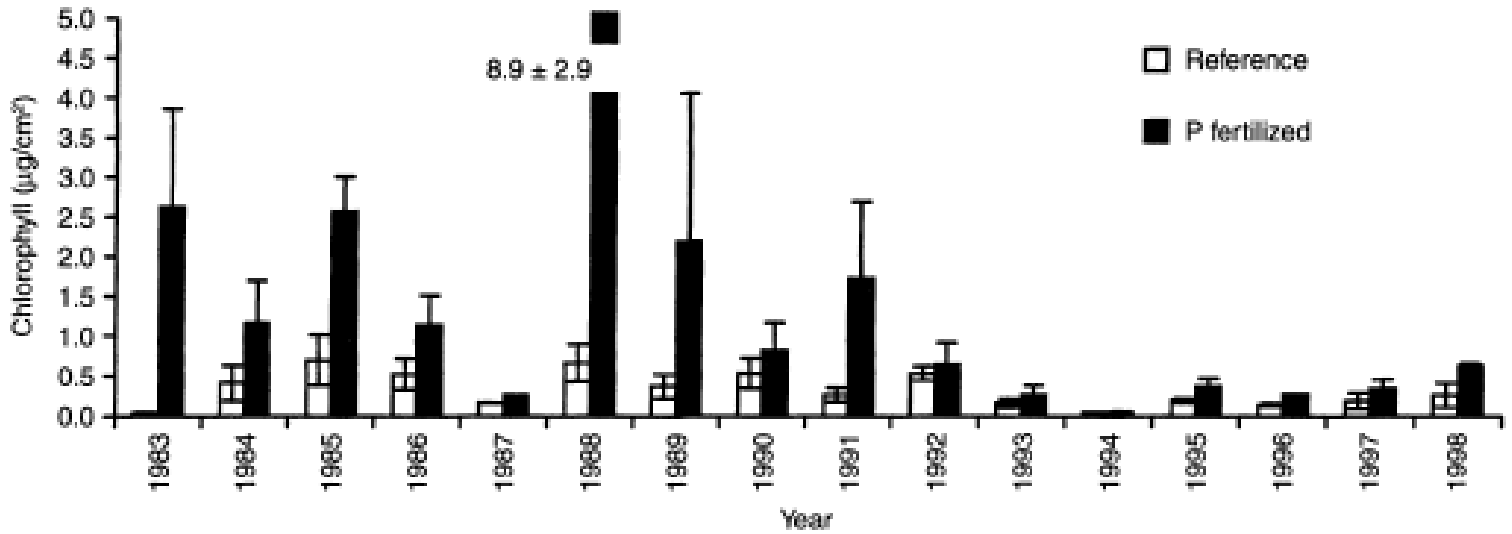


FIG. 5. Epilithic total chlorophyll in the reference and fertilized reach riffles of the Kuparuk River during fertilization (July and August). Values for 1987 and 1994 means only include August chlorophyll values. In 1988, fertilized reach values are inflated due to contamination by green algal filaments. 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, 1993*a*), 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

Ecology, 89(4), 2008, pp. 952–961

UNDERSTANDING AND PREDICTING ECOLOGICAL DYNAMICS: ARE MAJOR SURPRISES INEVITABLE?

Daniel F. Doak,[1,11] James A. Estes,[2] Benjamin S. Halpern,[3] Ute Jacob,[4] David R. Lindberg,[5] James Lovvorn,[1] Daniel H. Monson,[6] M. Timothy Tinker,[7] Terrie M. Williams,[7] J. Timothy Wootton,[8] Ian Carroll,[9] Mark Emmerson,[4] Fiorenza Micheli,[10] and Mark Novak[8]

Community interactions

Long-term fertilization of Kuparuk Creek

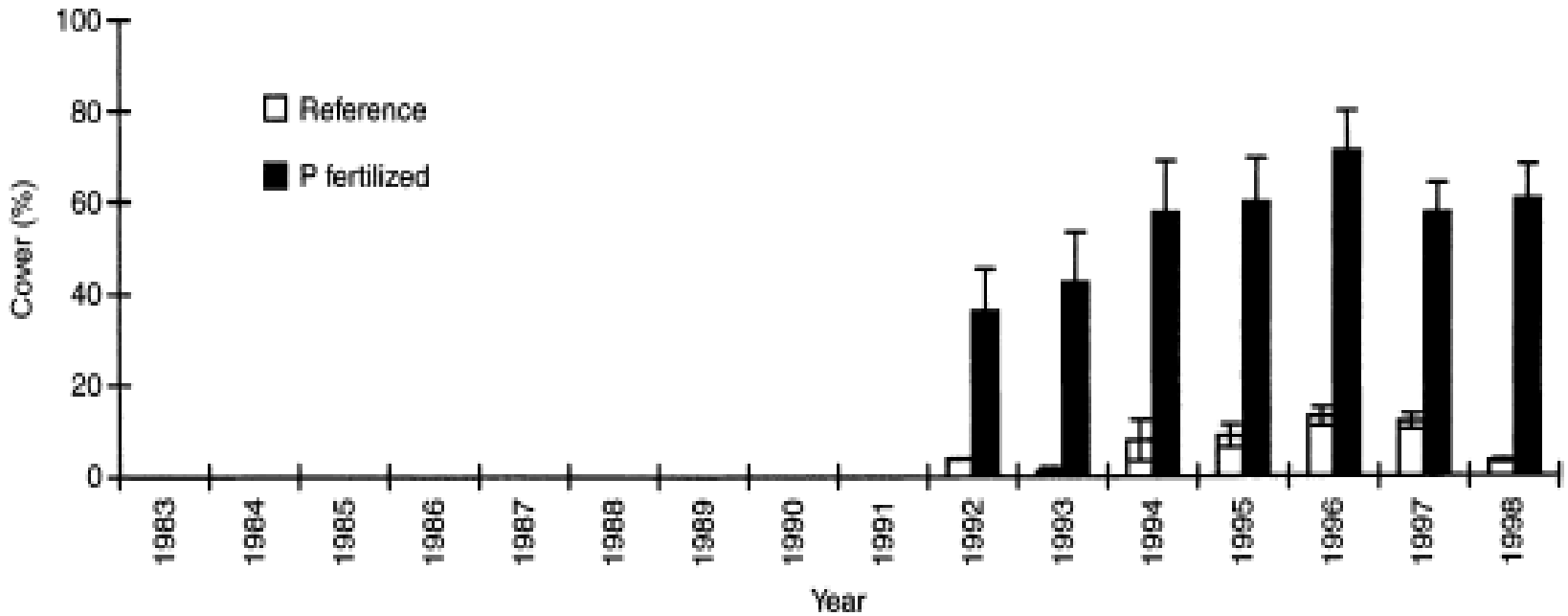
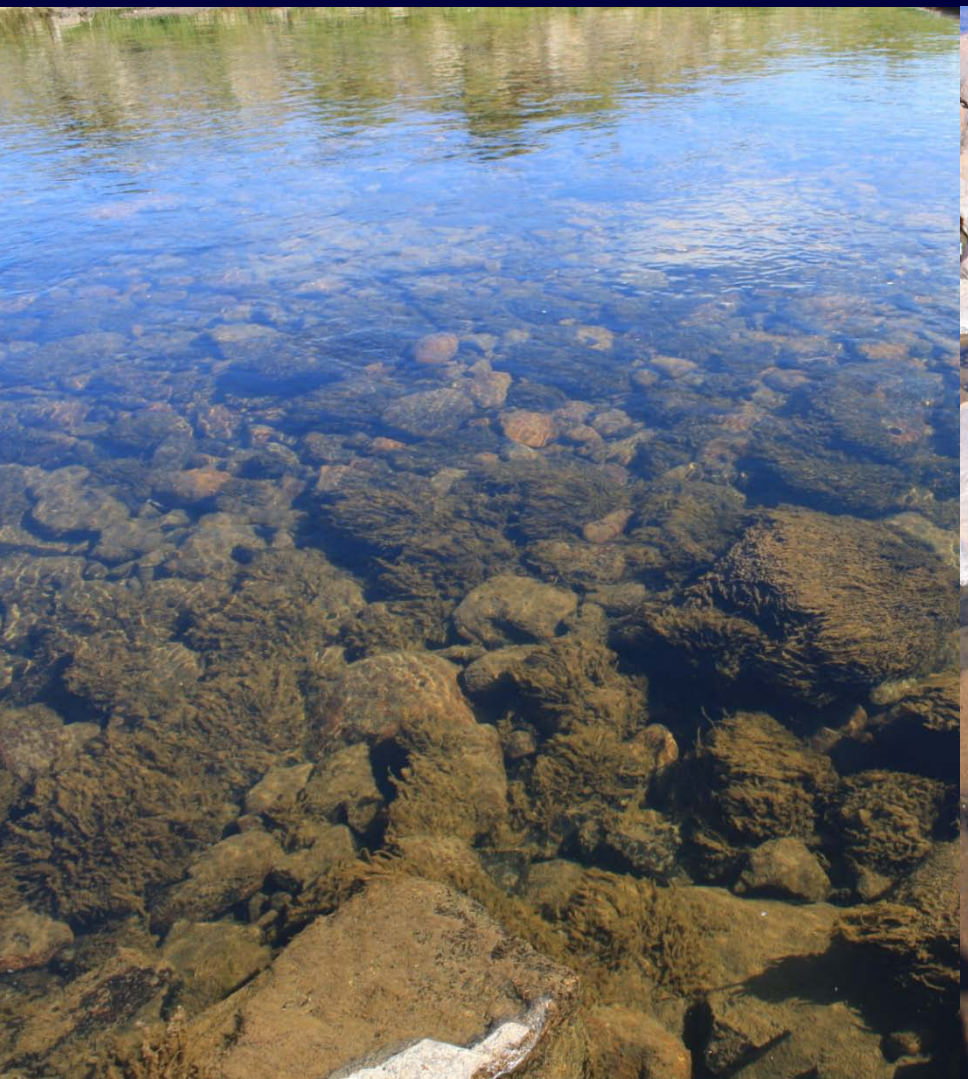


FIG. 6. Percentage of total bryophyte coverage (mean ± 1 SE) in the Kuparuk River, 1992–1998.

Long-term fertilization of Kuparuk Creek



Long-term fertilization of Kuparuk Creek

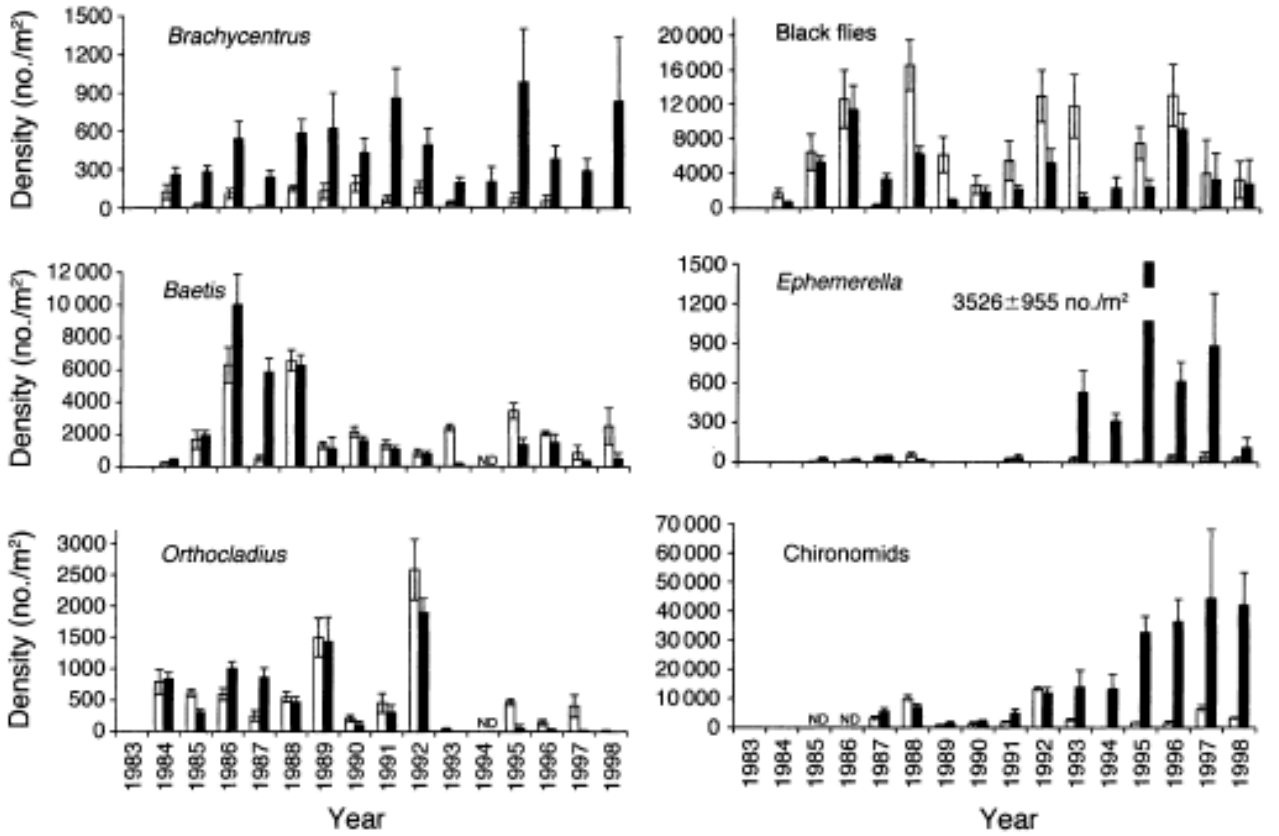


FIG. 7. Mean July densities of major benthic insect taxa in the reference (open bars) and fertilized (solid bars) reaches of the Kuparuk River, 1984–1998. Data were not available for 1983, the 1994 reference reach, and where "ND" appears.

Bottom-up effects of nutrient additions on shredders

Nutrient effects

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

Site	Years fertilized	Nutrient added	Periphyton (chlorophyll)	Invertebrate (density/ biomass)	Fish (growth/ density)	Reference
Alaska, USA						
Kuparuk River	16	P	+	+/−	+	
Kuparuk River	4	P, N + P	+	+	+	Peterson et al. (1993*a*)
Oksrukuyik Creek	4	N + P	+	+	+	Harvey et al. (1998)
Oregon, USA						
Lookout Creek	3	N	+	+	+	Gregory and Lamberti (1993)
British Columbia, Canada						
Keogh River	4	N + P	+	+	+	Johnston et al. (1990), Perrin et al. (1987)
Salmon River	3	N + P	+	+	+	Slaney et al. (1994)
Mesilinka River	4	N + P	+	+	+	Slaney and Ashley (1998), Koning et al. (1995), Paul et al. (1996)
Adam River	4	N + P	+	+	+	Toth et al. (1997), Slaney and Ashley (1998)
Big Silver Creek	2	N + P	+	+	+	Toth et al. (1996)
Tennessee, USA						
Walker Branch	95 days	P	+	+	NA	Elwood et al. (1981)

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

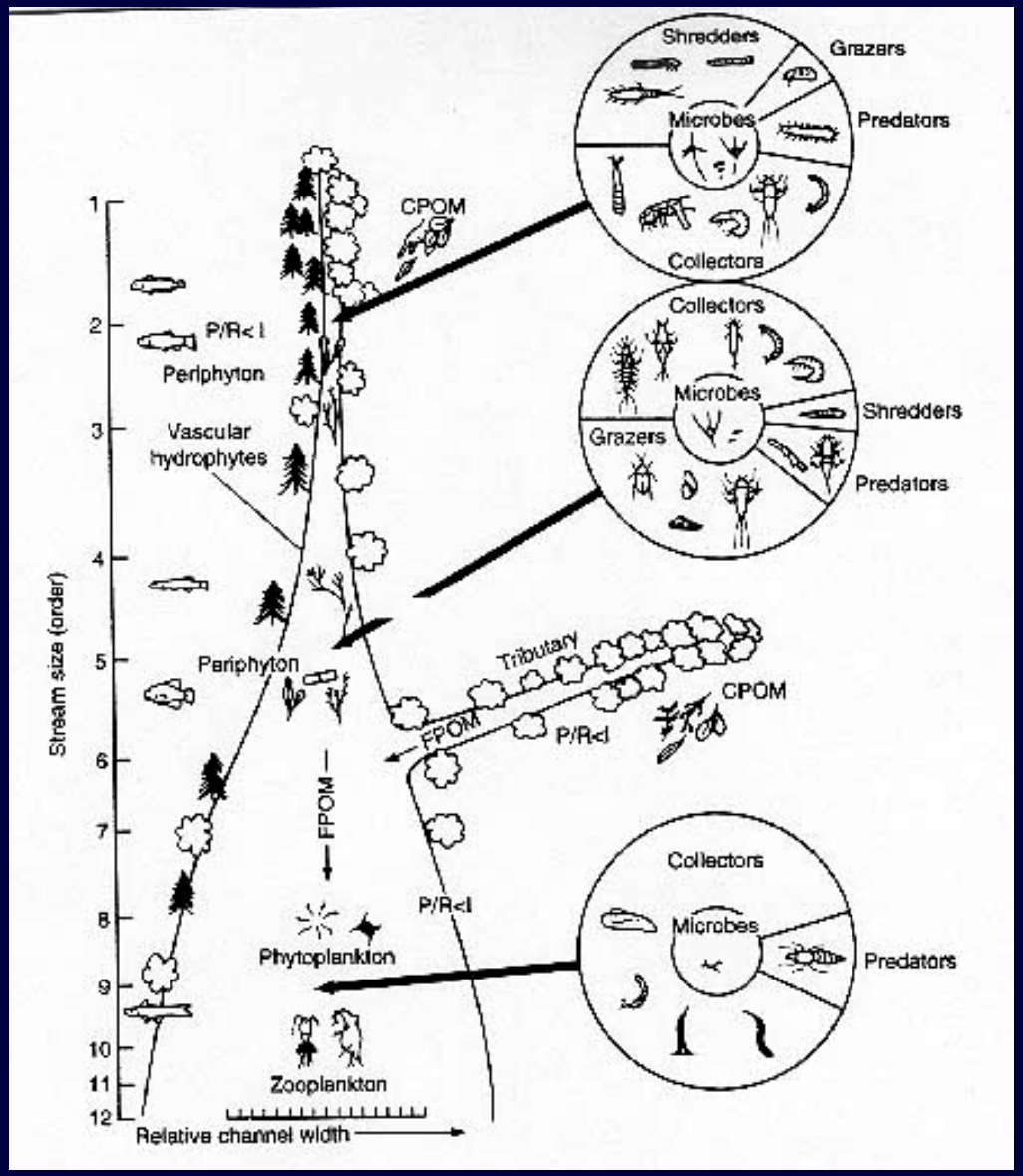
- Autotrophic food webs
  - Rely on living organic matter
- Heterotrophic food webs
  - Rely on non-living organic matter
- Autochthonous
  - Organic matter produced in the river system
- Allochthonous
  - Organic matter from outside the river system

Trophic relationships

Table 5.3 Functional feeding groups of aquatic larval stages and adults and their dominant food. (Modified from Cummins and Merritt, 1996. From *An introduction to the aquatic insects of North America*, (ed. R. W. Merritt and K. W. Cummins). © 1996, Kendall Hunt Publishing Company. Used with permission.)

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

River continuum concept

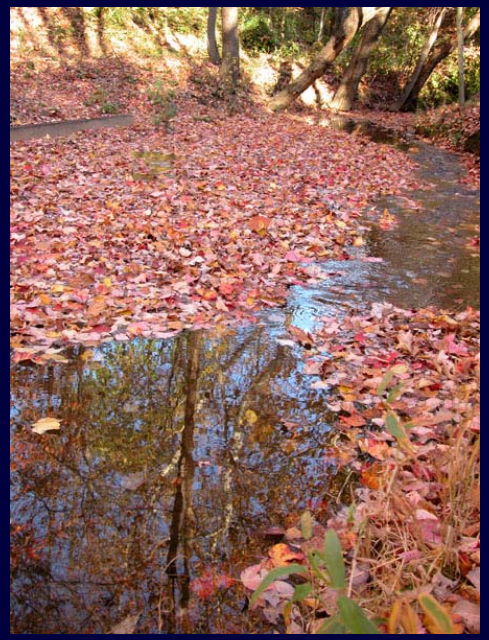


Low-order streams

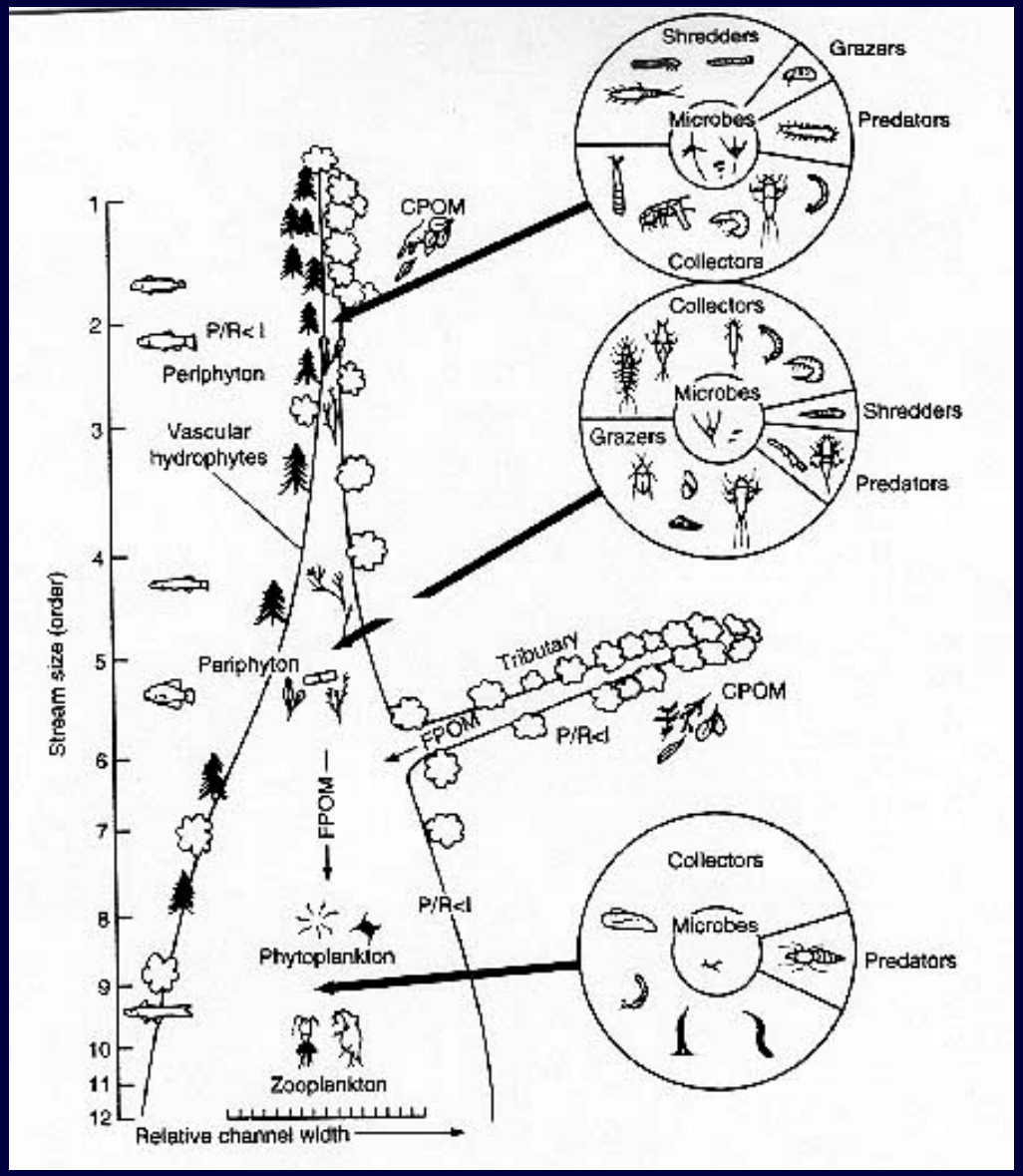
Lots of CPOM

Autotrophy < Heterotrophy (P/R)

Lots of shredders and collectors



River continuum concept



<u>Mid-order streams</u>

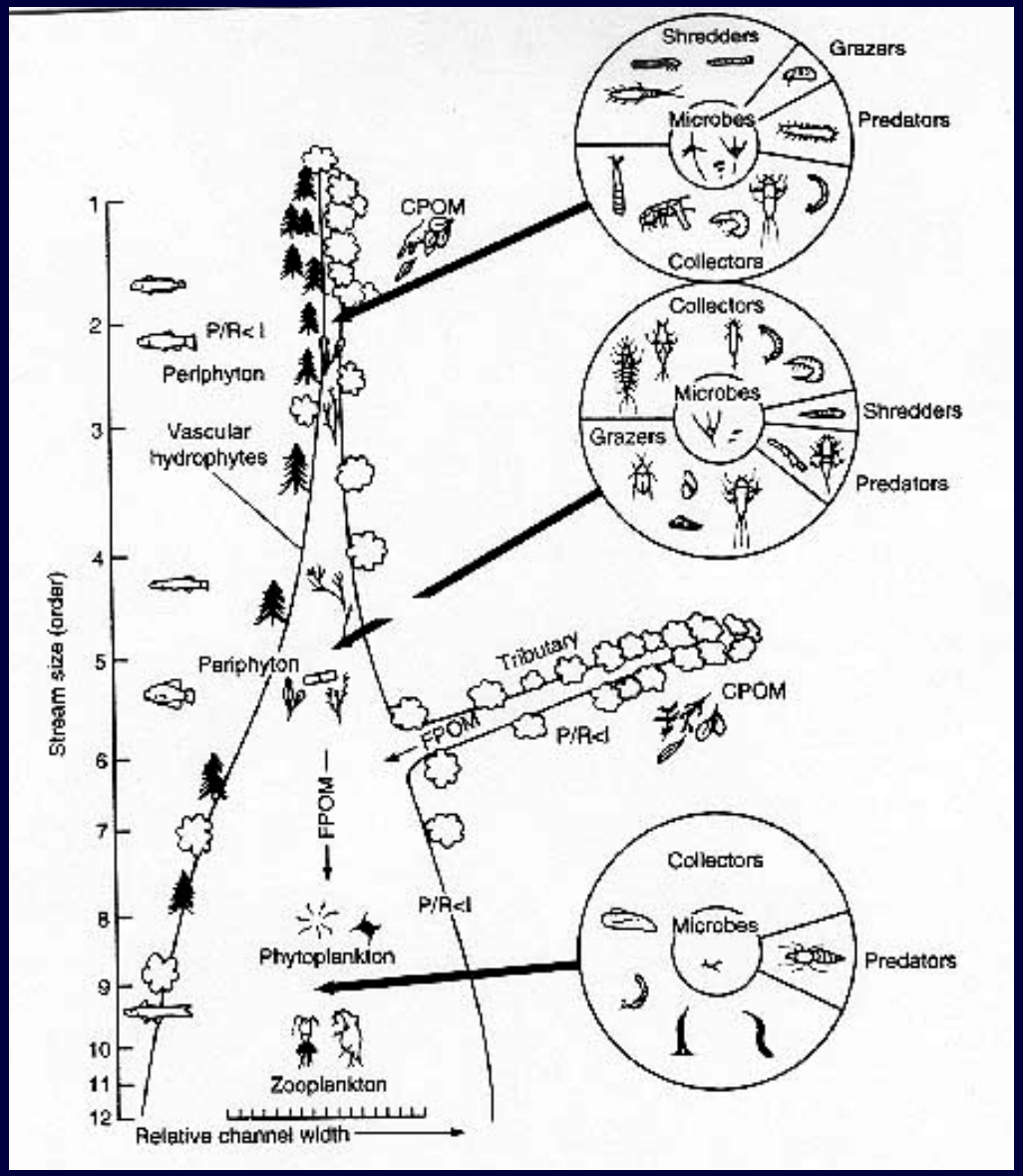
Macrophytes/Periphyton

Lots of FPOM

Autotrophy > Heterotrophy (P/R)

Lots of collectors and grazers

River continuum concept



<u>High-order streams</u>

Phytoplankton

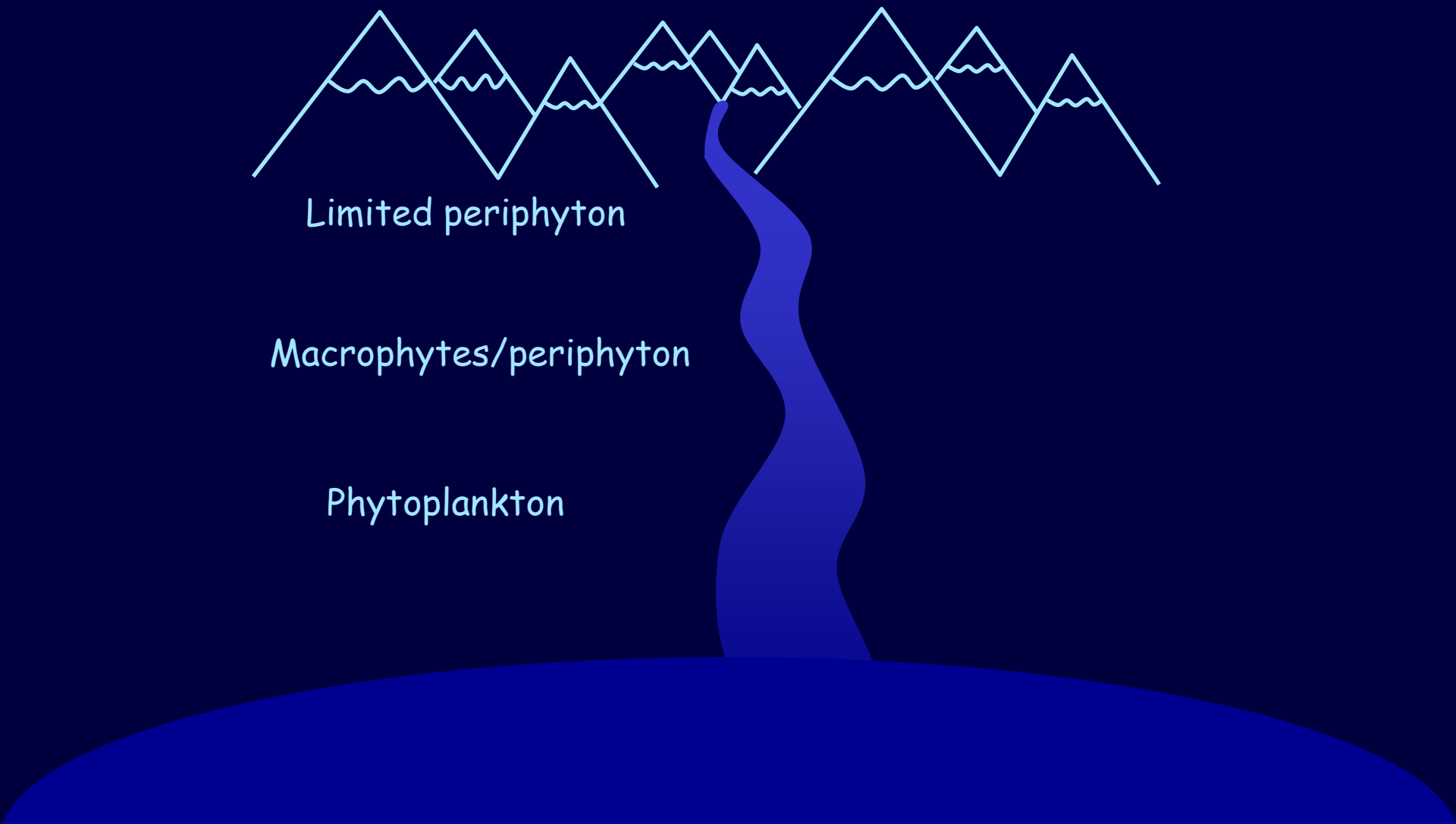
Lots of FPOM

Autotrophy < Heterotrophy (P/R)

Lots of collectors

Lake-like !

Autotrophy in the River Continuum

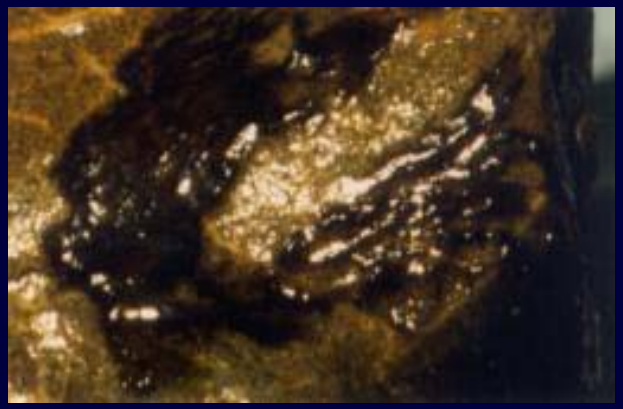


Periphyton Examples

Thin green film of green algae

Thick brown film of diatoms

Filamentous green algae



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

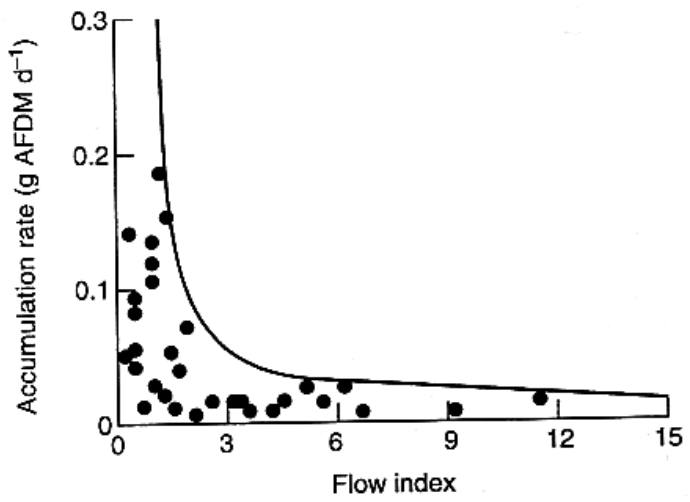


FIGURE 4.9 The relationship between periphyton accumulation rate and a flow index in a small stream (Carnation Creek) in the high rainfall environment of the west coast of Vancouver Island. See text for definition of flow index. (From Shortreed and Stockner, 1983.)

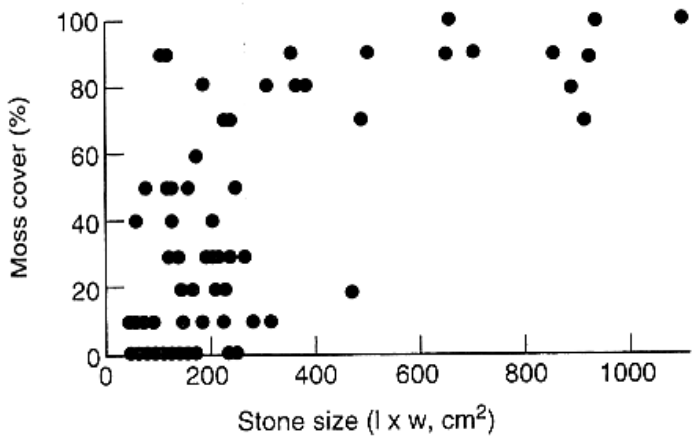


FIGURE 4.10 Amount of stone surface covered by the moss *Hygrohypnum* as a function of stone size in a mountain stream. (From McAuliffe, 1983.)

A rolling stone gathers no moss

Periphyton: Nutrient Limitation

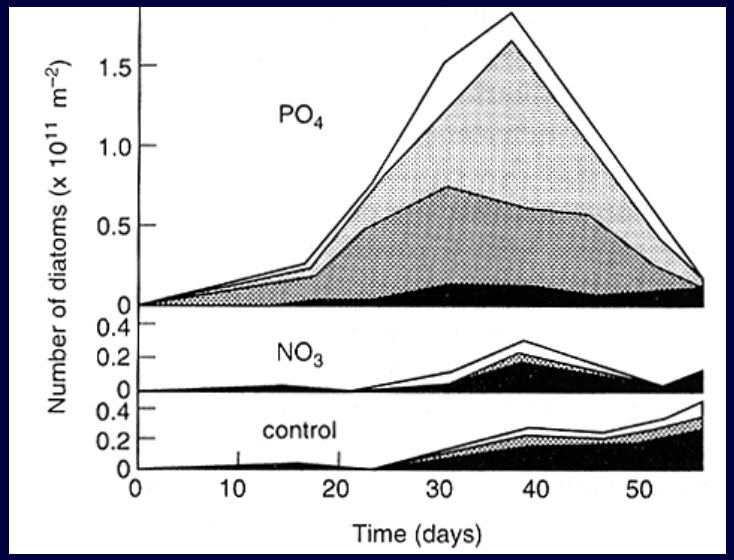
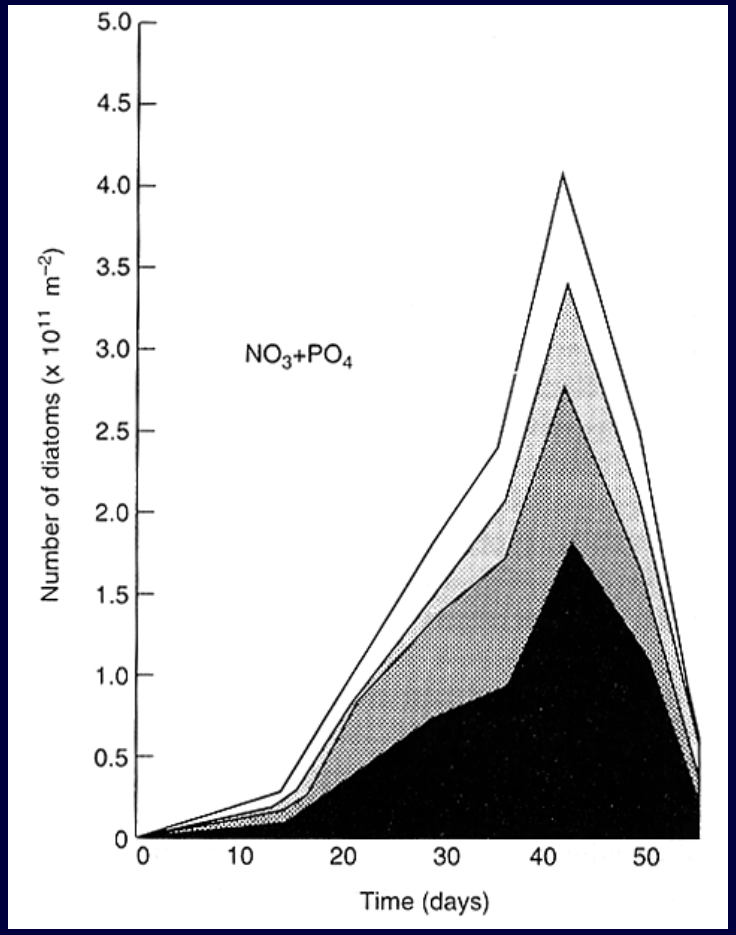


FIGURE 4.5 Changes in the numbers of the dominant diatom species in troughs enriched with NO_3-N, PO_4-P, or both in combination. Troughs were placed in Carnation Creek, Vancouver Island, allowed 4 weeks to colonize, and then fertilized for 52 days. Note that periphyton populations peaked after 30–40 days, and then declined sharply, prior to termination of the fertilization experiment. (After Stockner and Shortreed, 1978.)



Periphyton: Light Limitation

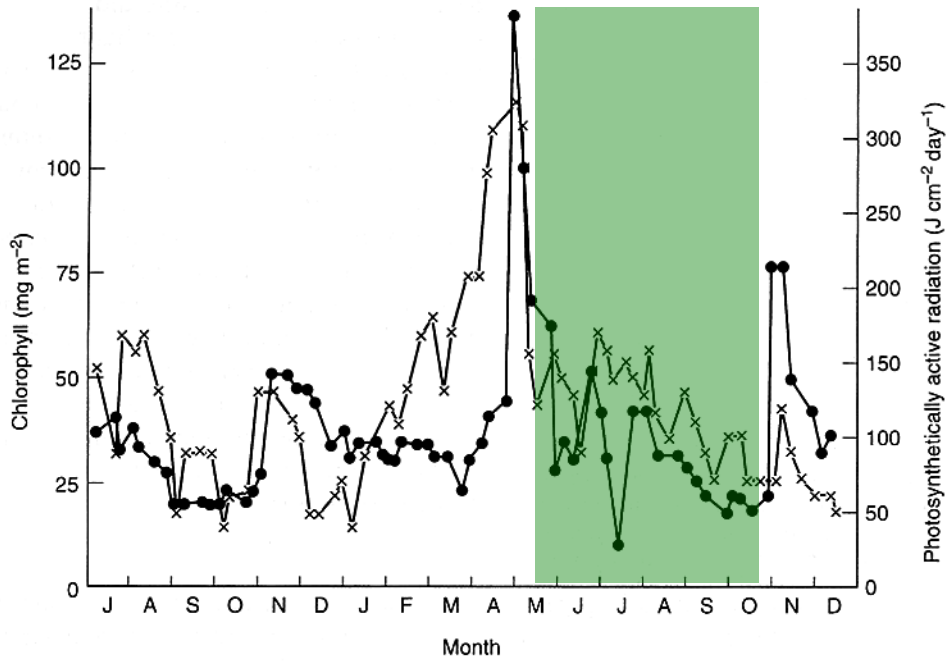
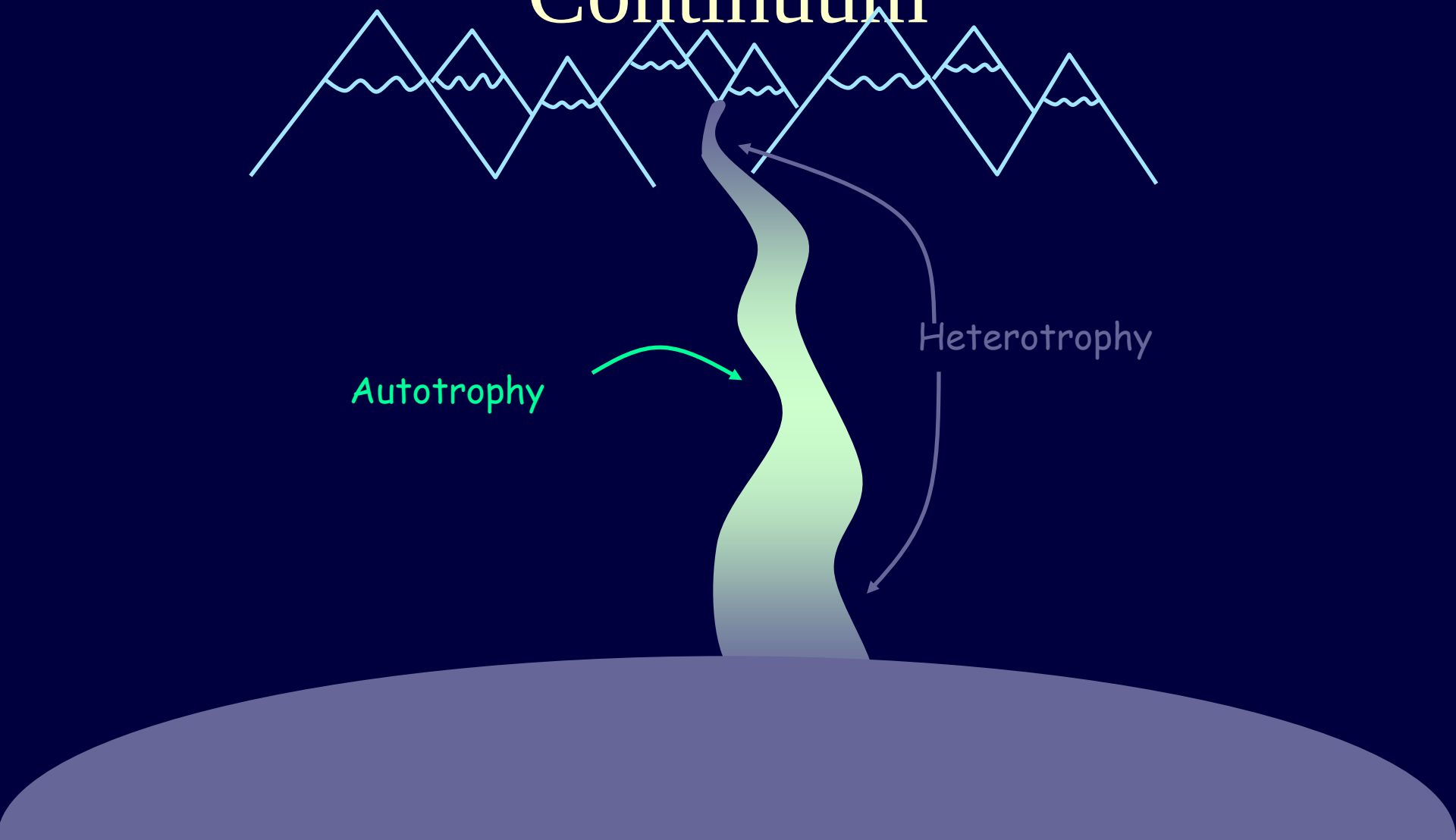


FIGURE 4.4 Seasonal change in mean periphyton abundance, measured as chlorophyll *a*, in a small Massachusetts river flowing through mostly agricultural land but with riparian shading. The shaded period extended from 10 May until 20 October. Note the major peak in chlorophyll (3.9 × mean summer values)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

Heterotrophy in the River Continuum



Leaf Conditioning

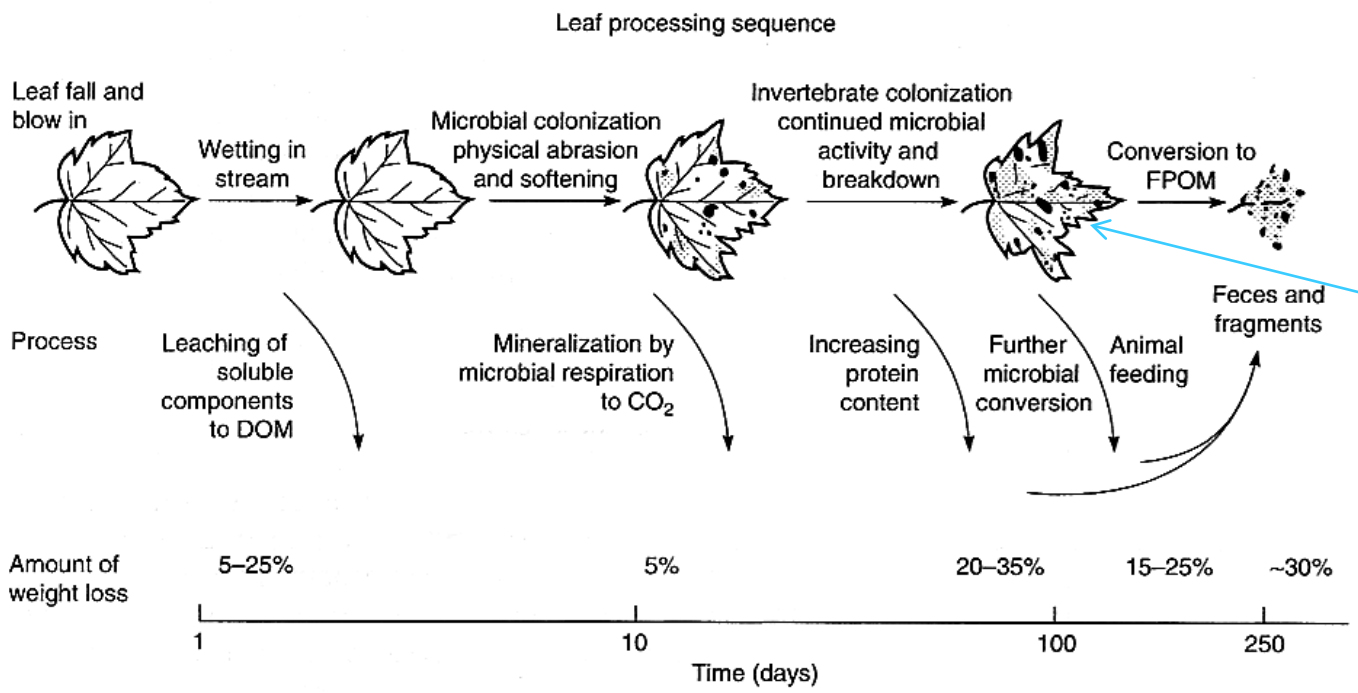
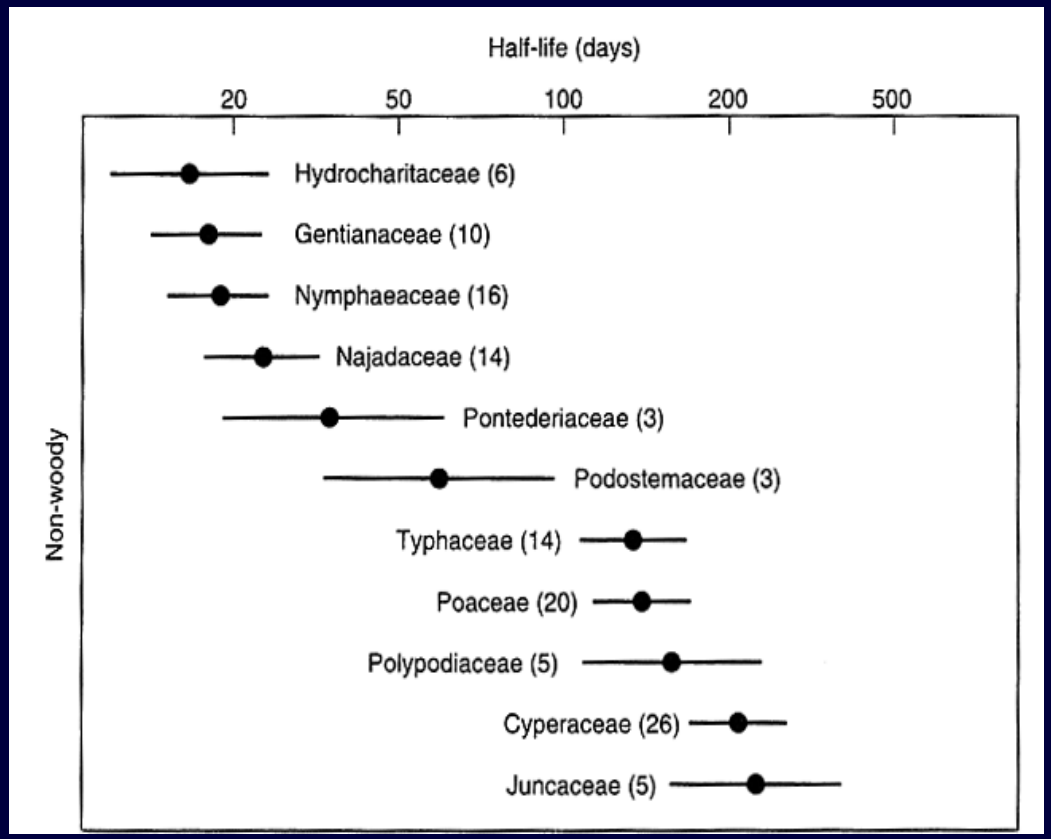


FIGURE 5.2 The processing or 'conditioning' sequence for a medium-fast deciduous tree leaf in a temperate stream. Details of the fate of material converted to fine particulate organic matter (FPOM) are unknown. Leached dissolved organic matter (DOM) is thought to be rapidly transferred into the sediment layer, primarily by microbial uptake.

24 – 40 % from invertebrates

Also increases surface area for microbes

Breakdown Rates by Species

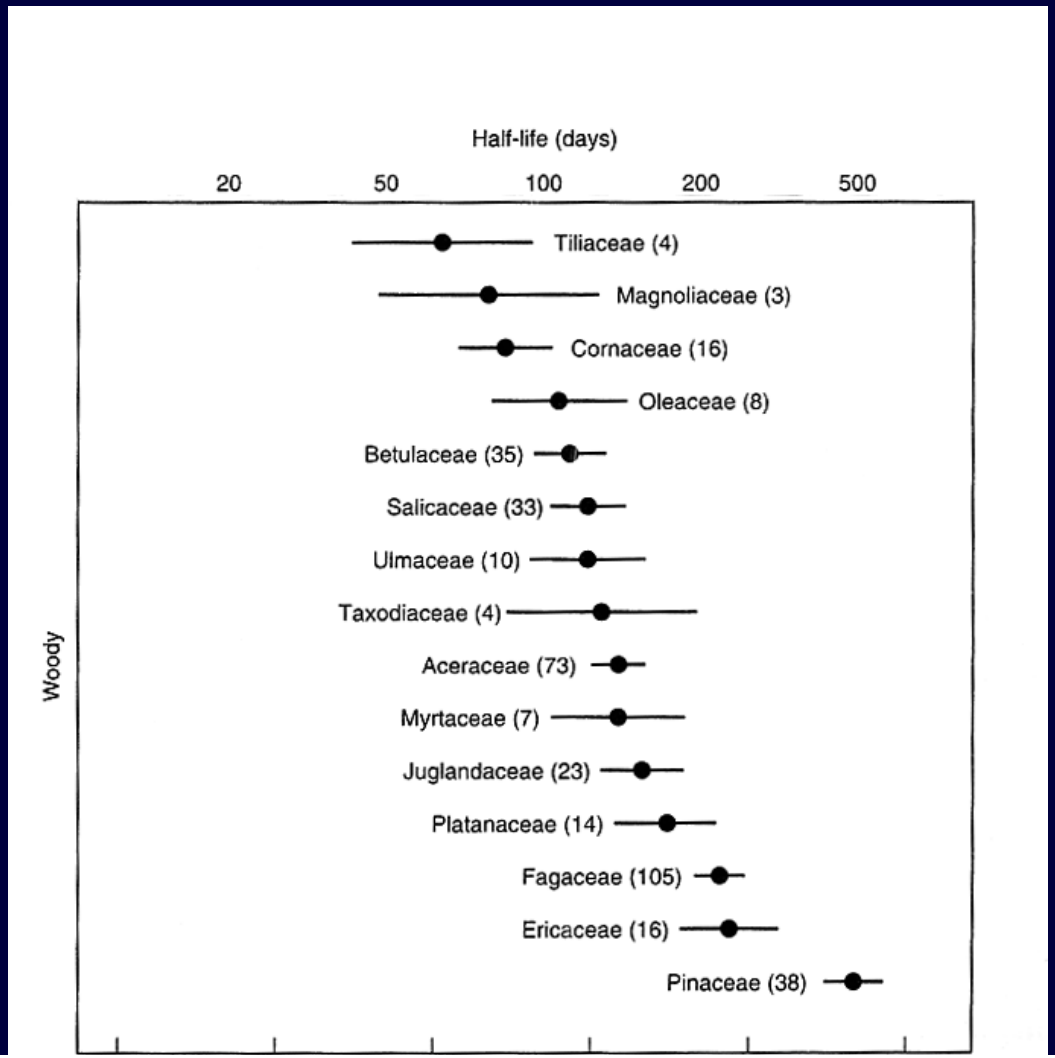


Elodea spp. (Hydrocharitaceae)

Juncus spp. (Juncaceae)

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.)

Breakdown Rates by Species



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Tiliaceae
(Linden)

Pinaceae

Breakdown Rates: Environmental Factors

Temperature ↑

Acidity ↓

Current ↑↓

Collecting FPOM

Shredders prefer conditioned CPOM

- CPOM with microbial colonization

leaves

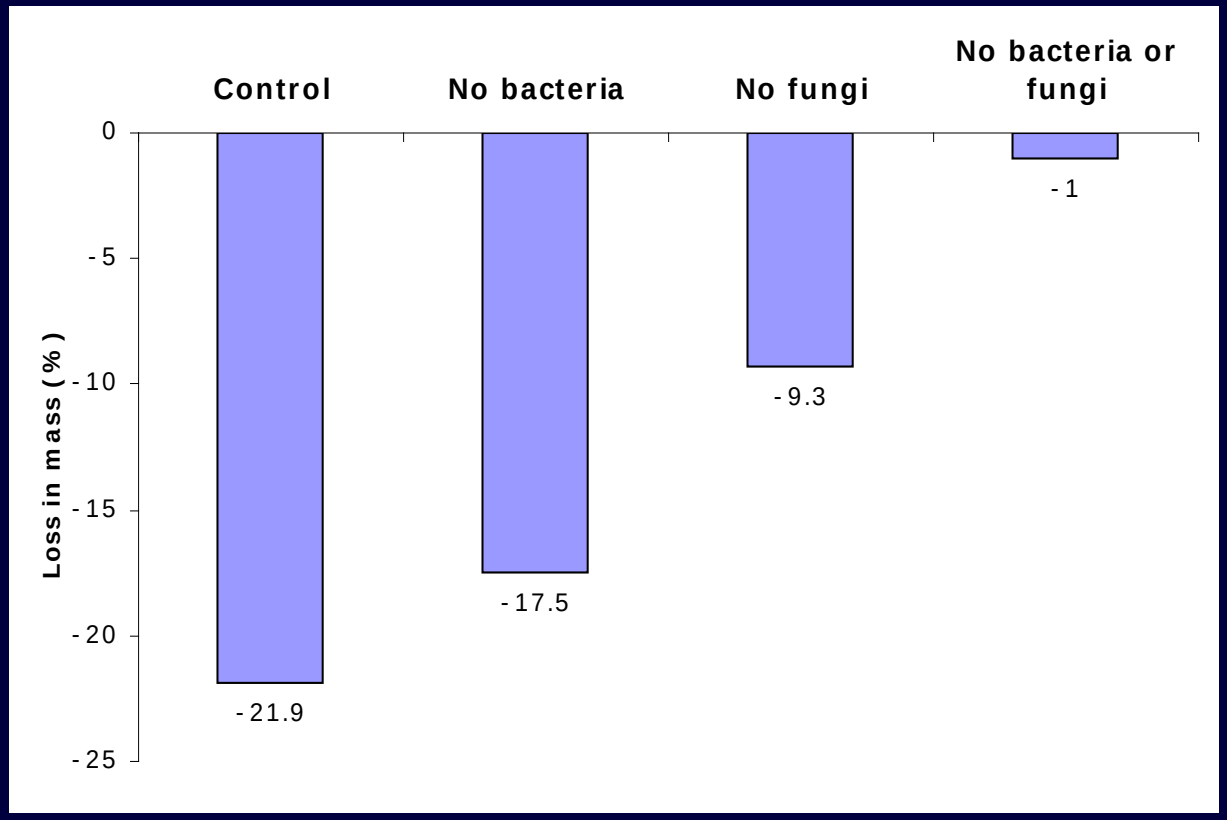
microbes

- Like peanut butter on a cracker

CPOM

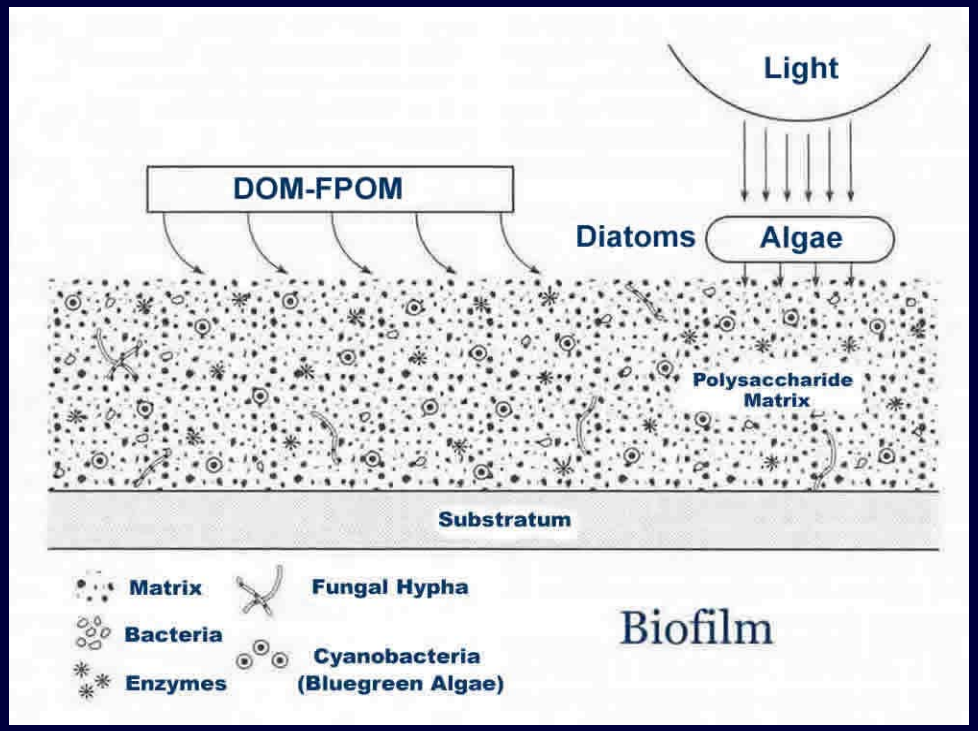
- Microbes more nutritious than leaves

Breakdown Rates: Importance of Microbes



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

Biofilms

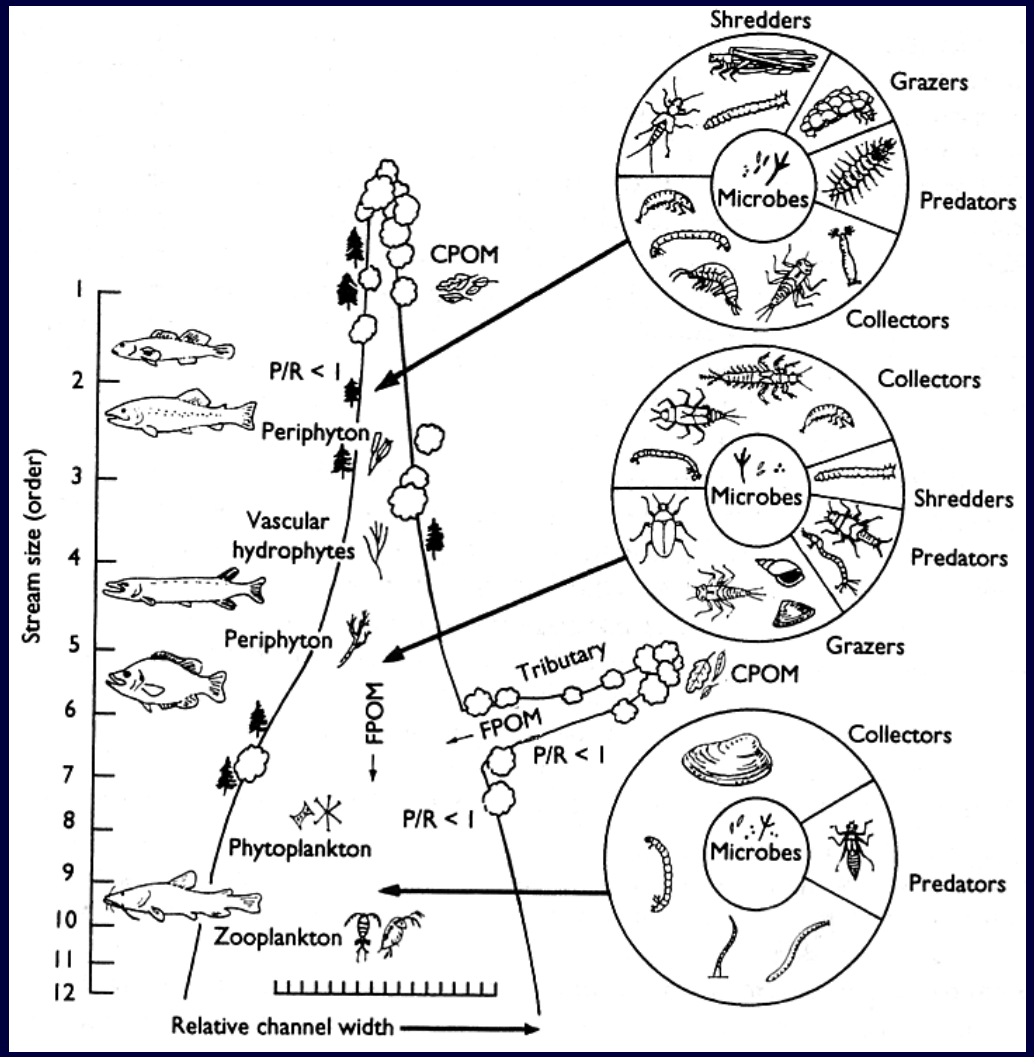


Complex of bacteria, algae, fungi on and in sediment or wood

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

Vannote, R.L. et al. 1980. The river continuum concept. *Can. J. Fish. Aquat. Sci.* 37: 130-137

River Continuum Concept: Does it work?

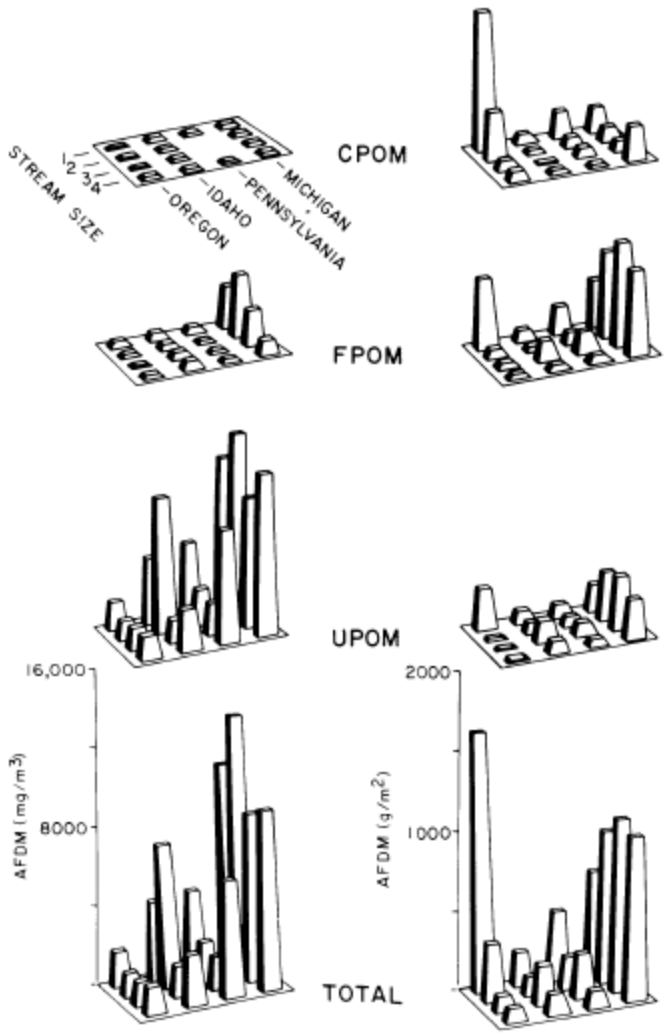


FIG. 8. Annual means of transport and benthic organic matter by particle size category (coarse [CPOM], fine [FPOM], ultrafine [UPOM]) and totals for all sites and stream sizes.

Prediction: shift from CPOM to FPOM dominated

From: Minshall, G.W. 1983. Interbiome Comparison of Stream Ecosystem Dynamics. *Ecological Monographs* 53(1): 1-25

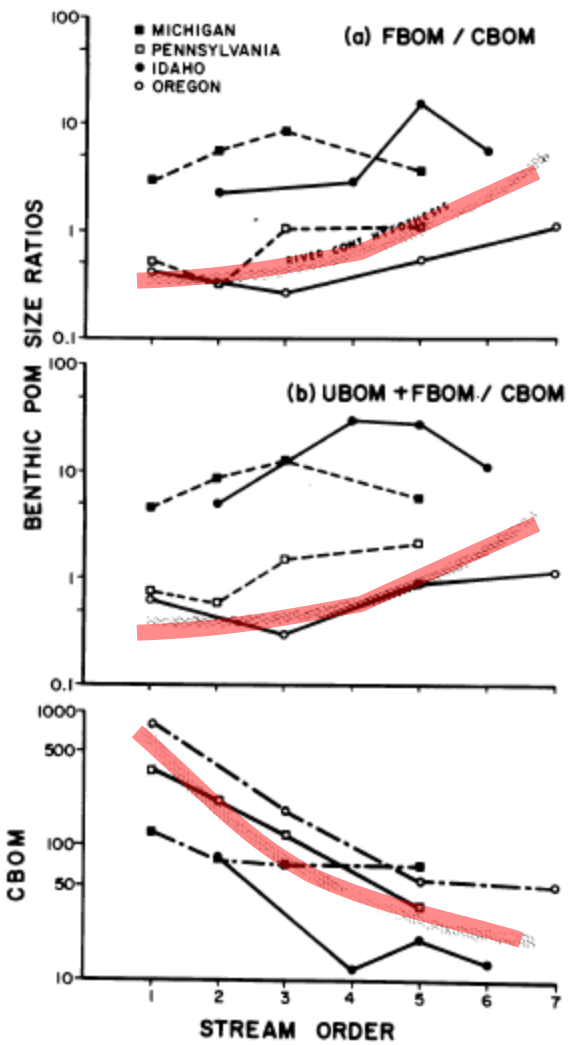


FIG. 10. Trends in benthic organic matter particle sizes expressed in relation to the coarse fraction and mean absolute amounts (AFDM, g/m²) of coarse material; based on mean annual values. The shaded curve shows predictions of the River Continuum Hypothesis.

Predictions:

Ratio of FPOM/CPOM will increase

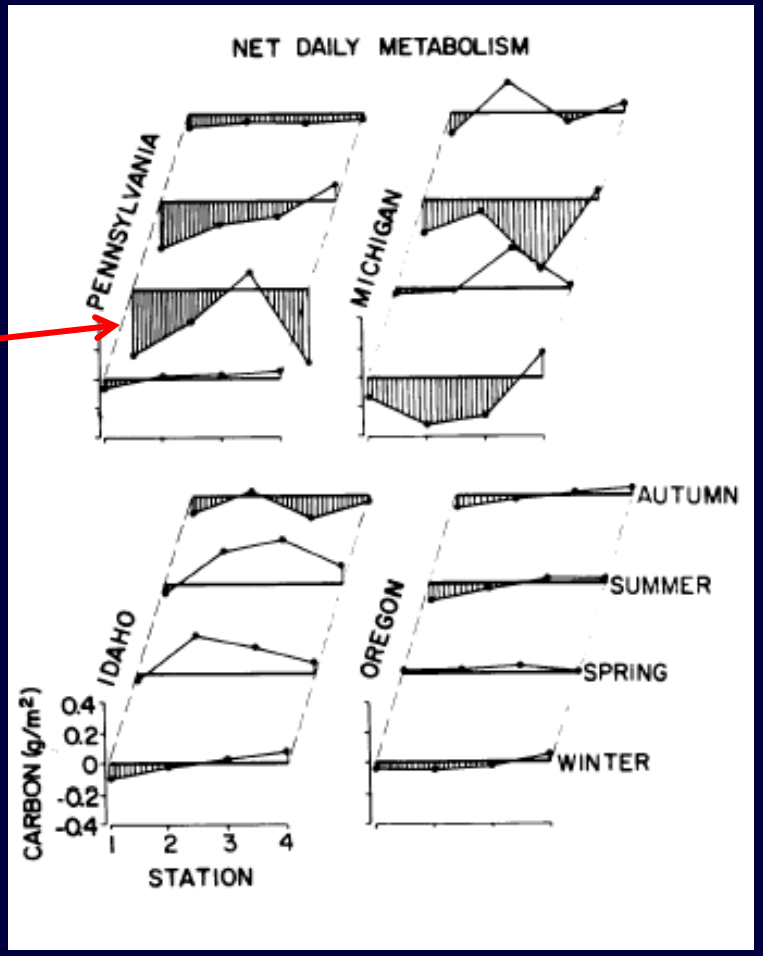
CPOM will decrease

Verified?

Importance of tributaries

From: Minshall, G.W. 1983. Interbiome Comparison of Stream Ecosystem Dynamics. *Ecological Monographs* 53(1): 1-25

River Continuum Concept: Does it work?



Prediction:
Heterotrophy in headwaters and lower stations

Verified?

Yes for headwaters

Generally increased autotrophy, in contrast to predictions

From: Minshall, G.W. 1983. Interbiome Comparison of Stream Ecosystem Dynamics. *Ecological Monographs* 53(1): 1-25

River Continuum Concept: Does it work?

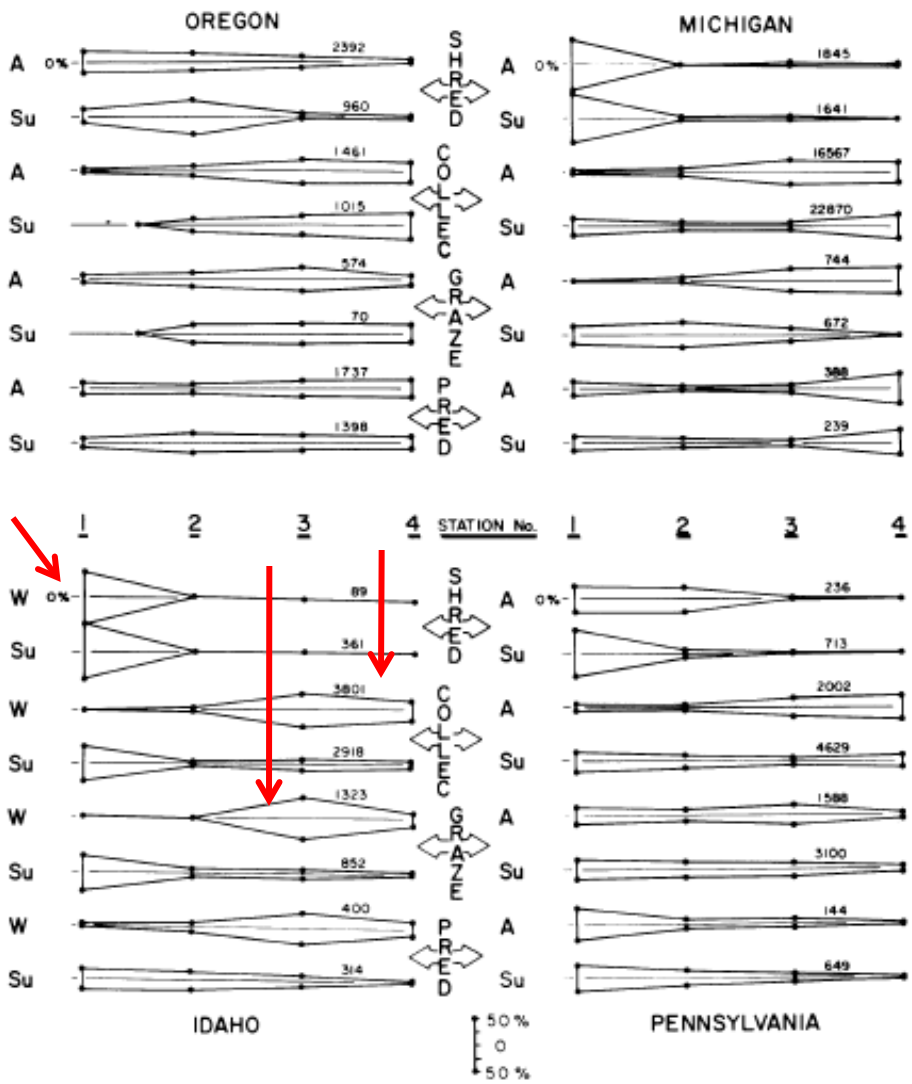
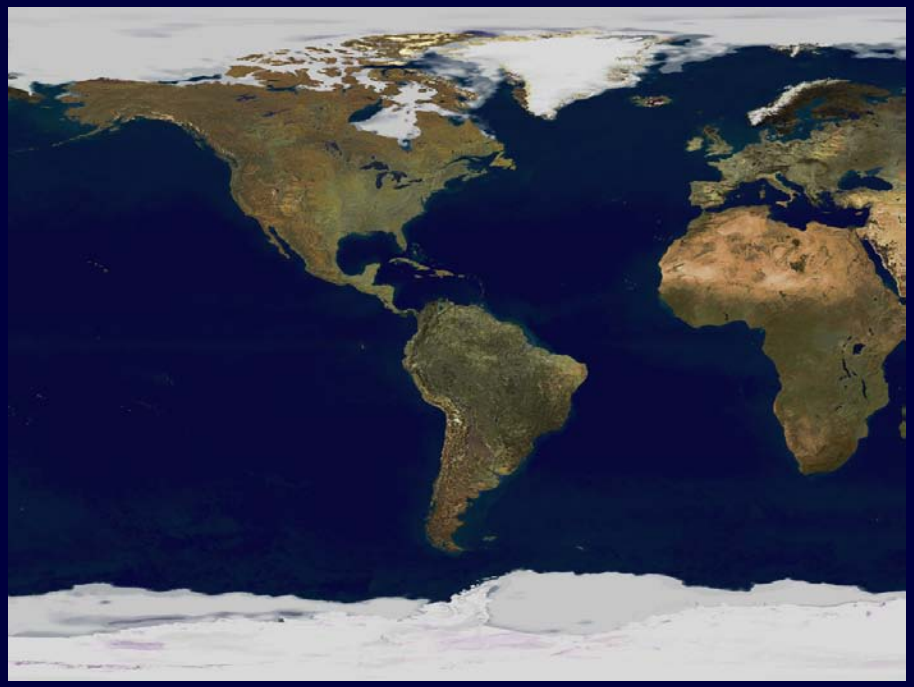


FIG. 15. Spatial distribution of benthic invertebrate functional groups, expressed as a percent of the total number of each group collected (given on the figure), at each of the four stations of each site during summer (Su) and autumn (A) or winter (W).

River Continuum Concept: Does it work?



- Strong regional and seasonal effects

- General paradigm, starting point