Arctic LTER 2017-2023:
The Role of Biogeochemical and Community Openness in Governing Arctic Ecosystem Response to Climate Change and Disturbance (NSF 1637459)

http://arc-lter.ecosystems.mbl.edu

look under "About"

Four Key Concepts

Ecosystem-level concepts:

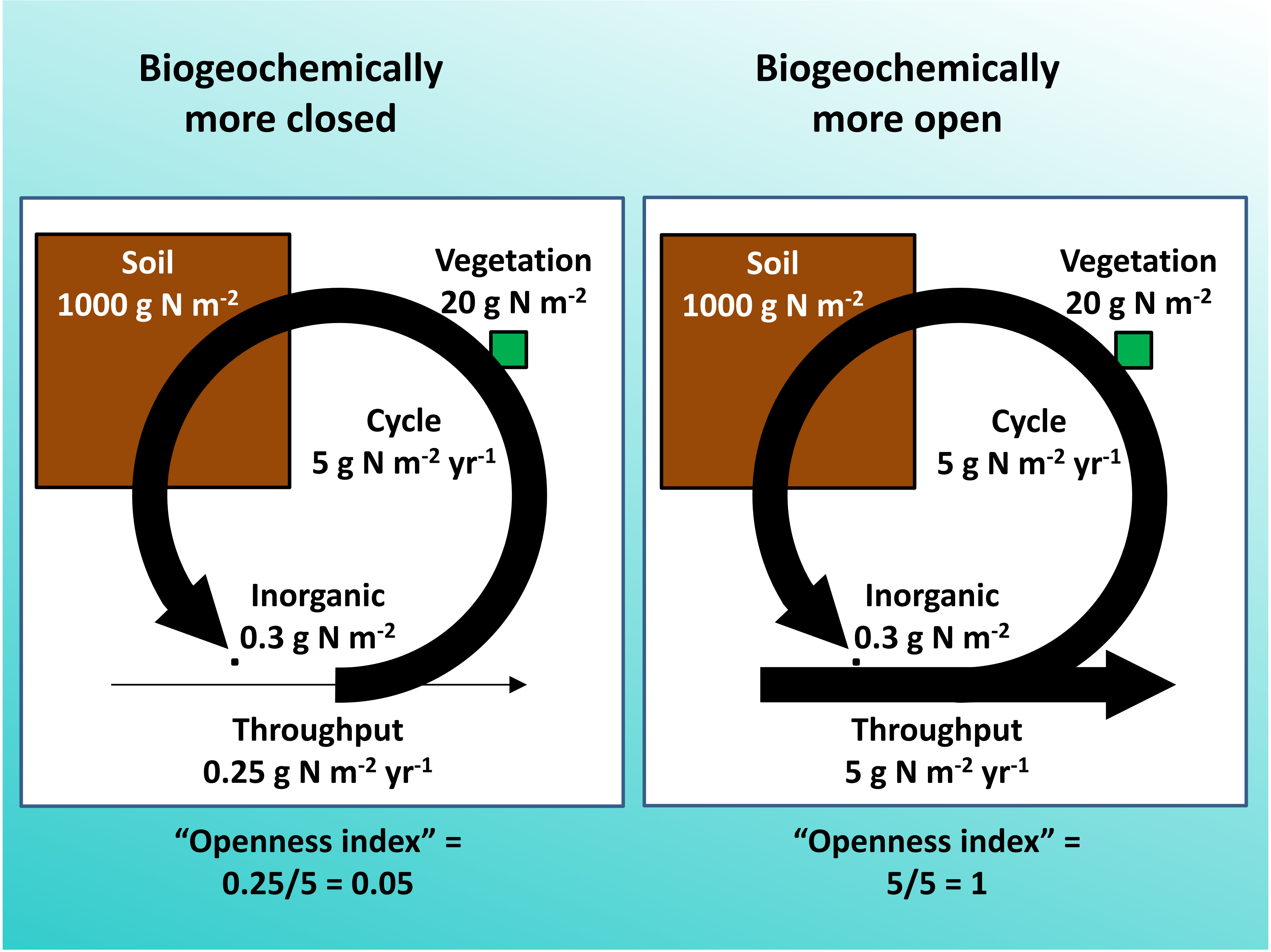
"Biogeochemical openness" is the degree to which the ecosystem depends on external supplies of nutrients and organic C (allochthonous C) versus internally recycled nutrients and locally fixed organic C (autochthonous C).

"Community Openness" is the degree to which the ecosystem allows versus resists the establishment or loss of organisms or species.

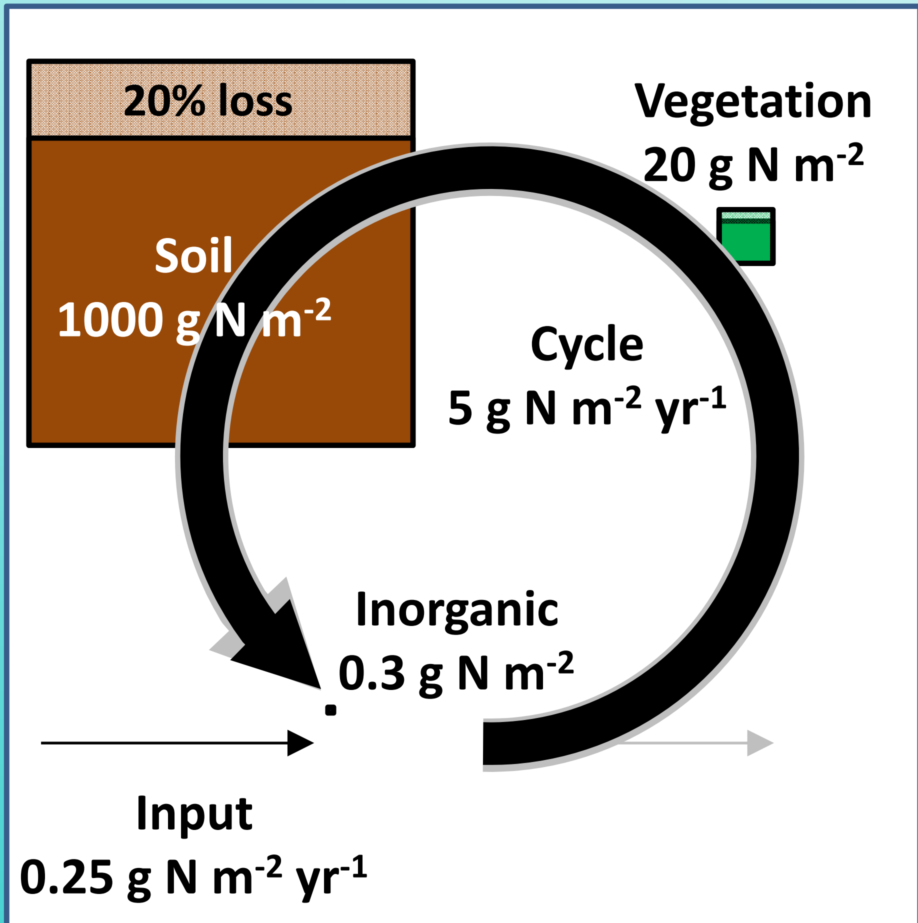
Landscape-level concepts:

"Biogeochemical Connectivity" is the degree to which the transfer of nutrients and organic matter among ecosystems maintains biogeochemical function and fosters the propagation of ecological signals across the landscape.

"Community Connectivity" is the degree to which the movement of organisms among ecosystems maintains community and trophic structure and fosters the propagation of ecological signals across the landscape.

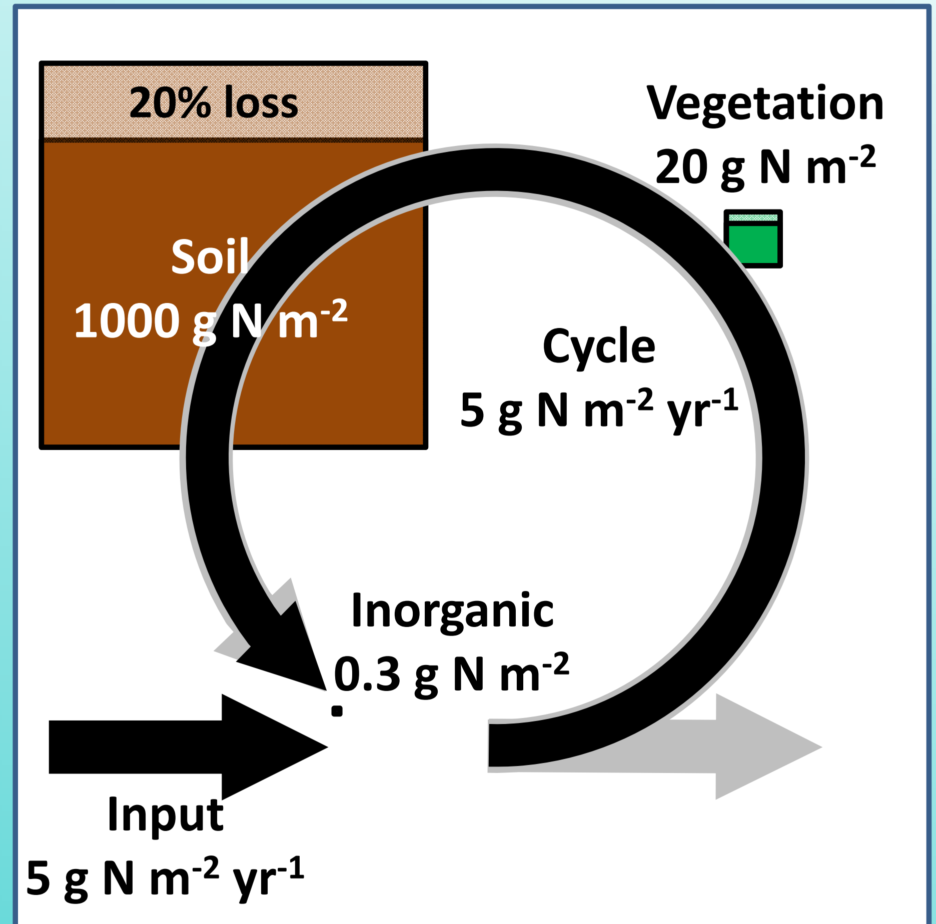

Biogeochemically
more closed
Biogeochemically
more open
Soil
1000 g N m-2
Vegetation
20 g N m-2
Cycle
5 g N m-2 yr-1
Inorganic
0.3 g N m-2
Throughput
0.25 g N m-2 yr-1
Soil
1000 g N m-2
Vegetation
20 g N m-2
Cycle
5 g N m-2 yr-1
Inorganic
0.3 g N m-2
Throughput
5 g N m-2 yr-1
"Openness index" =
0.25/5 = 0.05
"Openness index" =
5/5 = 1

Biogeochemically more closed

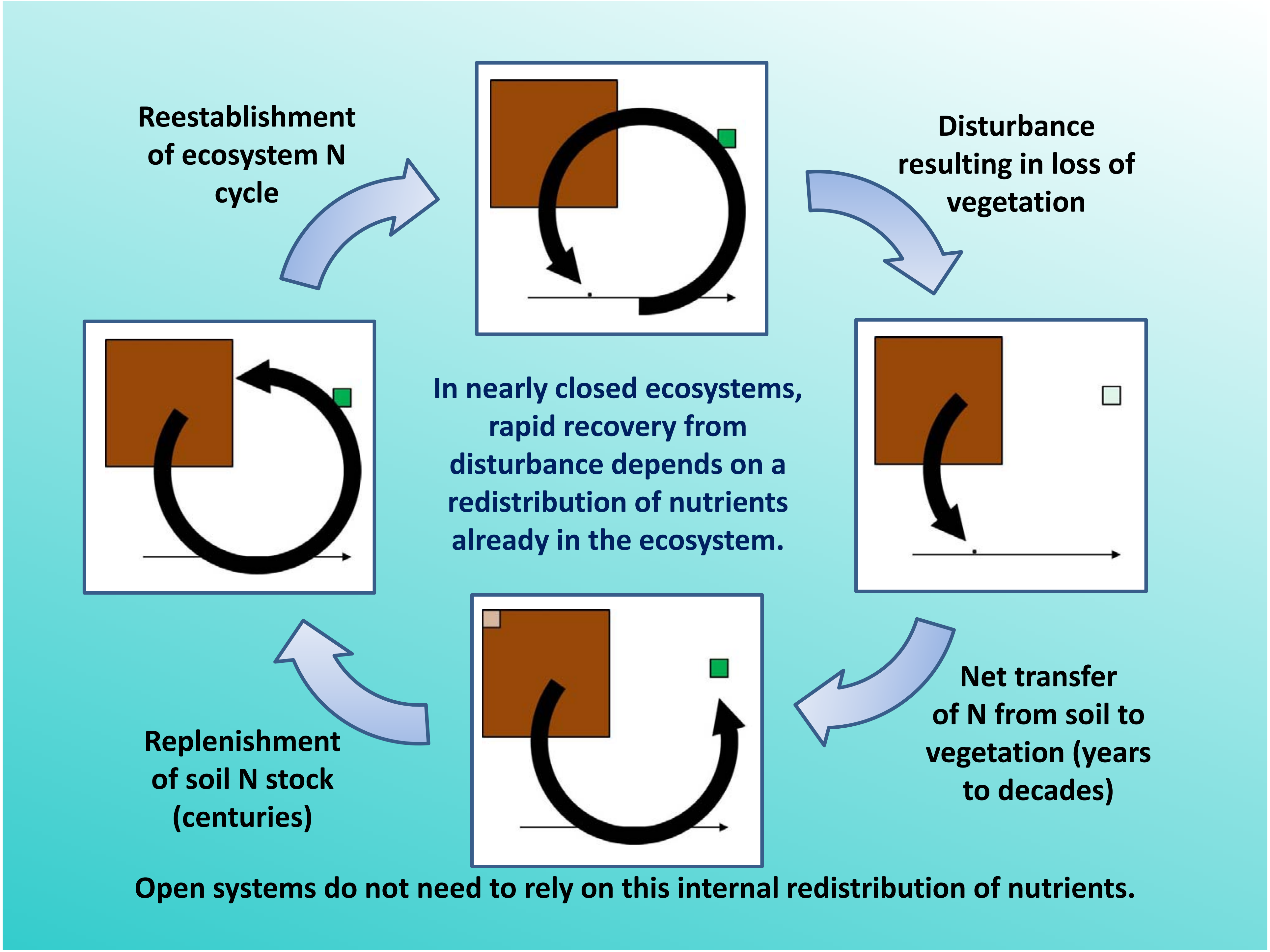


Recovery time > 816 yrs
even if all losses are stopped

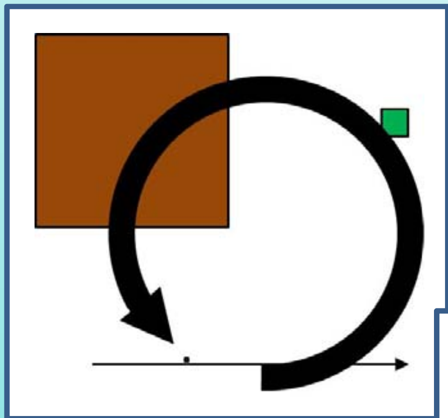
Biogeochemically more open



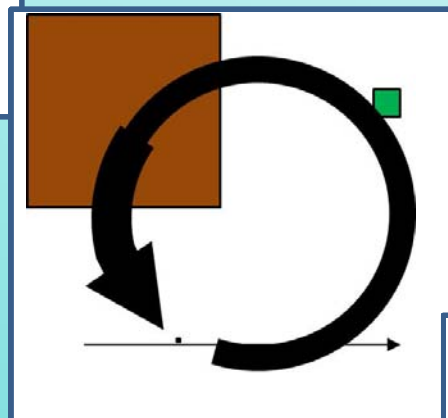
Recovery time > 40.8 yrs
even if all losses are stopped


Reestablishment of ecosystem N cycle
Disturbance resulting in loss of vegetation
In nearly closed ecosystems, rapid recovery from disturbance depends on a redistribution of nutrients already in the ecosystem.
Net transfer of N from soil to vegetation (years to decades)
Replenishment of soil N stock (centuries)
Open systems do not need to rely on this internal redistribution of nutrients.

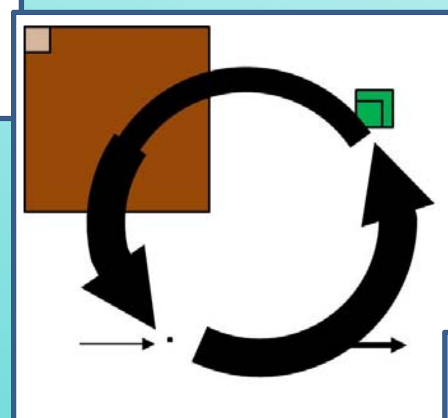
In nearly closed ecosystems, response to elevated CO_2 and warming results in faster nutrient cycling and a redistribution of nutrients from soil to vegetation.



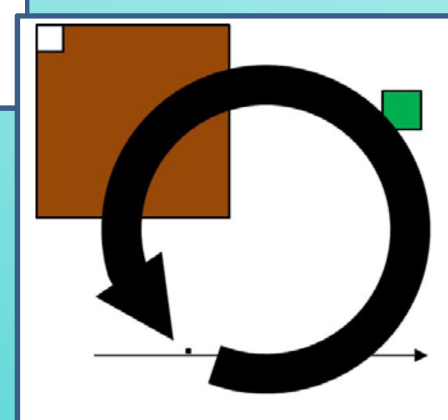
Climate warming accelerates N mineralization



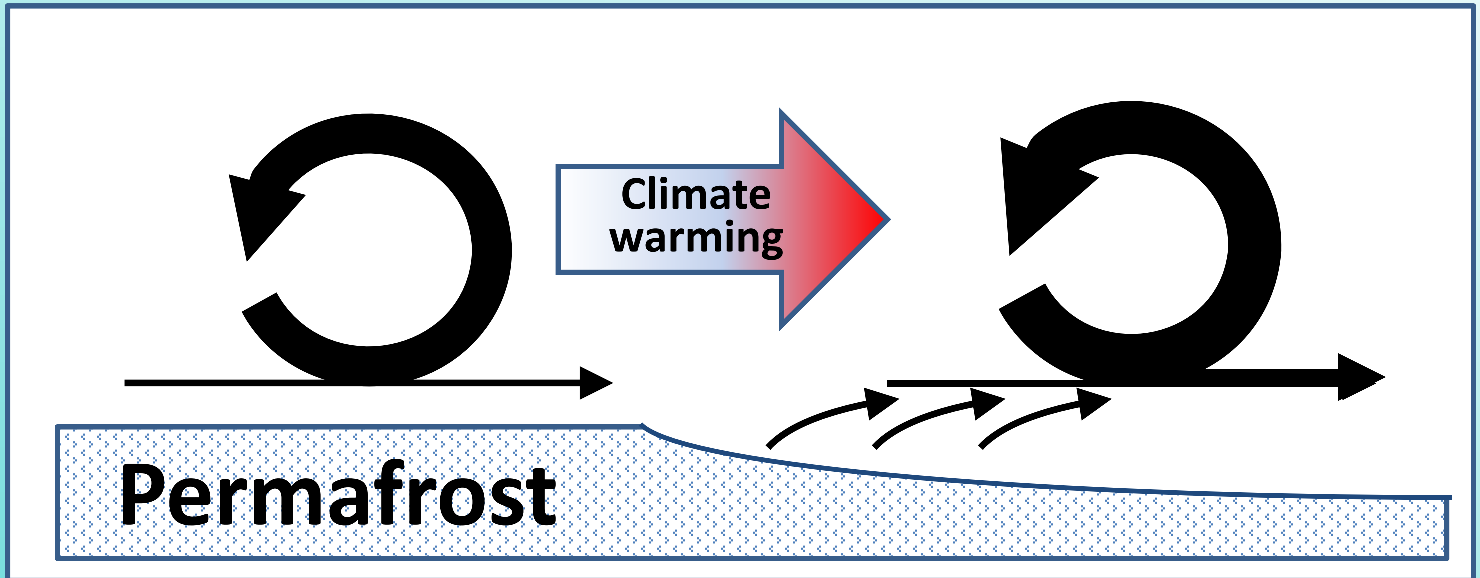
Increased N availability and elevated CO_2 stimulates plant growth



New steady state with faster N cycle & proportionally more N in vegetation

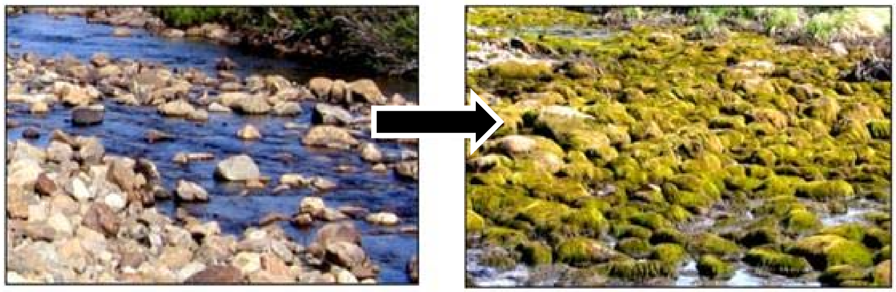


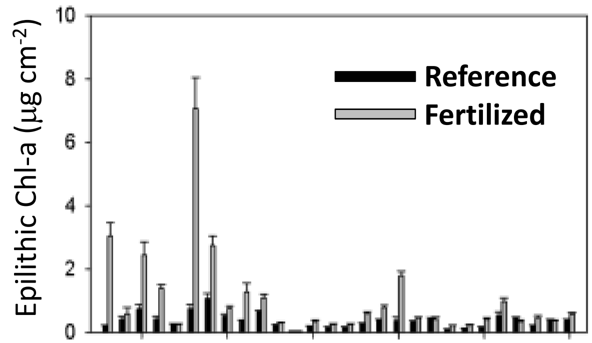
Open systems that rely more on external nutrient sources than internal cycling would not get the warming stimulation of nutrient supply unless something happened to the upstream source.

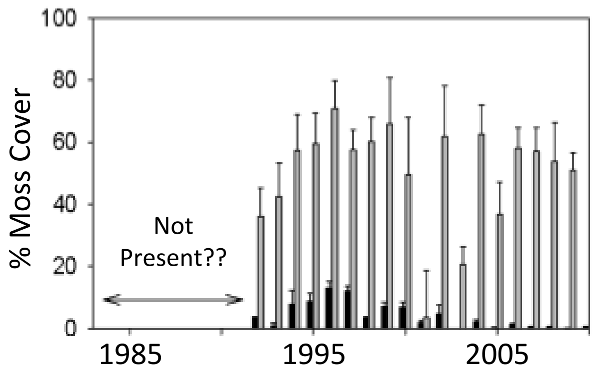


Warming will increase internal nutrient cycling, nutrient inputs from thawing permafrost, and downslope nutrient losses (leakiness).

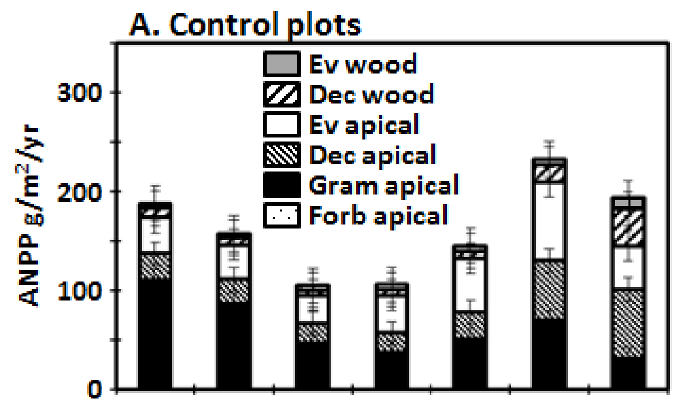
Closed communities resist colonization by other species in response to changes in the environment (e.g. increased fertility), open systems do not.

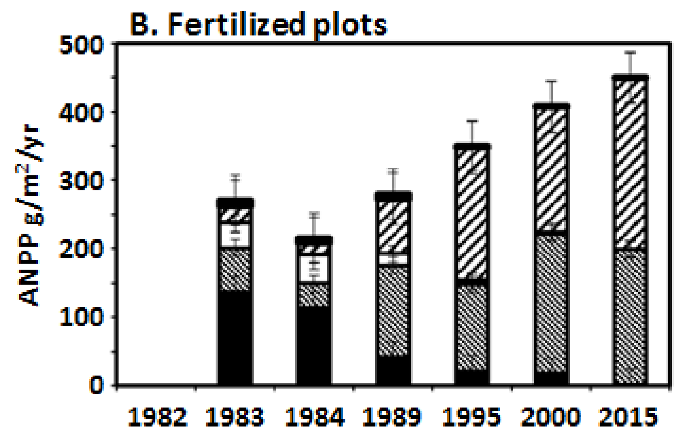






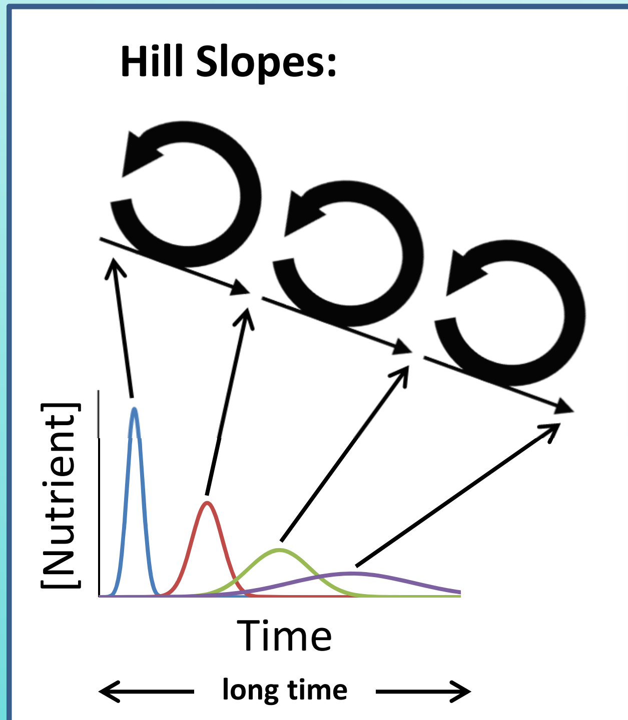
Open community

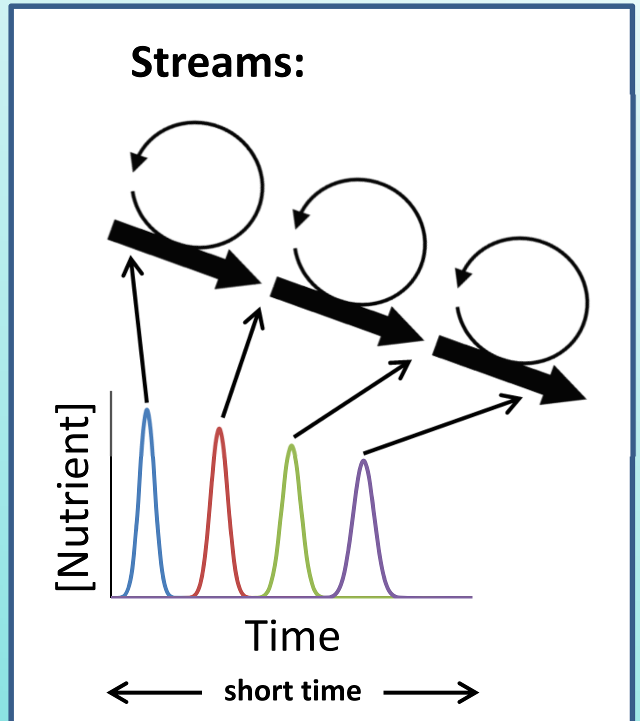




Closed community

Biogeochemical Connectivity of Landscapes



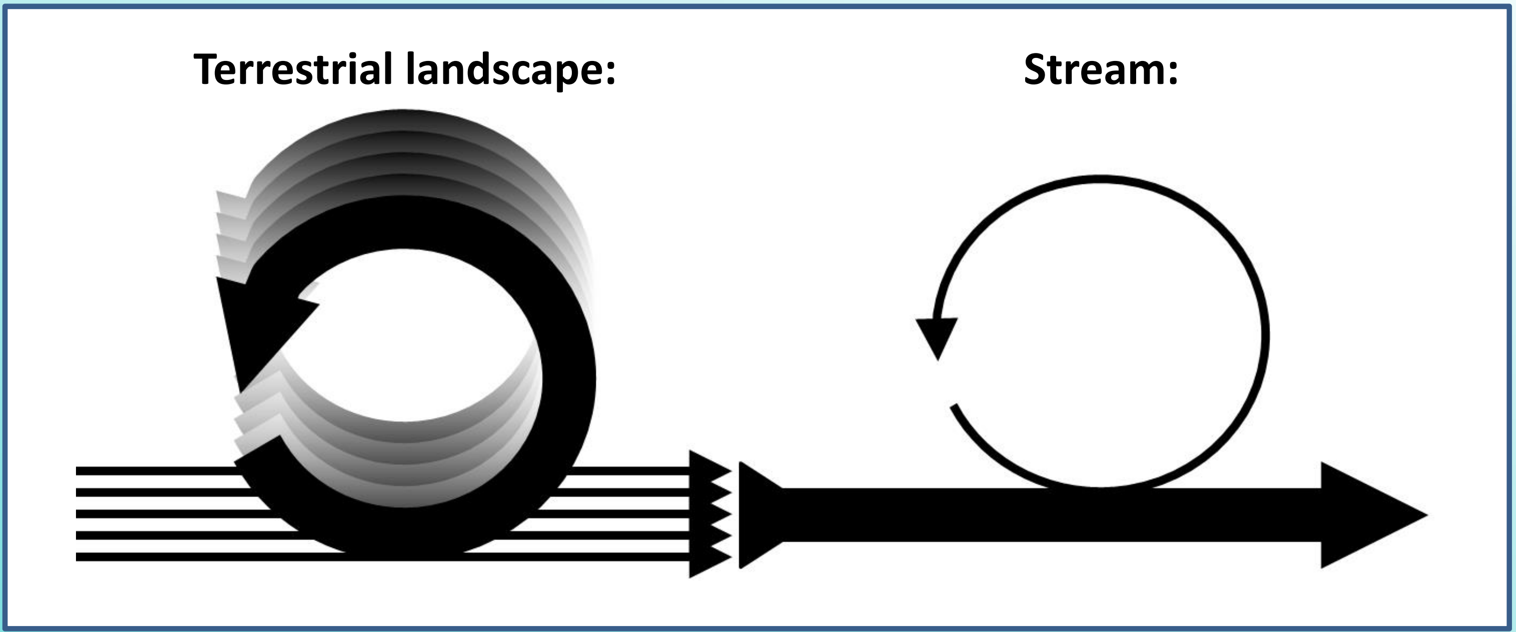


The nearly closed ecosystems on hill slopes are poorly connected and therefore delay and attenuate signals moving down slope (e.g., nutrient pulse)

Within-patch nutrient cycling

The more open ecosystems in streams are well connected and therefore propagate signals moving downstream (e.g., nutrient pulse)

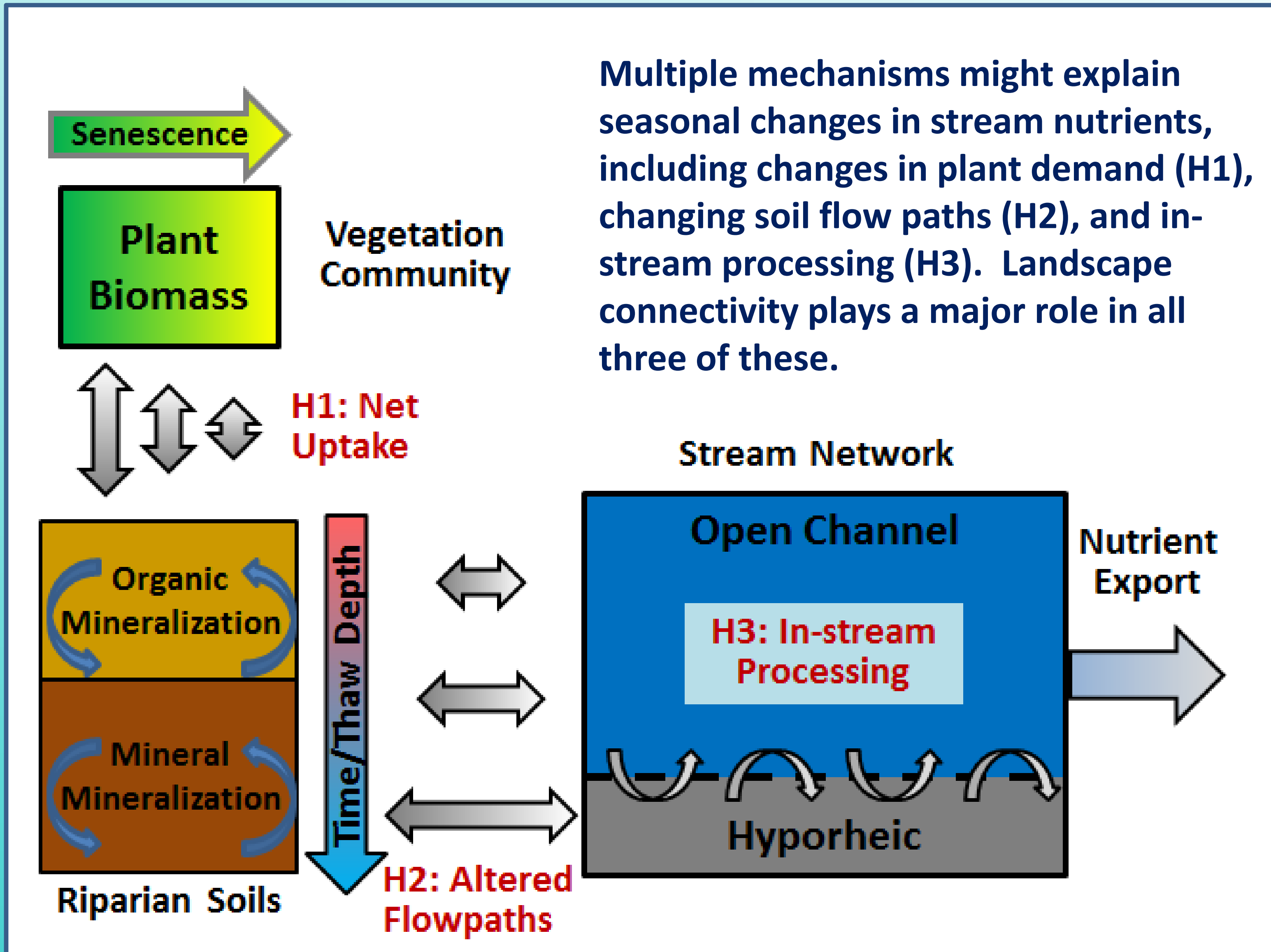
Downstream nutrient spiraling

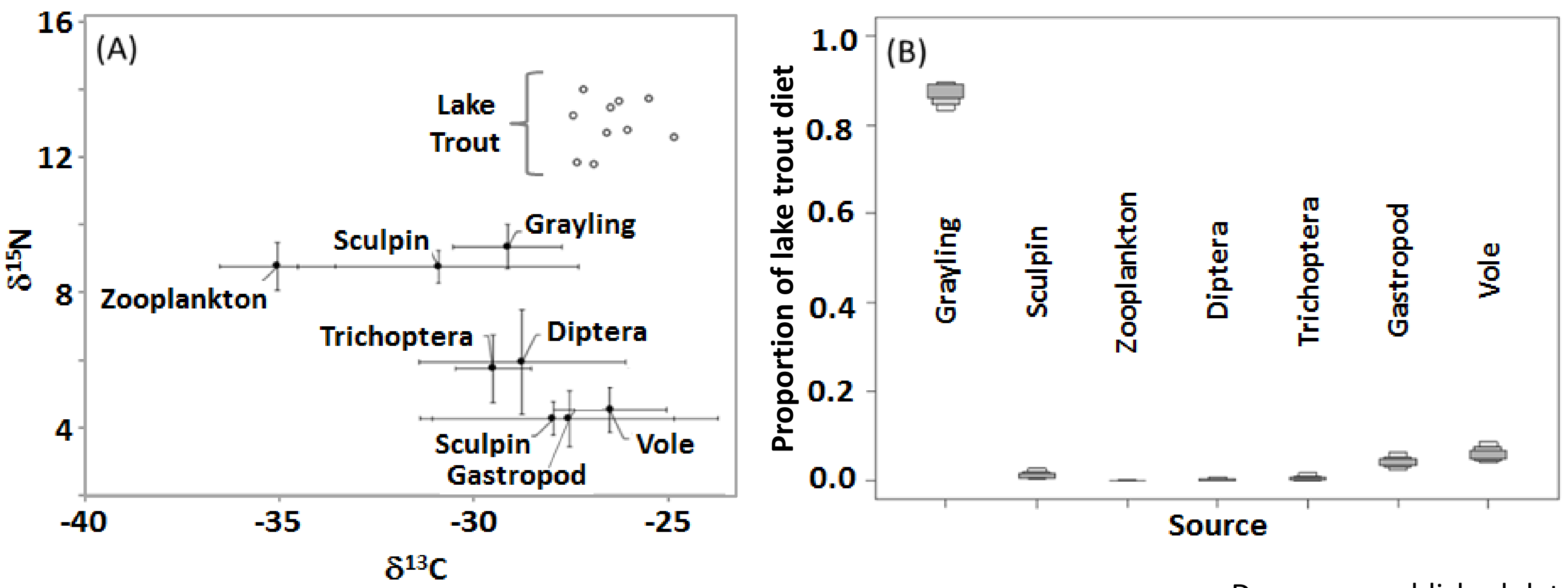


Each patch of the terrestrial landscape accumulates the nutrients upon which it relies over 1000s of years and leaks only a small fraction of these nutrients downslope each year.

Each stream reach relies upon this slow leakage of nutrients from terrestrial ecosystems accumulated over 1000s of m^2 of the terrestrial landscape and most of these nutrients pass through the ecosystem.

The stream is strongly connected to the terrestrial landscape.
Is the reverse true?


Senescence
Plant Biomass
Vegetation Community
Multiple mechanisms might explain seasonal changes in stream nutrients, including changes in plant demand (H1), changing soil flow paths (H2), and in-stream processing (H3). Landscape connectivity plays a major role in all three of these.
H1: Net Uptake
Stream Network
Organic Mineralization
Mineral Mineralization
Riparian Soils
Time/Thaw Depth
H2: Altered Flowpaths
Open Channel
H3: In-stream Processing
Hyporheic
Nutrient Export



Deegan unpublished data

One aspect of community connectivity is the seasonal movement of organisms in and out of the ecosystem.

Grayling migration has important ramifications on the community and trophic structure of both streams and lakes.

Does this migration influence ecosystem-level responses to climate and disturbance?

Clearly grayling migration also contributes to biogeochemical openness of streams and lakes through the movement of organic matter and nutrients in their bodies.

Conclusion:

Arctic landscapes are diverse and interconnected.

The concepts of openness and connectivity apply to all ecosystems and biomes, but they also help us compare the Arctic with other biomes, to contrast ecosystems within the Arctic (e.g., tundra v. streams v. lakes), and to examine characteristics unique to the Arctic (e.g., permafrost thaw, rapid climate change).

Ecosystem properties including openness and connectivity determine differences among ecosystems in their sensitivity and response to disturbance (e.g., climate warming, wildfire, thermokarst).

Through our research we hope to use the concepts of openness and connectivity to better understand the structure and function of ecosystems in general but also to address issues unique to the Arctic.