Climate Change Effects in Aquatic Ecosystems

Common themes within regional perspectives

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Themes: Aquatic ecosystem structure and function

- Controlled by means and extremes of **climate driven-hydrologic cycle**
- Controlled by changes in light availability and intensity- more summer-likely, +/- DOM ?
- Interactions with other stressors
- Approaches for "scaling up" to river networks

Background: Climate Change and Freshwater Ecosystems

- *ASLO-NABS workshop and study: 1995-1997*
- *Science Initiative on the Global Water Cycle (Hornberger report-2002)*
- *Current concerns for sustainability of freshwaters*

Okefenokee Swamp in Georgia

Climate Change and Freshwater Ecosystems

- *ASLO-NABS workshop and study: 1995-1997*

HYDROLOGICAL PROCESSES, VOL. 11, 971–992 (1997)

EFFECTS OF CLIMATE CHANGE ON INLAND WATERS OF THE PACIFIC COASTAL MOUNTAINS AND WESTERN GREAT BASIN OF NORTH AMERICA

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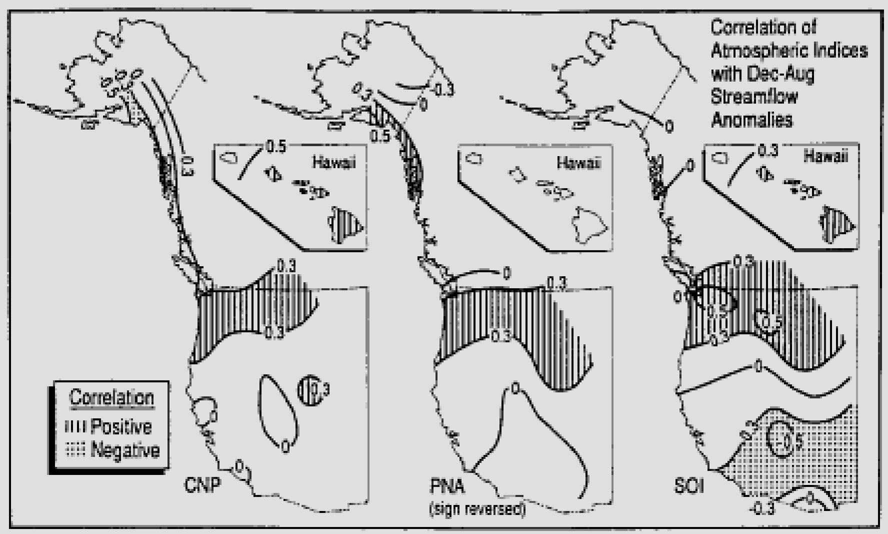


Figure 3. Correlation between December–August stream flow anomalies and winter CNP (left), PNA middle) and SOI (right). The sign on PNA is reversed to aid comparison with other indices. (From Cayan and Peterson, 1989)

ASLO-NABS studies of 8 regional systems to consider both types of surface waters and particular climate sensitivities of each region

EFFECTS OF CLIMATE CHANGE ON INLAND WATERS OF THE PACIFIC COASTAL MOUNTAINS AND WESTERN GREAT BASIN OF NORTH AMERICA

- **HYDROLOGICAL PROCESSES, VOL. 11, 971±992 (1997)**
- Hydrological response: decrease in snow and increased runoff during winter and less in summer
- Saline lakes: increase in meromixis
- Sub-alpine lakes: more productivity
- Glacial fed-rivers: more flow and scour, less productivity
- Warming: reduced growth and survival of salmon in freshwater, and increase marine mortality

Hornberger report: Science questions

- 1. What are the causes of variability in the water cycle at regional and global scales? To what extent are variations induced by human activities?
- 1*. Are we changing water cycle variability?
- 1**.What will happen?

Hornberger report: Science questions

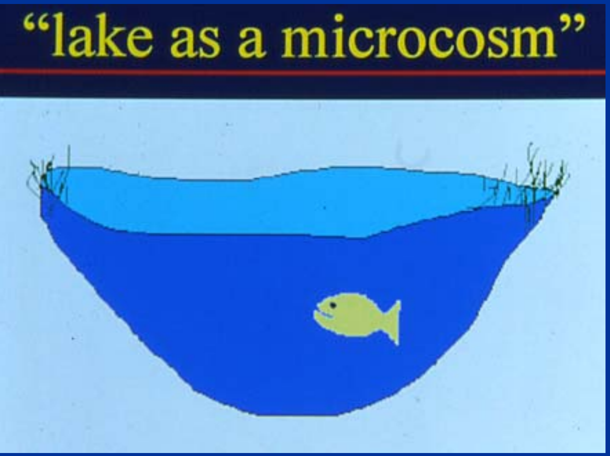
- 2. To what extent are variations in the water cycle predictable at the global and regional scale?
- 2*. How well can we predict water cycle variability?
- 2**. How well can we know what will happen?

Hornberger report: Science questions

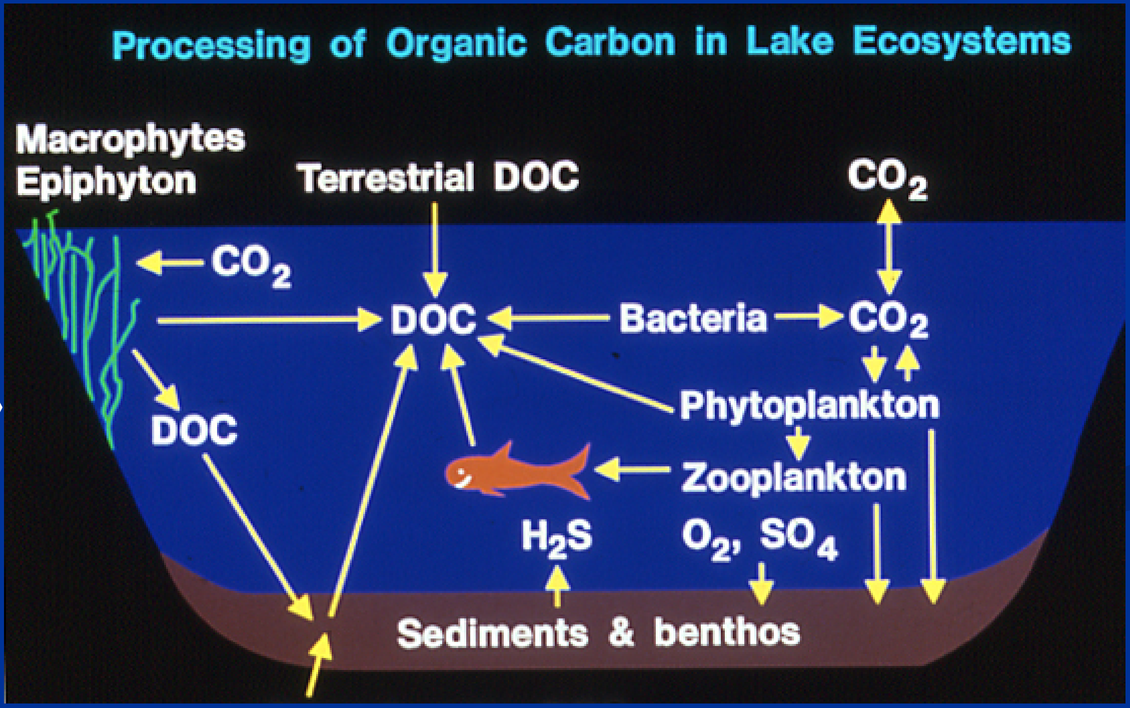
- 3. How are water and nutrient cycles linked in terrestrial and freshwater ecosystems?
- 3*. How will water quality and ecosystems change with water cycle variability?
- 3**. ***What else will happen?***

Ecosystem framework

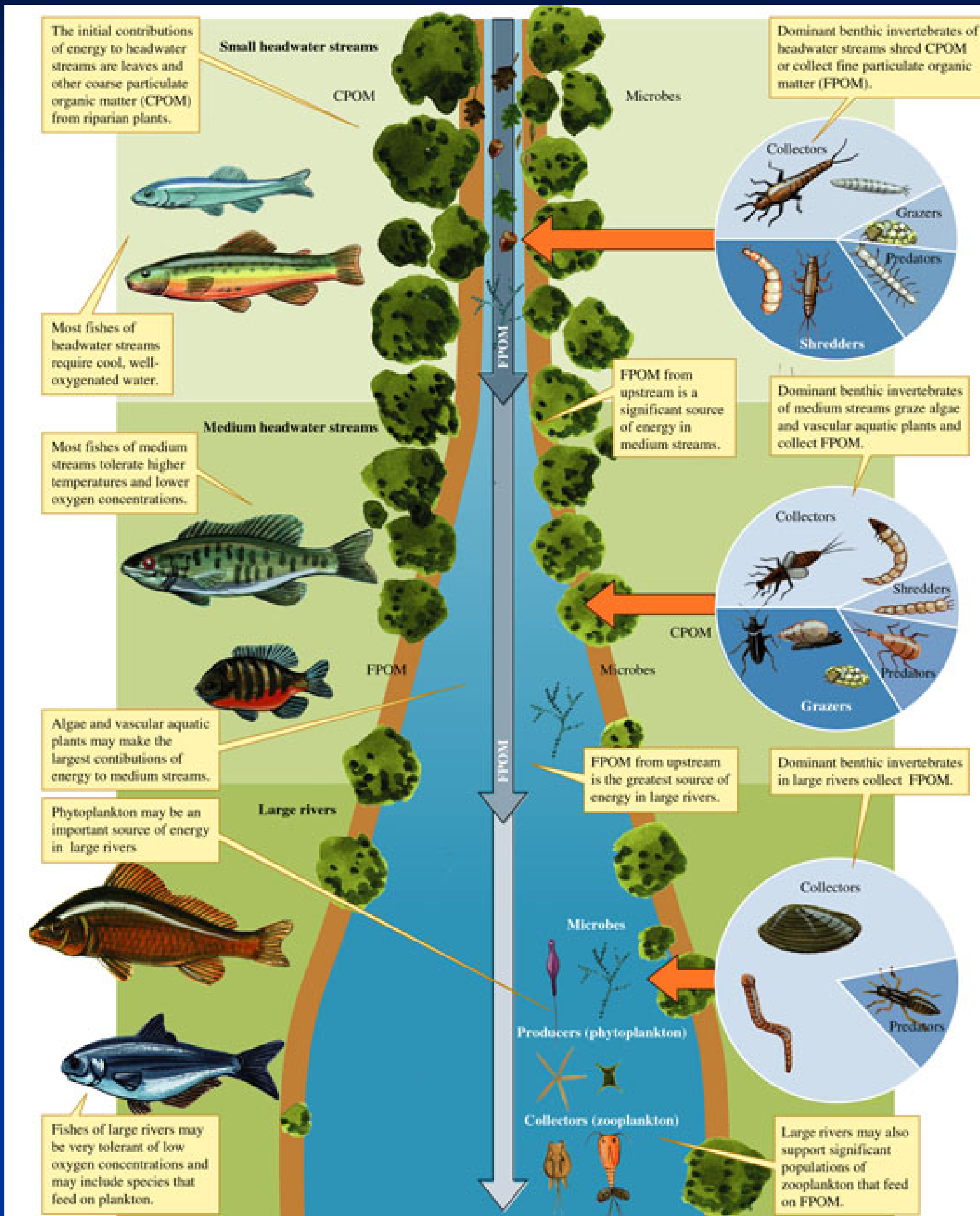
- Lindeman (1953): Trophic Dynamics Concept, addressing the cycling of C in ecosystems



Forbes- 1892



River Continuum Concept: Vannote et al. 1980



Connections from upstream to downstream habitats control flow of energy and carbon in fluvial ecosystems, as well as the species of aquatic organisms

Theme: importance of light availability in controlling in situ production (e.g. P/R)

Examples: mountain lakes and streams

- AMD streams
- Snowmelt dominated annual hydrograph
- Inflows from mines carry acid and metals

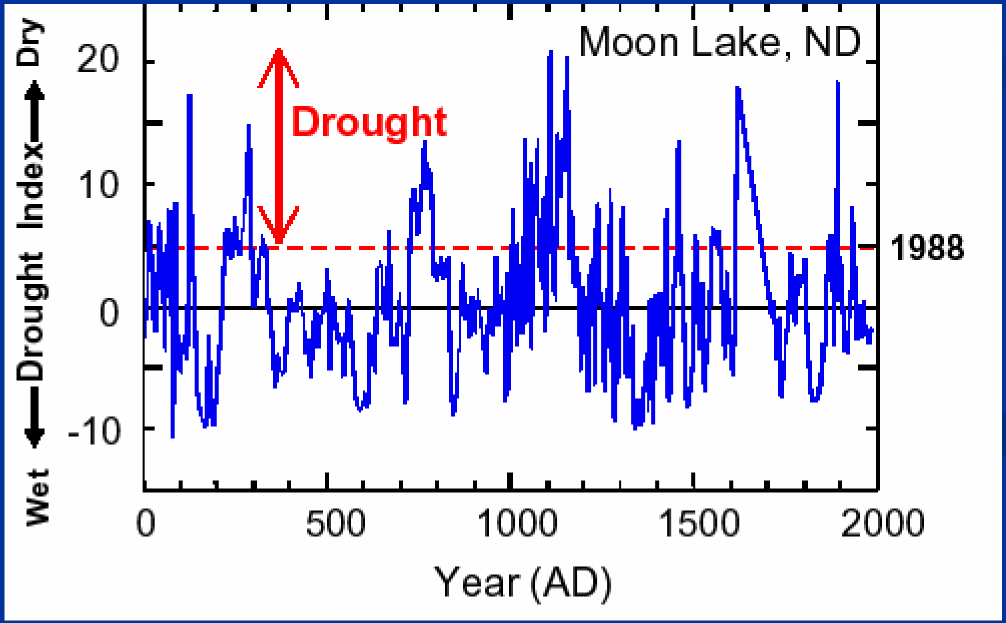
- NWTLTER
- Snowmelt dominated annual hydrograph
- Watershed inflows carry DOM and nutrients

Controlled by means and extremes of climate driven-hydrologic cycle

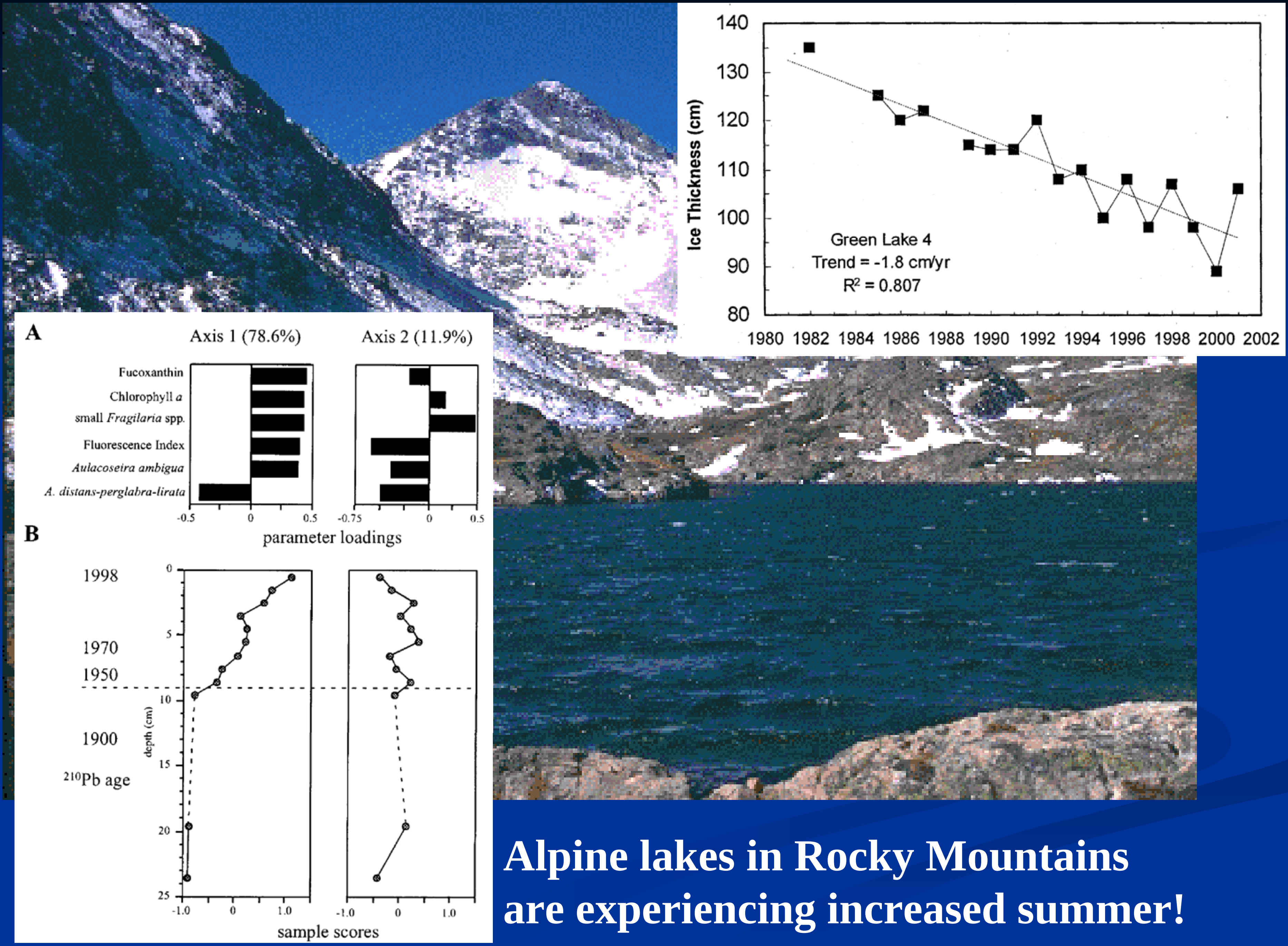
Climate system can shift rapidly between modes.

Paleolimnological analyses to forecast future trajectories

Merging hydrochemical and hydrologic modeling will enhance interpretation.

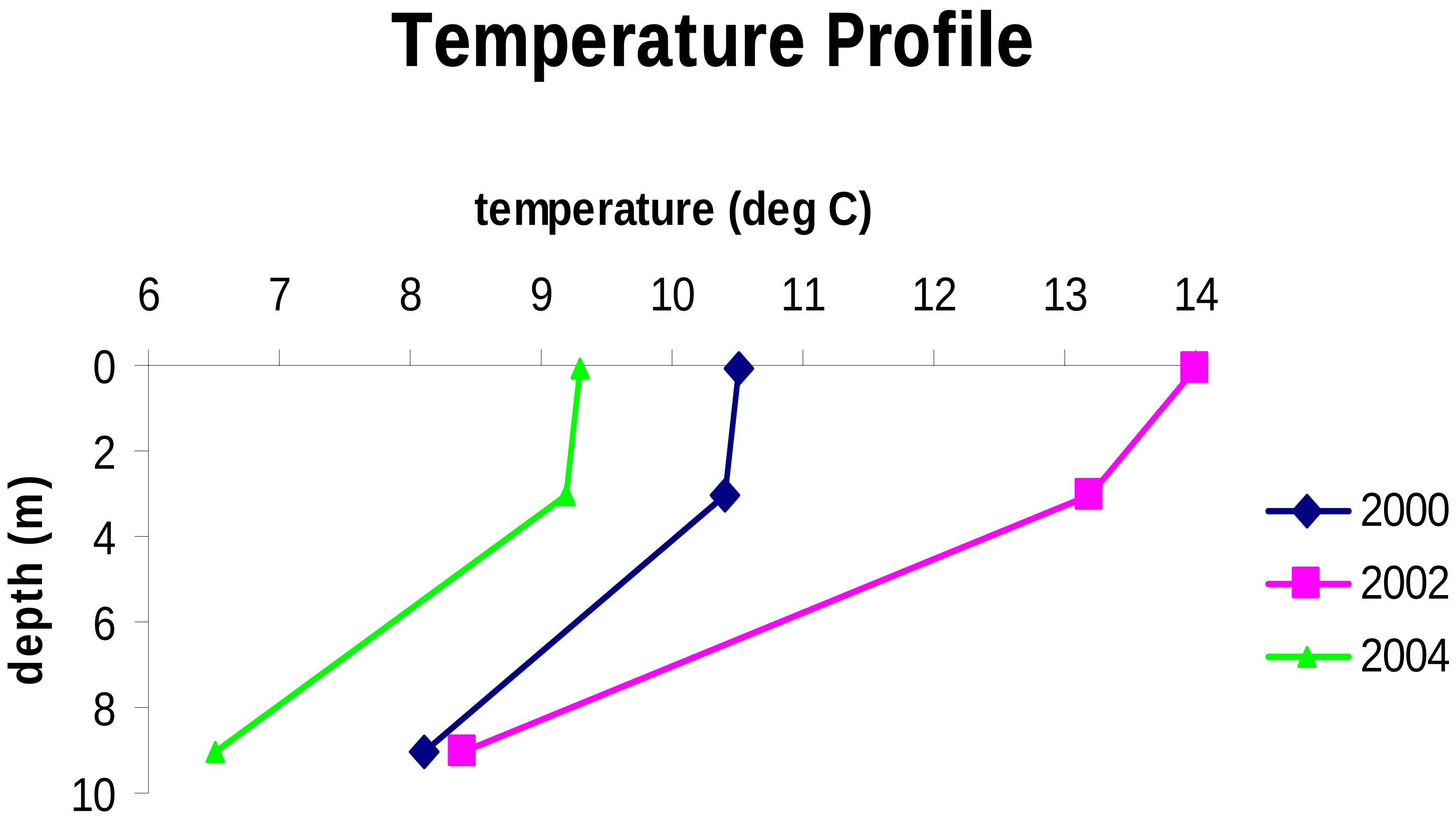


Nitrate deposited with snow and DOM from terrestrial ecosystem are mobilized during snowmelt
How are processes controlling the fate of nitrate changing? What will be ecosystem consequences?



Alpine lakes in Rocky Mountains are experiencing increased summer!

Drought of 2002

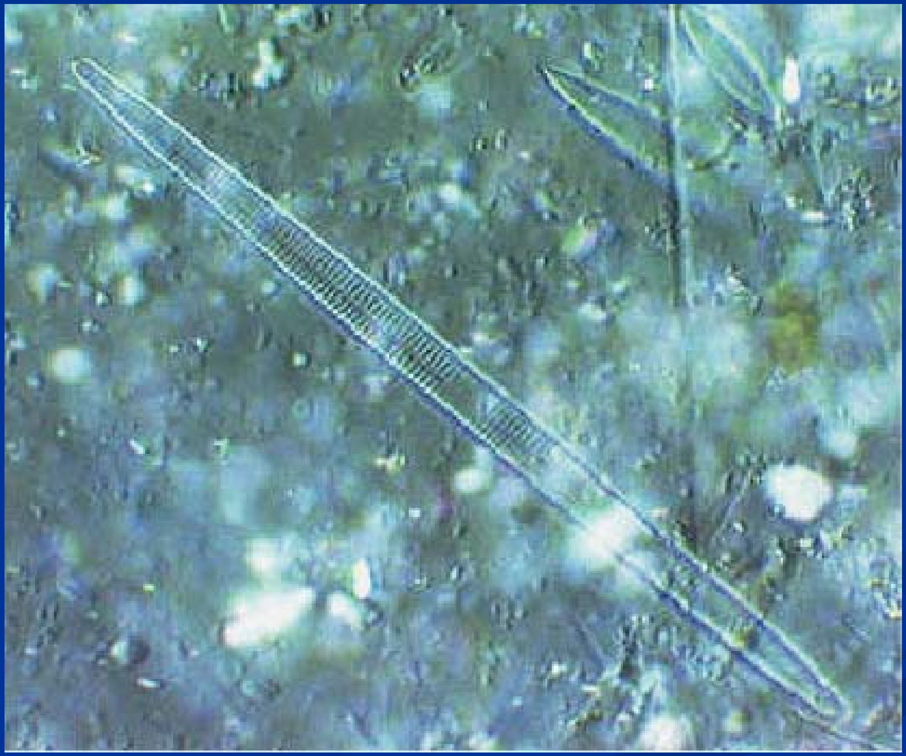


Drought of 2002

- Higher peak biomass
  - 8 μg/L in 2002, compared to ~6 μg/L
- Significant differences in algal distribution and abundance

Taxon-Specific Response during drought year

- More algal biomass as Chlorophyll a
- Bacillariophyta
  - *Synedra* sp.



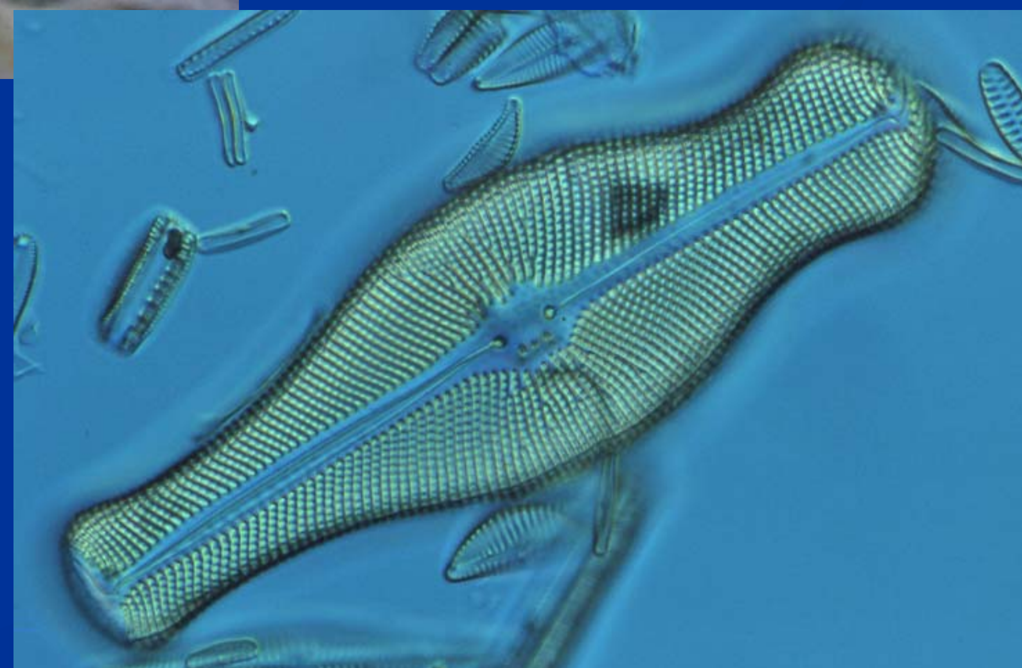
Diatom, Bacillariophyta, *Synedra* sp.

Image from Protist Information Server

Dramatic changes in sub-alpine stream

Didymosphenia growth habit

Since the 2002 drought, Didymo has taken on the characteristics of an invasive species within its native range



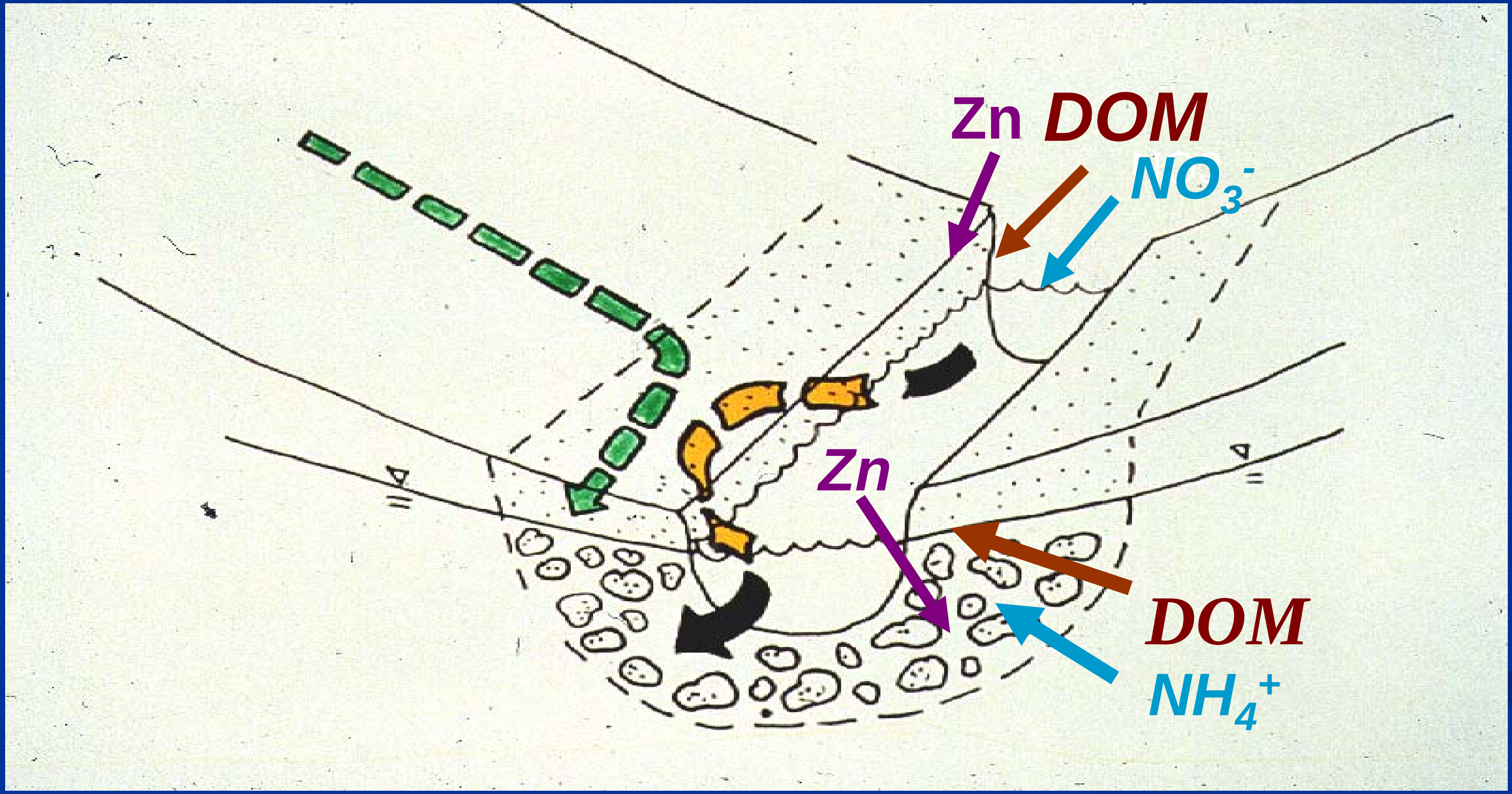
Changes in seasonal timing will restructure ecosystems and alter biogeochemical cycles

- Thermokarst lakes and stream networks evolving
- Nutrient pulses from hydrologic flushing
- Flushing of trace contaminants
- New technologies will allow tracking of transitional events

Toolik Lake- importance of ice-out

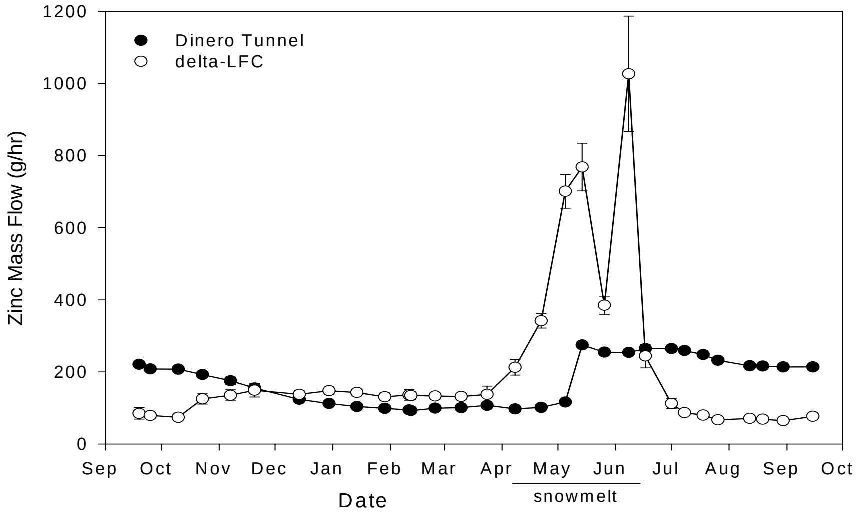
Changes in hydrology can change interaction between stream, hyporheic zone, and wetlands

Hydrologic complexity with reactions occurring along biogeochemical gradients



Quantifying hyporheic exchange and biogeochemical interactions

- Use tracers → Concentration vs Time and Space
- Recent experiment: Peru Creek 2005



During drought stream became disconnected from wetland- no metal retention!

Climate Change and Freshwater Streams: Controlled by changes in light availability and intensity

- Changes in timing of snowmelt, changing the flush of DOM
- Increased UV due to ozone loss
- UV inhibits aquatic organisms
- Changes concentrations of organic contaminants and toxicity of trace metals

Humic substances: Major chromophores and 50% of DOM

Terrestrial → Aquatic Humic Substances ← Microbial

Decreased metal bioavailability (Complexation)

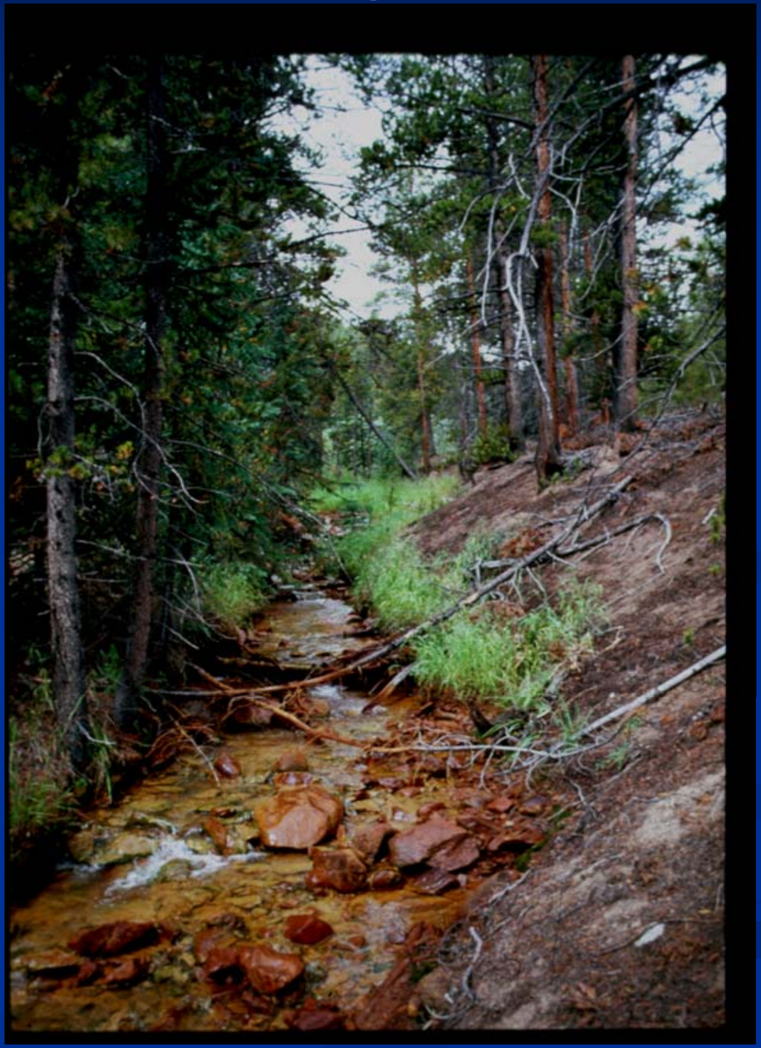
Aquatic Sunscreen (UV attenuation)

Altered chemical properties (photobleaching, LMW's, mineralization)

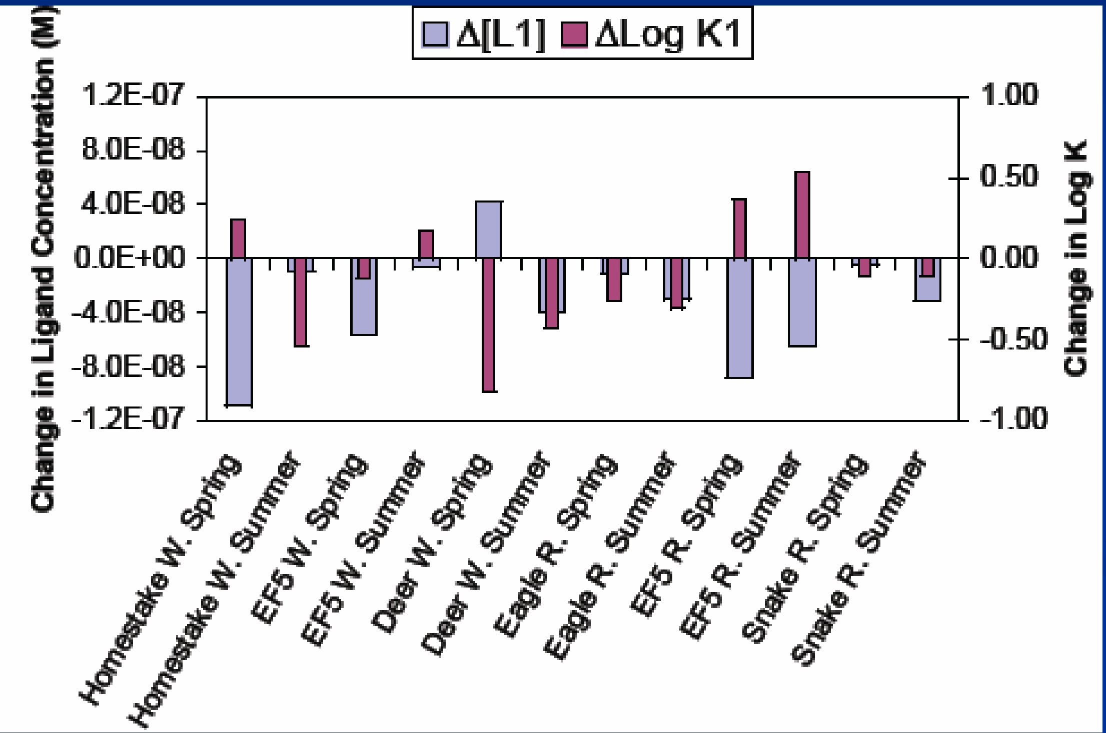
Implications?

Will increased UV exacerbate AMD problems in Rocky Mtns if photolysis destroys DOM binding sites?

- Historic mining has left legacy of metal pollution
- Increased metals are toxic to aquatic organisms at acute and chronic levels
- Determine metal binding by titration using Cu-ion selective electrode
- Values used in BLM for Cu standards

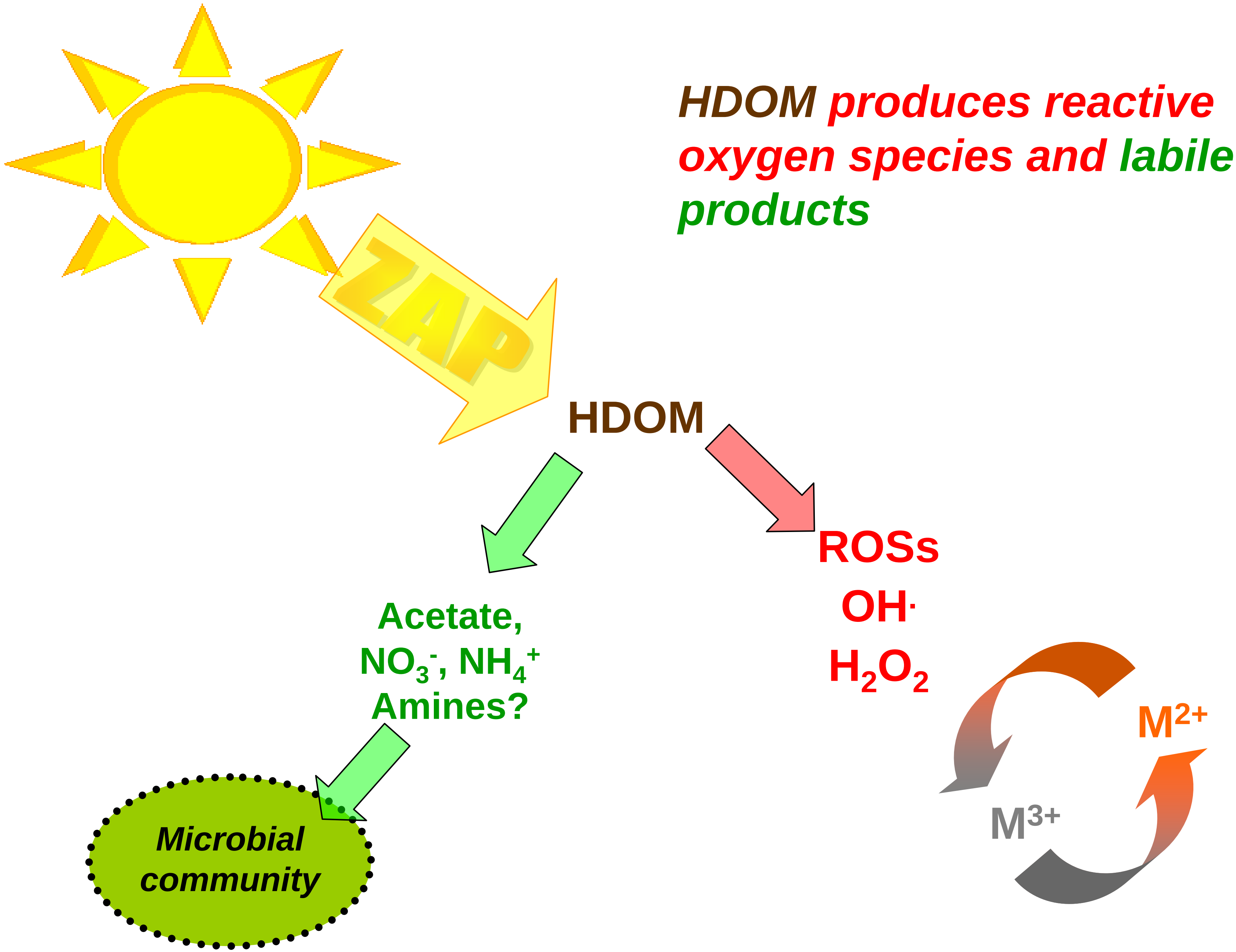


Strong Cu-binding change in wetland and river samples



Homestake Wetland % change in component loading

	Spr	Sum
C7-SQ2	-.8	-1.5
C13-Tyr	-.5	+3.7



HDOM produces reactive oxygen species and labile products
ZAP
HDOM
Acetate,
NO_3^-, NH_4^+
Amines?
Microbial community
ROSs
$OH^{\cdot}$
H_2O_2
M^{2+}
M^{3+}

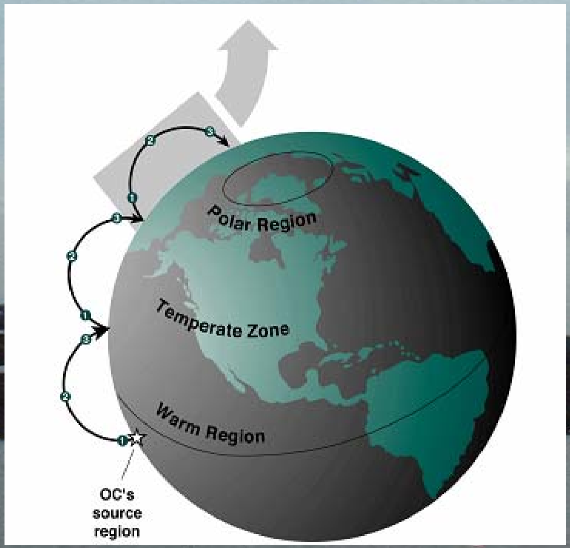
DOM Photochemistry: Important for North Slope of Alaska

Toolik Lake (LTER)

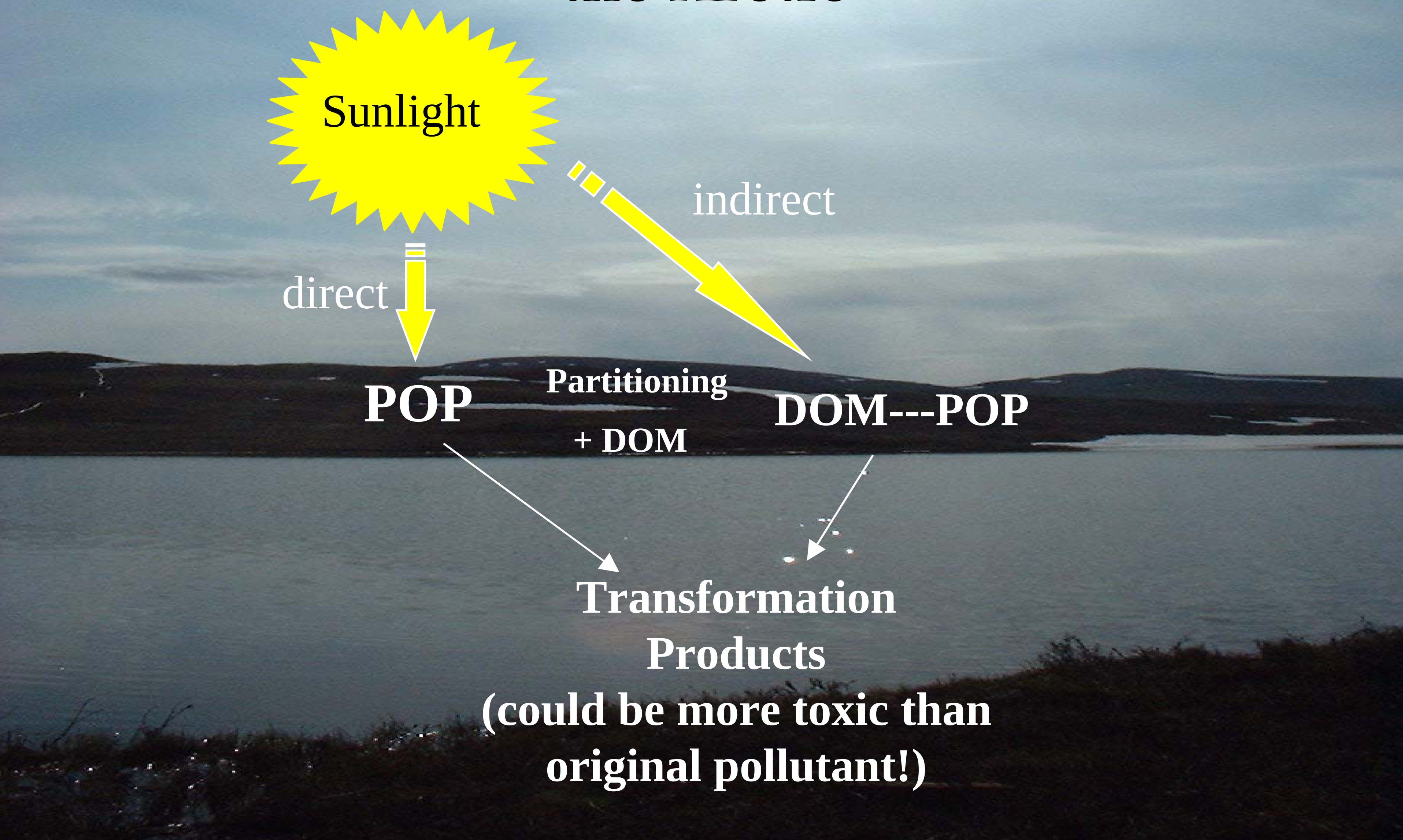
Prudhoe Bay (tour from Deadhorse Point

Importance of DOM Photochemistry in the Arctic

Global Distillation Effect Brings POPs to Arctic



Importance of DOM Photochemistry in the Arctic



Themes: Aquatic ecosystem structure and function

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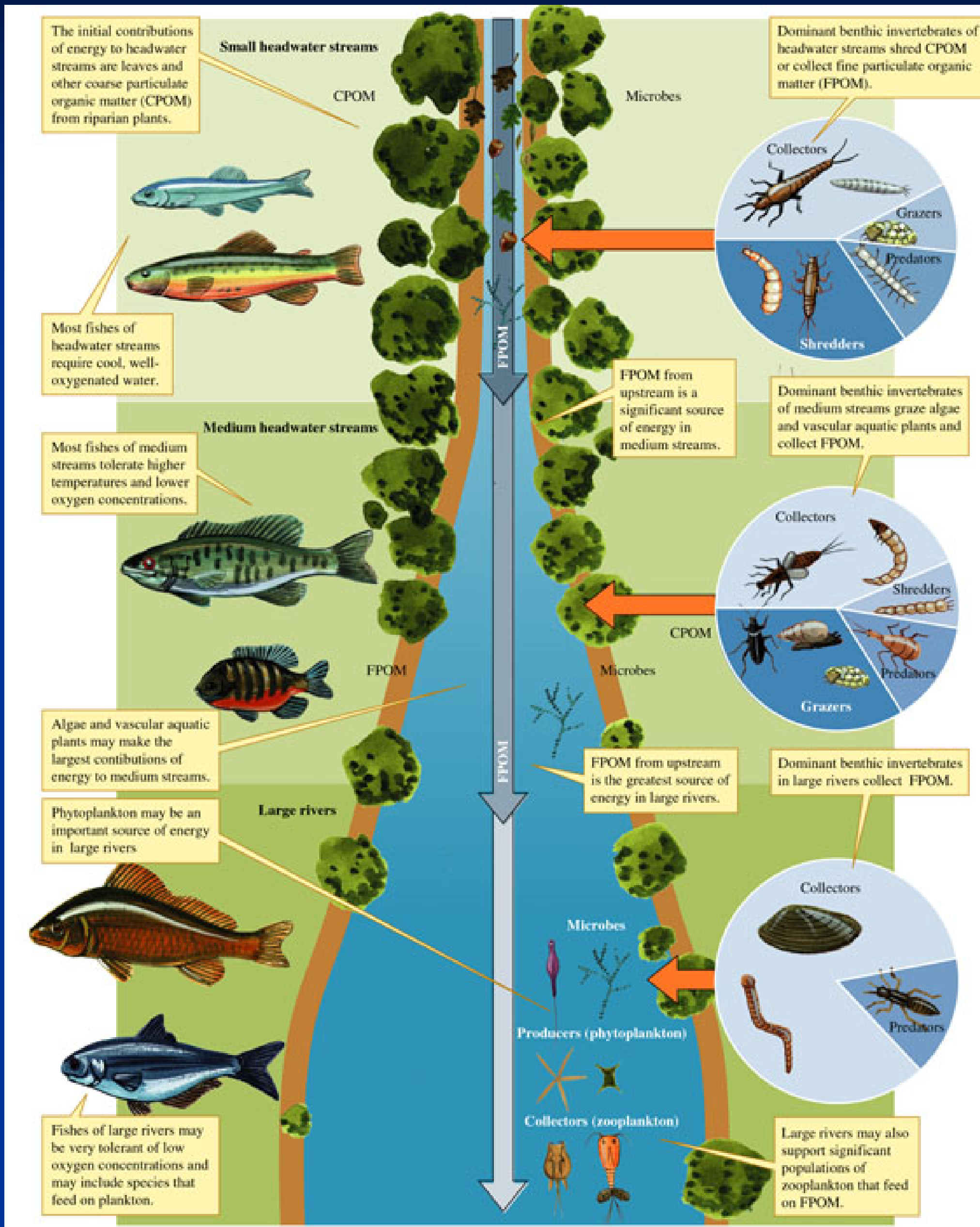
Ecosystem as a Fundamental Unit of Nature: Tansley



Connections from upstream to downstream habitats control flow of energy and carbon in fluvial ecosystems, as well as the species of aquatic organisms

Theme: importance of light availability in controlling in situ production (e.g. P/R)

Enabling Technologies

- Aquatic ecology must overcome the major "undersampling" problem
- Continuous and real time data acquisition
- Linkage between real-time data and near real-time modelling
- Improved year-round infrastructure

In Situ Sensors

- Large amounts of data, capture episodic events, reduce contamination
- Move within water column- remote operation
- Fiber optic chemical sensors
- MEMS (micro-electro-mechanical systems) not available now, but could be developed

In Situ Sensors

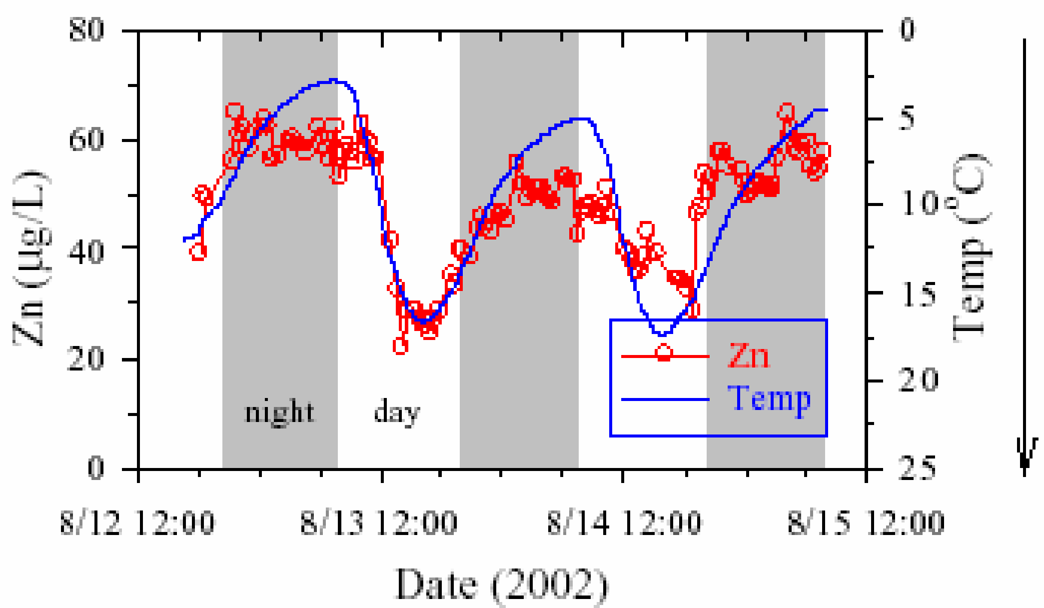
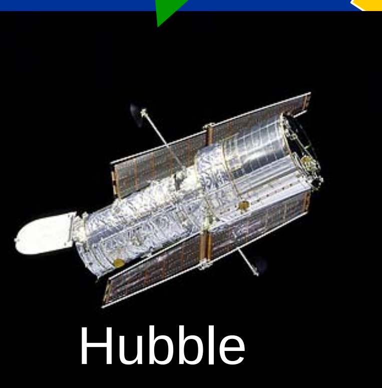


Figure 11. Diel variation in zinc concentrations and temperature in Fisher Creek, MT measured *in situ* with the Zn-DigiScanner. Submersible autoanalyzers such as this are beginning to provide fine-scale temporal and spatial data that was previously unattainable to aquatic chemists. Data of T. Chapin and R.B. Wanty.

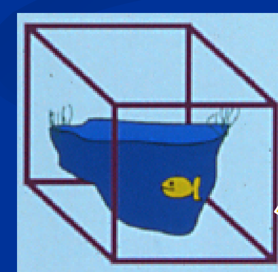
Freshwater Ecosystems and Climate Change

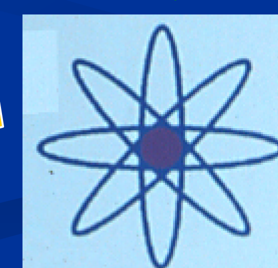


Waters?

NEON

CERN





Opportunity to gain more practical knowledge from effective monitoring and prediction