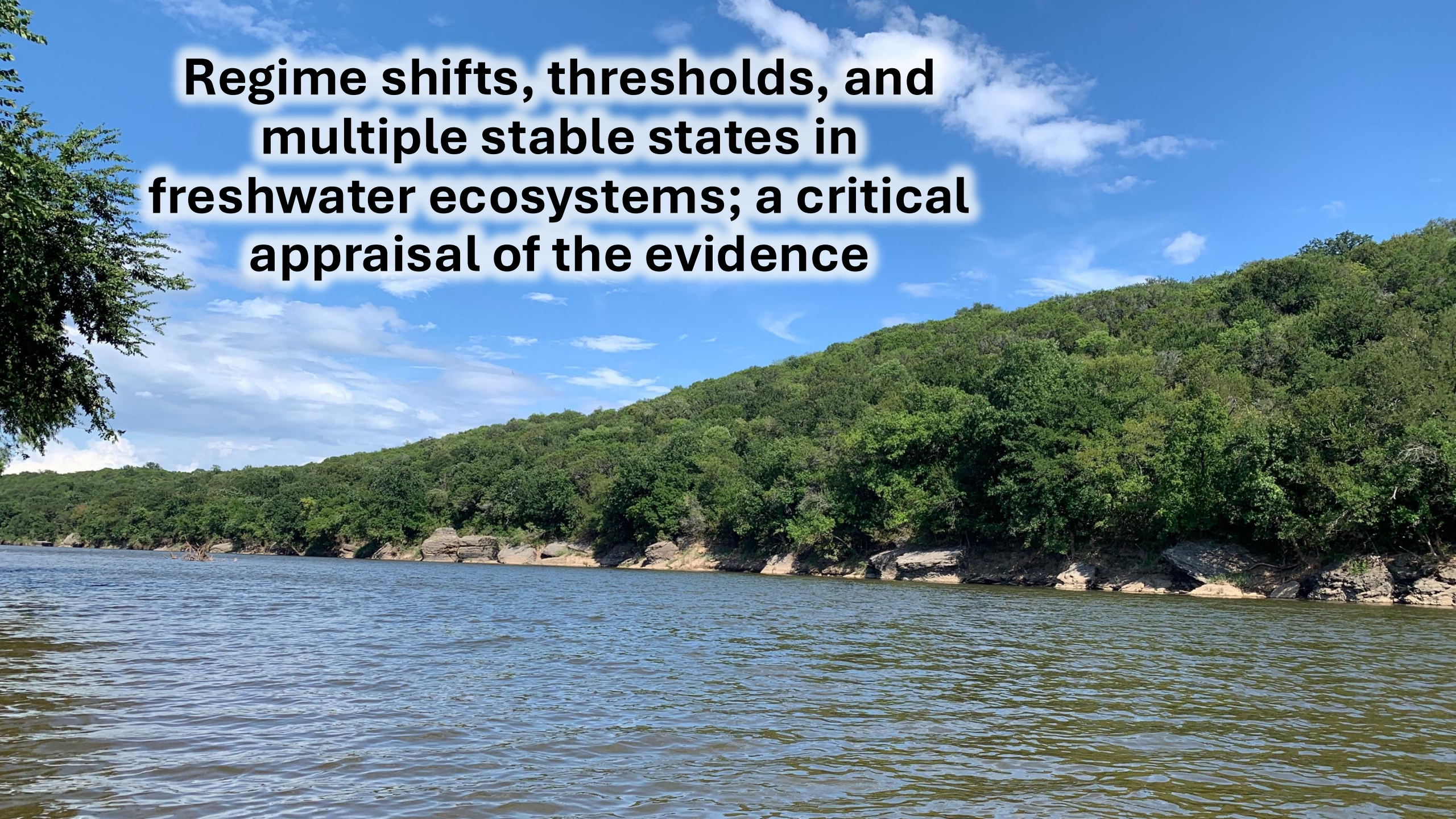


**Regime shifts, thresholds, and
multiple stable states in
freshwater ecosystems; a critical
appraisal of the evidence**



Terminology

- **Lotic**
- Lentic
- Oligotrophic
- Eutrophic



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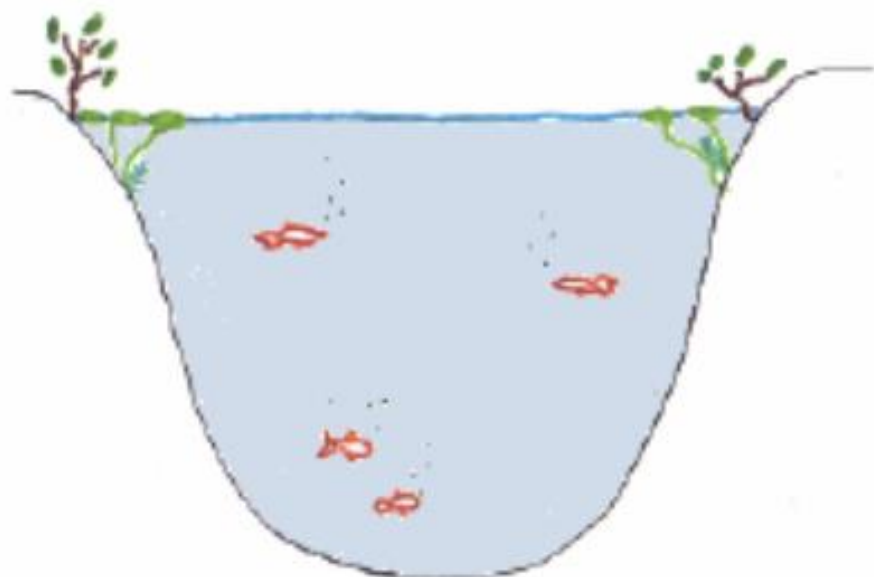


Terminology

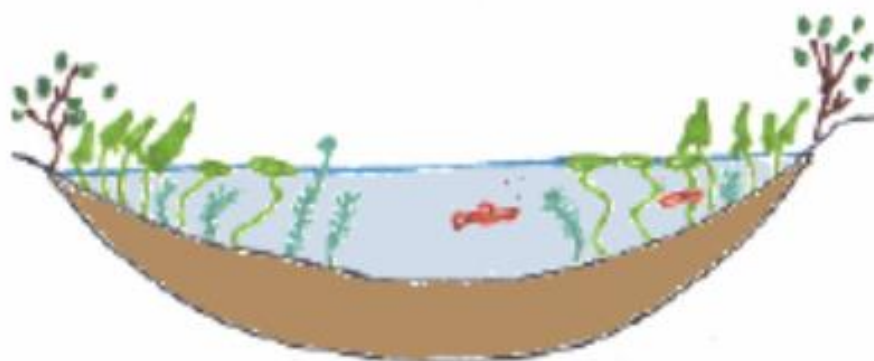
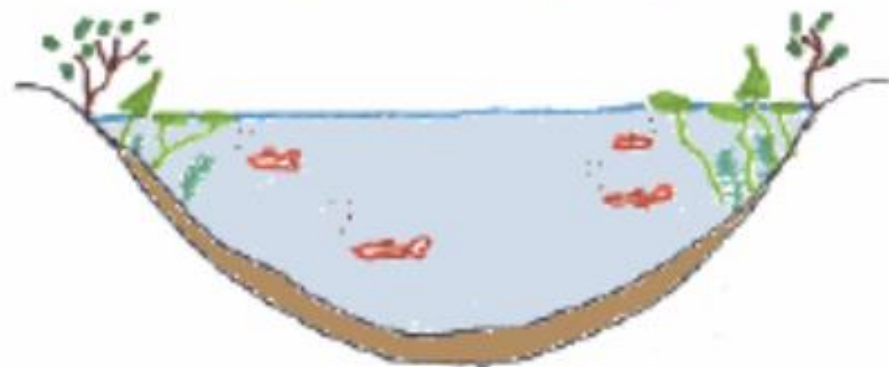
- Lotic
- Lentic
- Oligotrophic
- **Eutrophic**



OLIGOTROPHIC LAKE
(young)



MESOTROPHIC LAKE
(middle-aged)



EUTROPHIC LAKE
(old)



LAKE COMPLETELY FILLED-IN
(dead)

Impediments

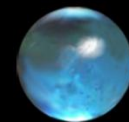
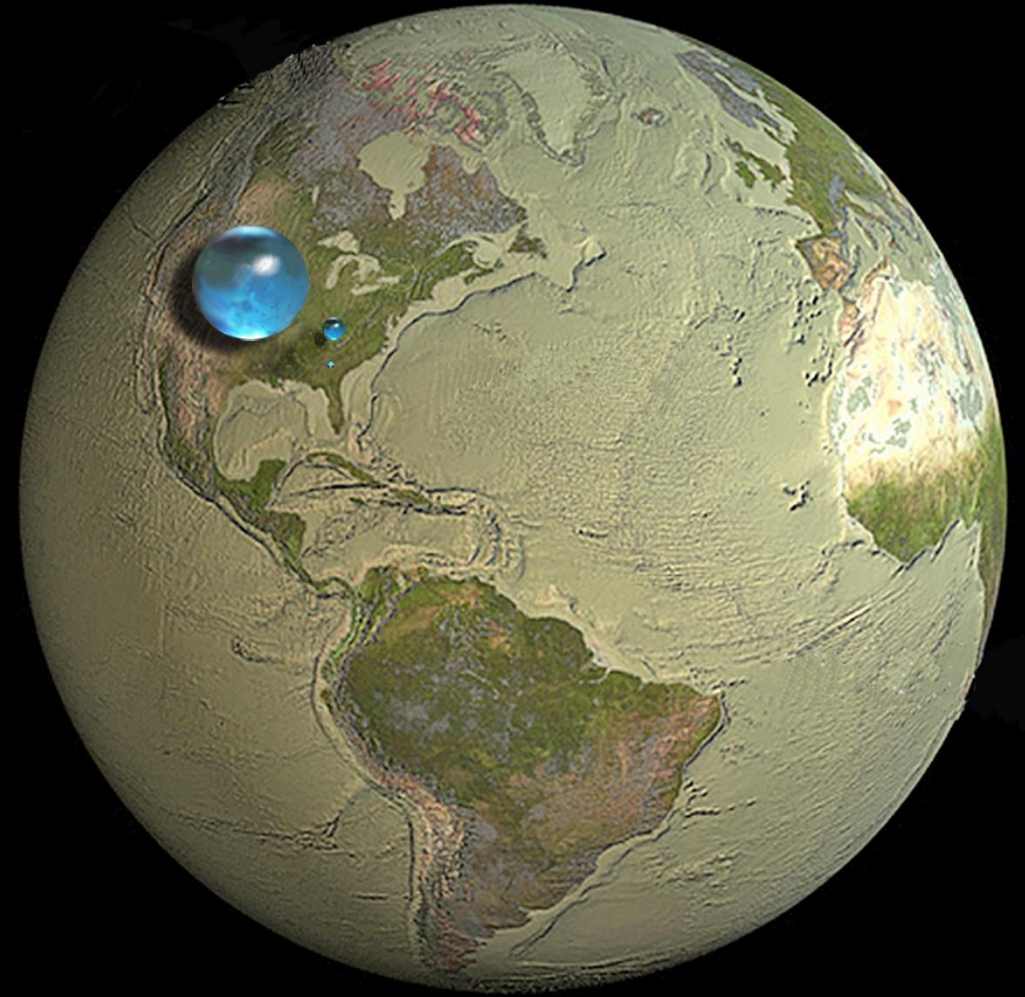
- Terminological proliferation and inconsistency
- Inadequacy of the temporal and spatial resolution and scope of datasets for evaluating change in relation to the range of system variability
- Insufficient demonstration of mechanistic links between pressures and consequent ecological change



Why freshwater?

- Cover 0.8% of earth's surface

The World's Water



All water on, in, and above the Earth



Liquid fresh water



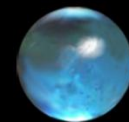
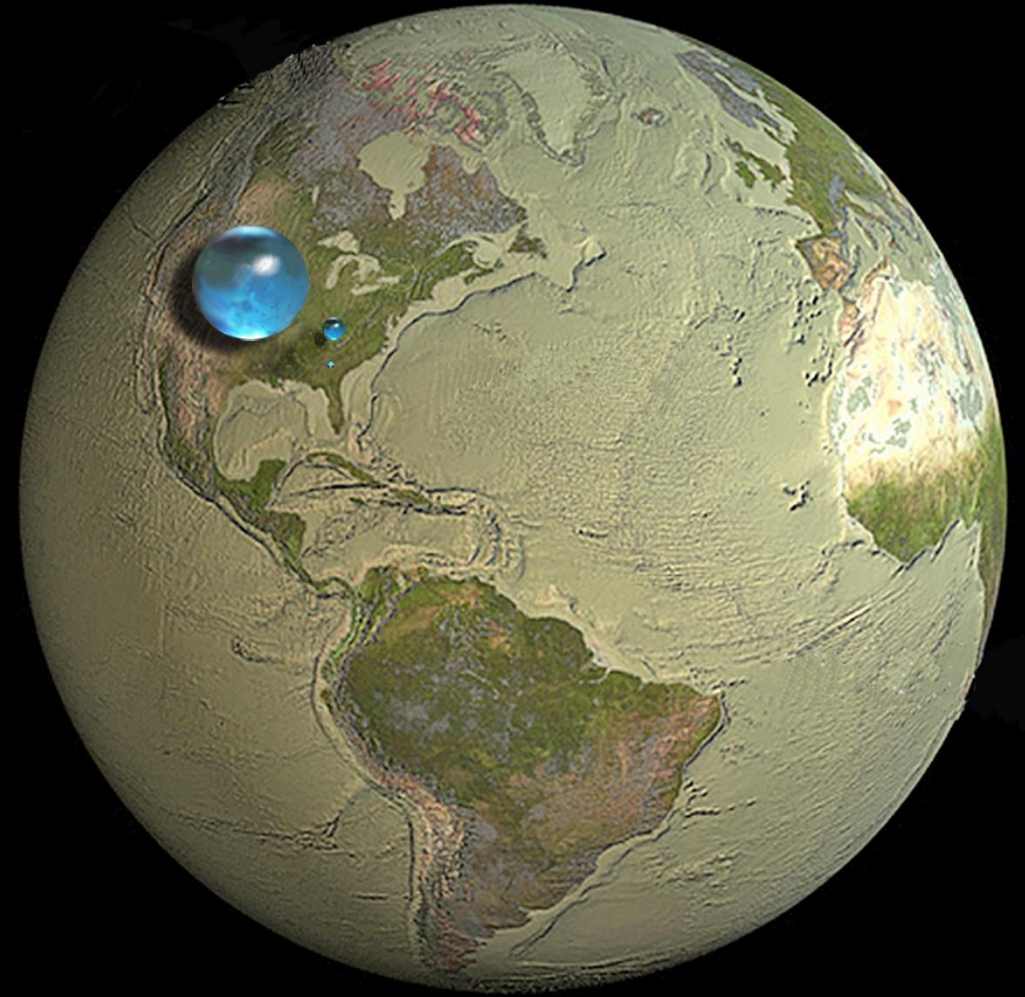
Fresh-water lakes and rivers

Howard Perlman, USGS,
Jack Cook, Woods Hole Oceanographic Institution,
Adam Nieman
Data source: Igor Shiklomanov
<http://ga.water.usgs.gov/edu/earthhowmuch.html>

Why freshwater?

- Cover 0.8% of earth's surface
 - 12% of all species
 - 33% of vertebrates

The World's Water



All water on, in, and above the Earth

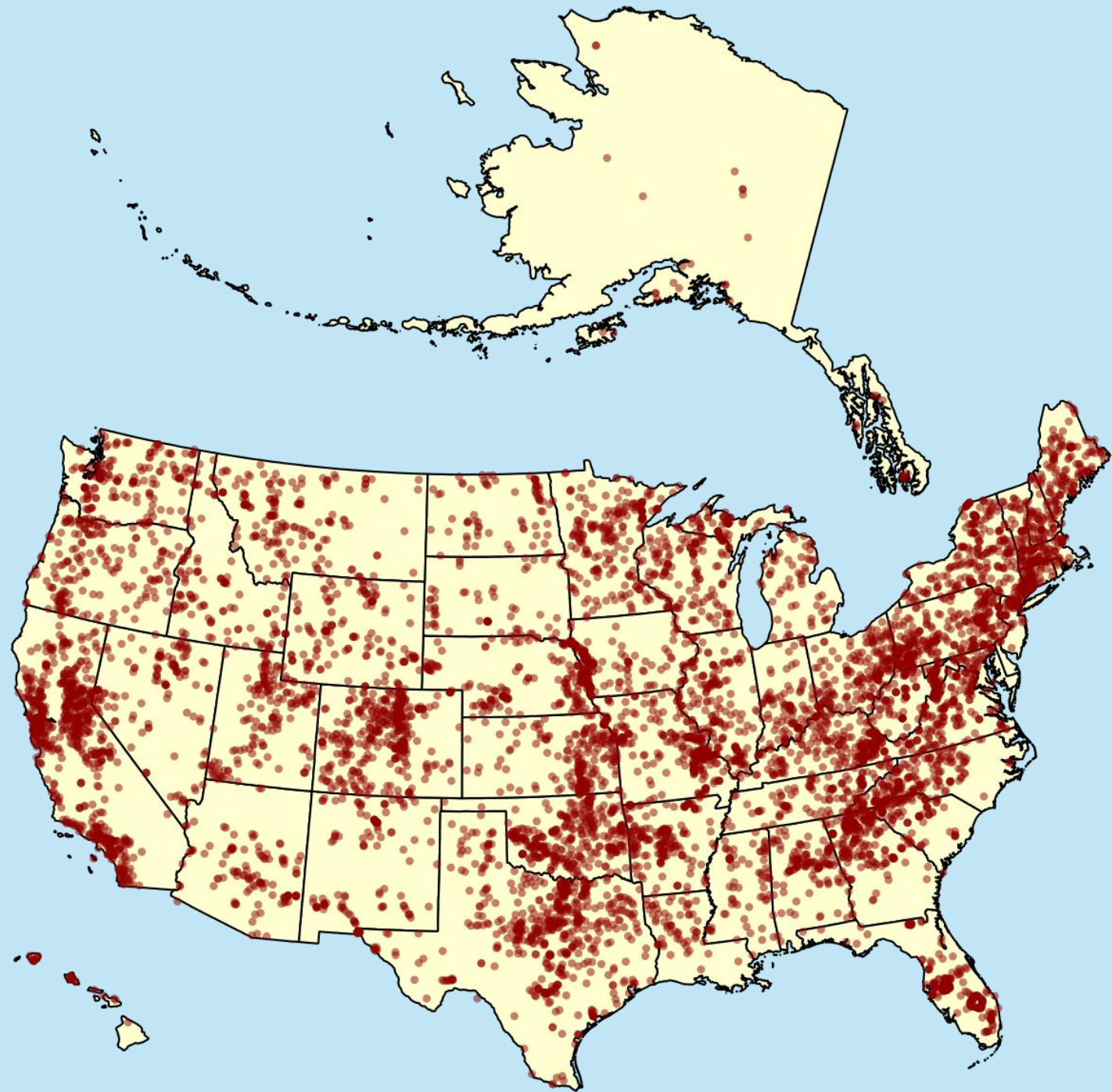


Liquid fresh water



Fresh-water lakes and rivers

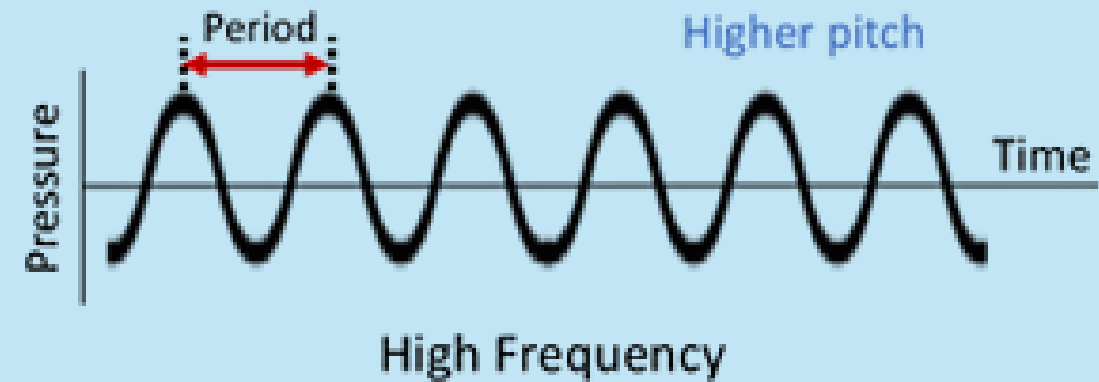
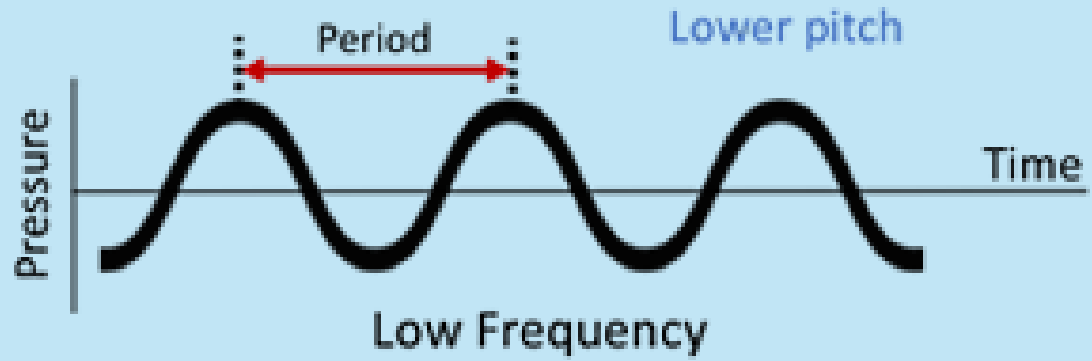
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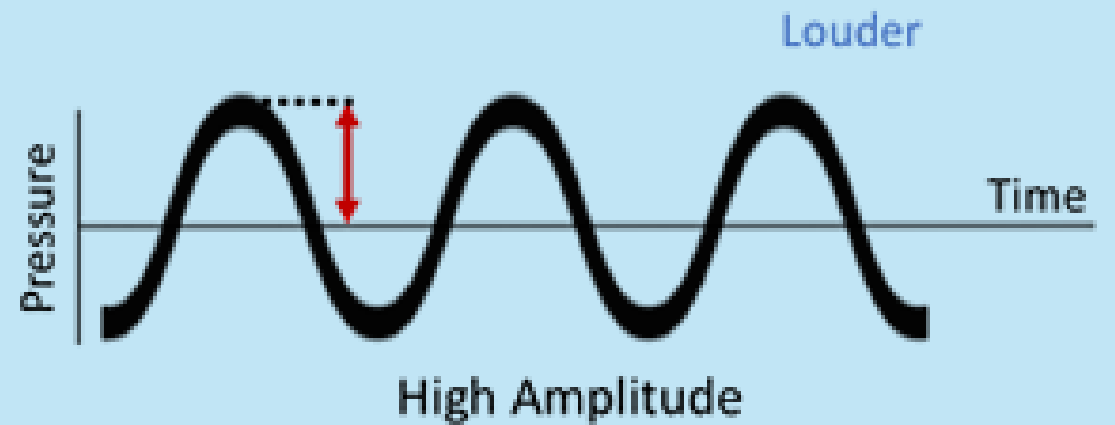
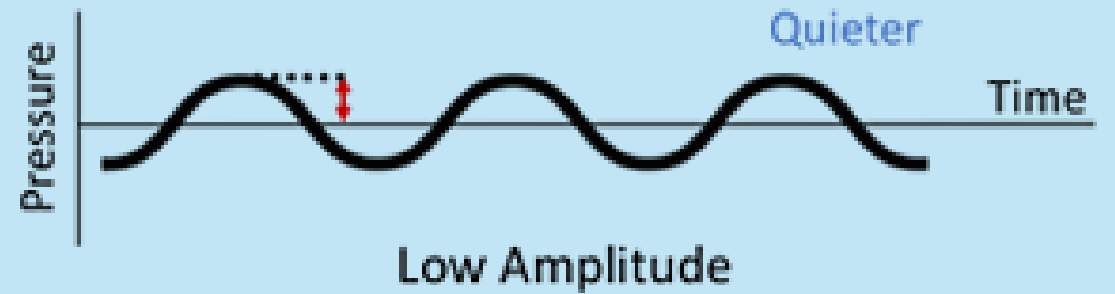
Defining characteristics of regime shifts

- Sudden and abrupt
- Involve change in both physical & biological components
- Embody ecological change across multiple trophic levels
- Occur with high amplitude but low frequency

Frequency



Amplitude



Peterson criteria

- “All published claims of the existence of multiple stable points fail in rigorous reexamination for one of three reasons:
 - The physical environment is different in the different alternative states
 - Continued application of artificial, external controls is necessary to maintain at least one of the (two) alternative states
 - The evidence is inadequate, often because of inappropriate temporal and/or spatial scales”

Response to Peterson criteria

- “The time series of data for the response variable must be long enough to allow detection of a change point and to distinguish pressure-induced changes from “normal” or historical variability”
- “A corresponding time series is required for one or more putative anthropogenic (or natural) pressures to statistically relate to the change point”

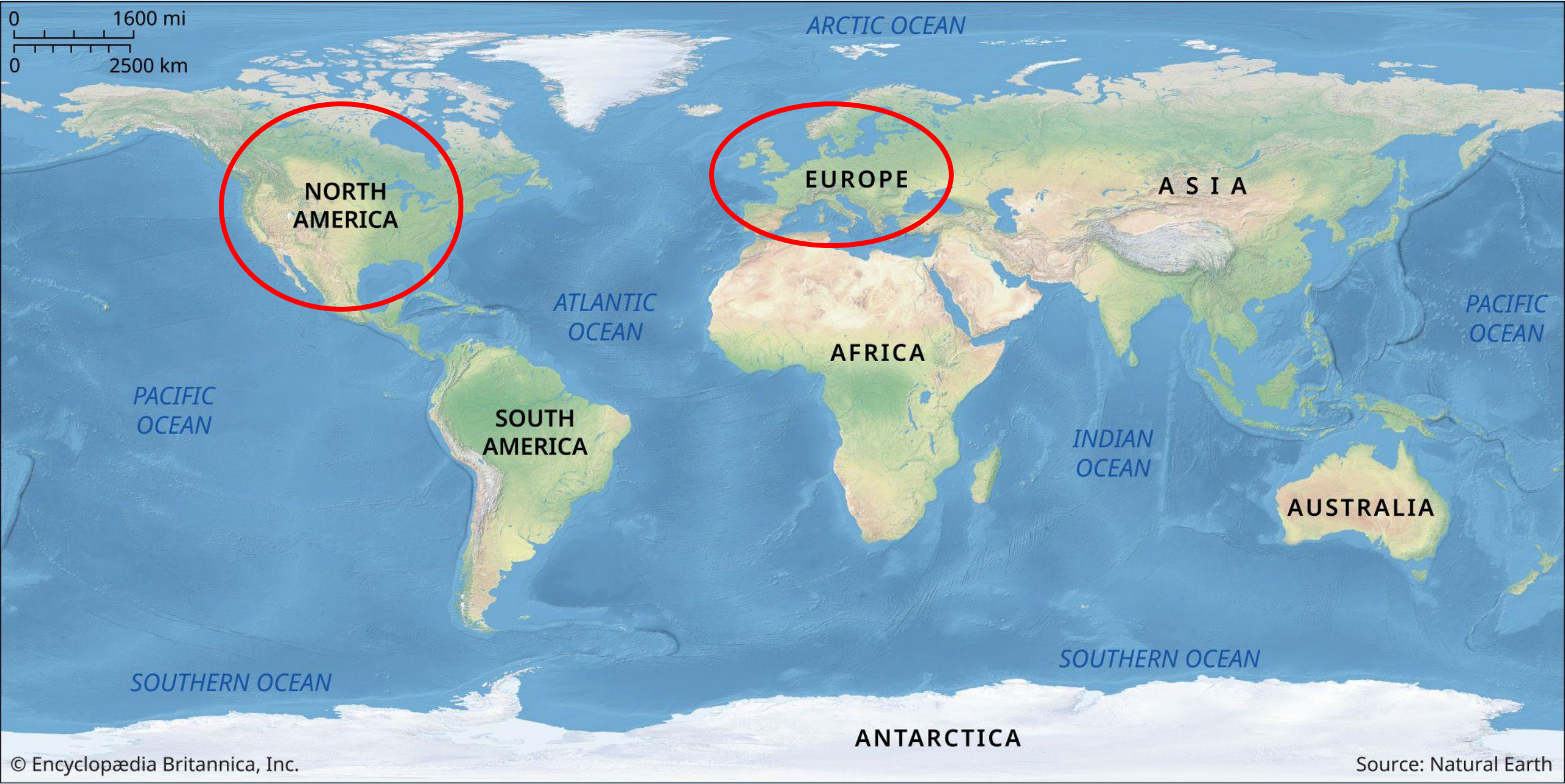
Results

- > 80% permanent freshwater systems
- Macroinvertebrates, macrophytes, & phytoplankton
- > 56% focused on a sole, single pressure type
- Why?

Results

- “Few studies demonstrated the maintenance of alternative stable state if nutrient loads were once again reduced”
 - Shallow lakes in Canada switched between states in successive years
- Water chemistry, top-down control
- Contribution of macrophytes
 - Germination/regeneration vs spread
 - Different pressures

0 1600 mi
0 2500 km



Effects of habitat



Effects of habitat



Effects of focal taxa



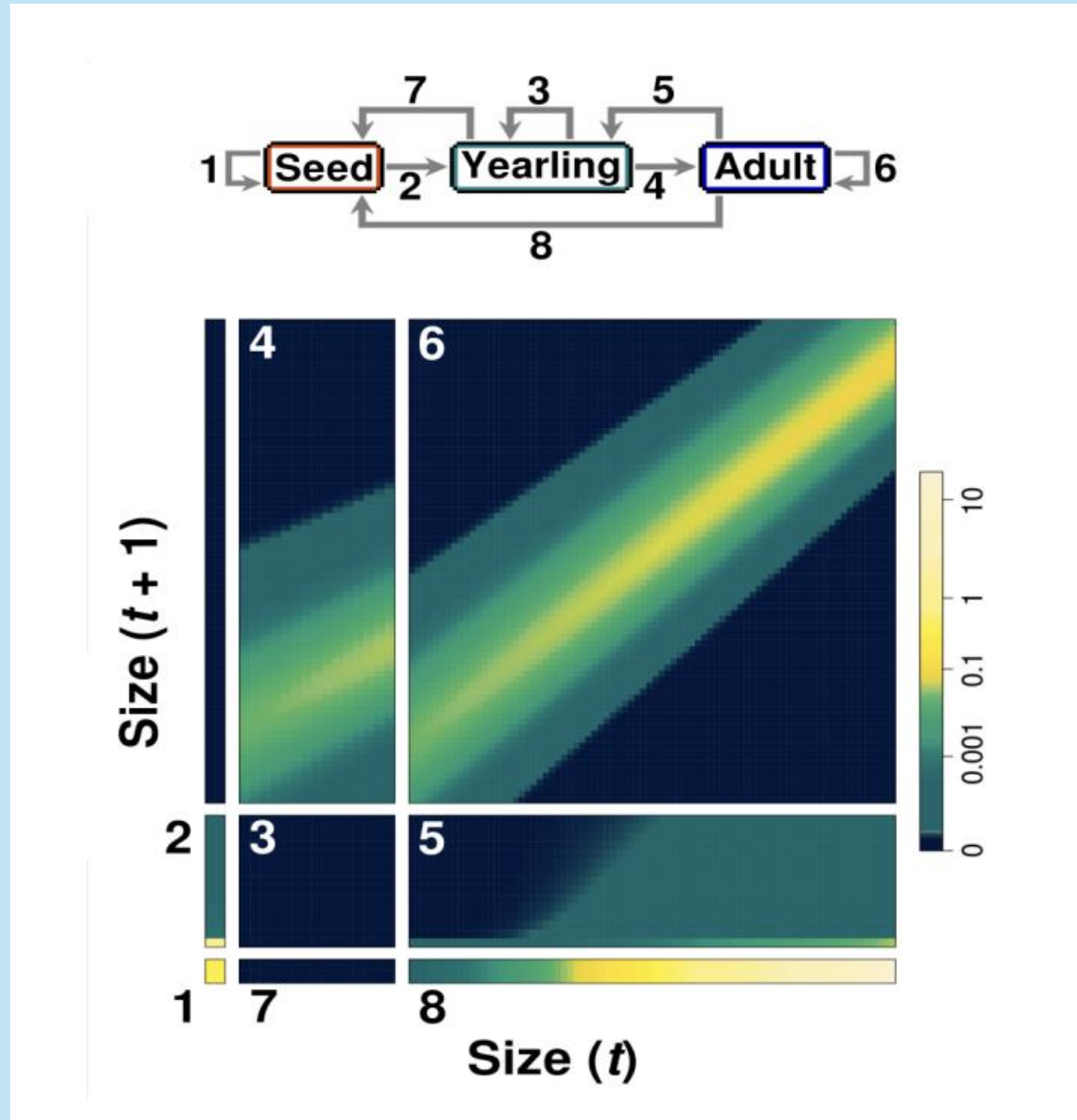
Effects of focal taxa



Effects of focal taxa



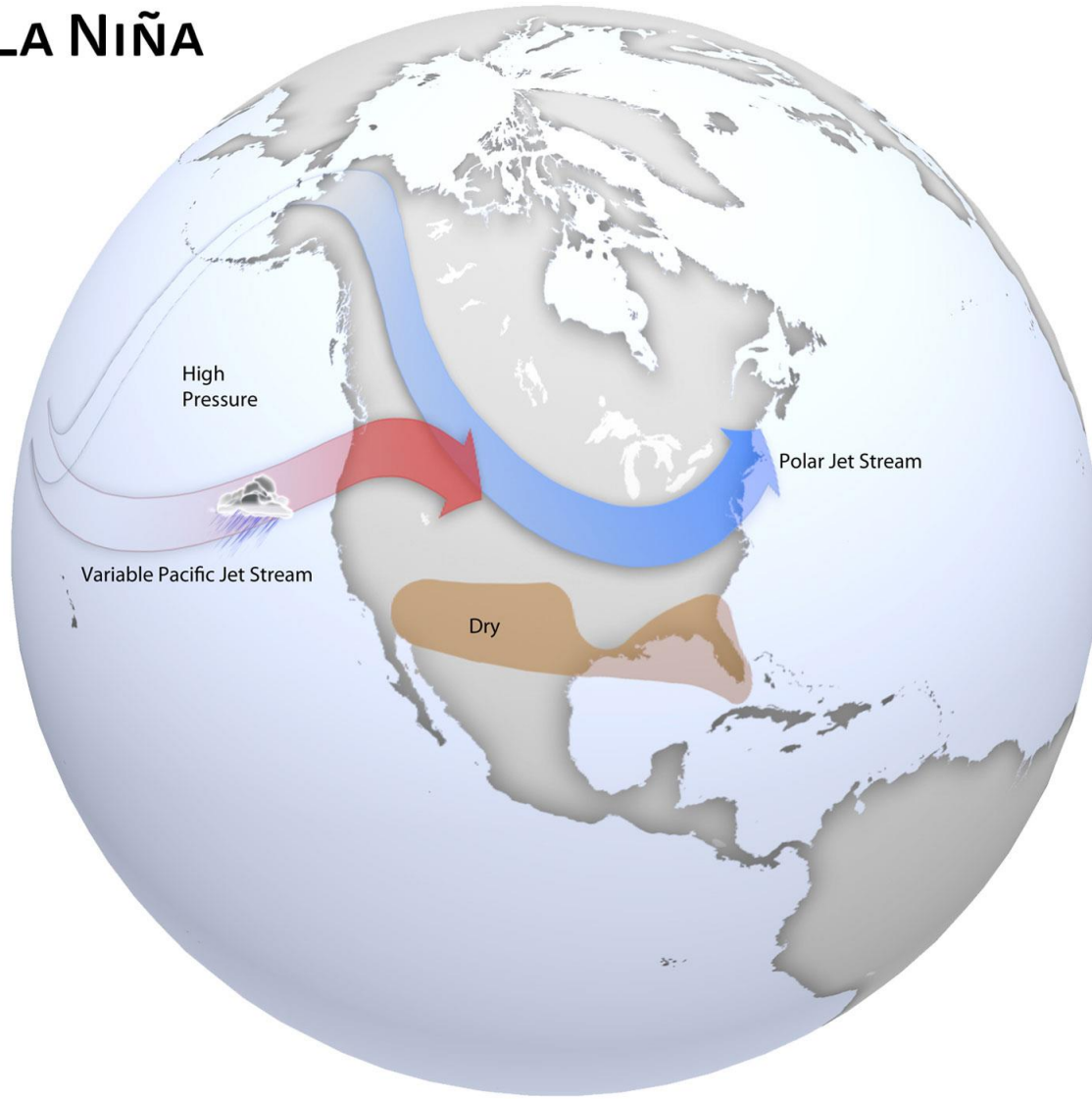
Effects of life-history stages



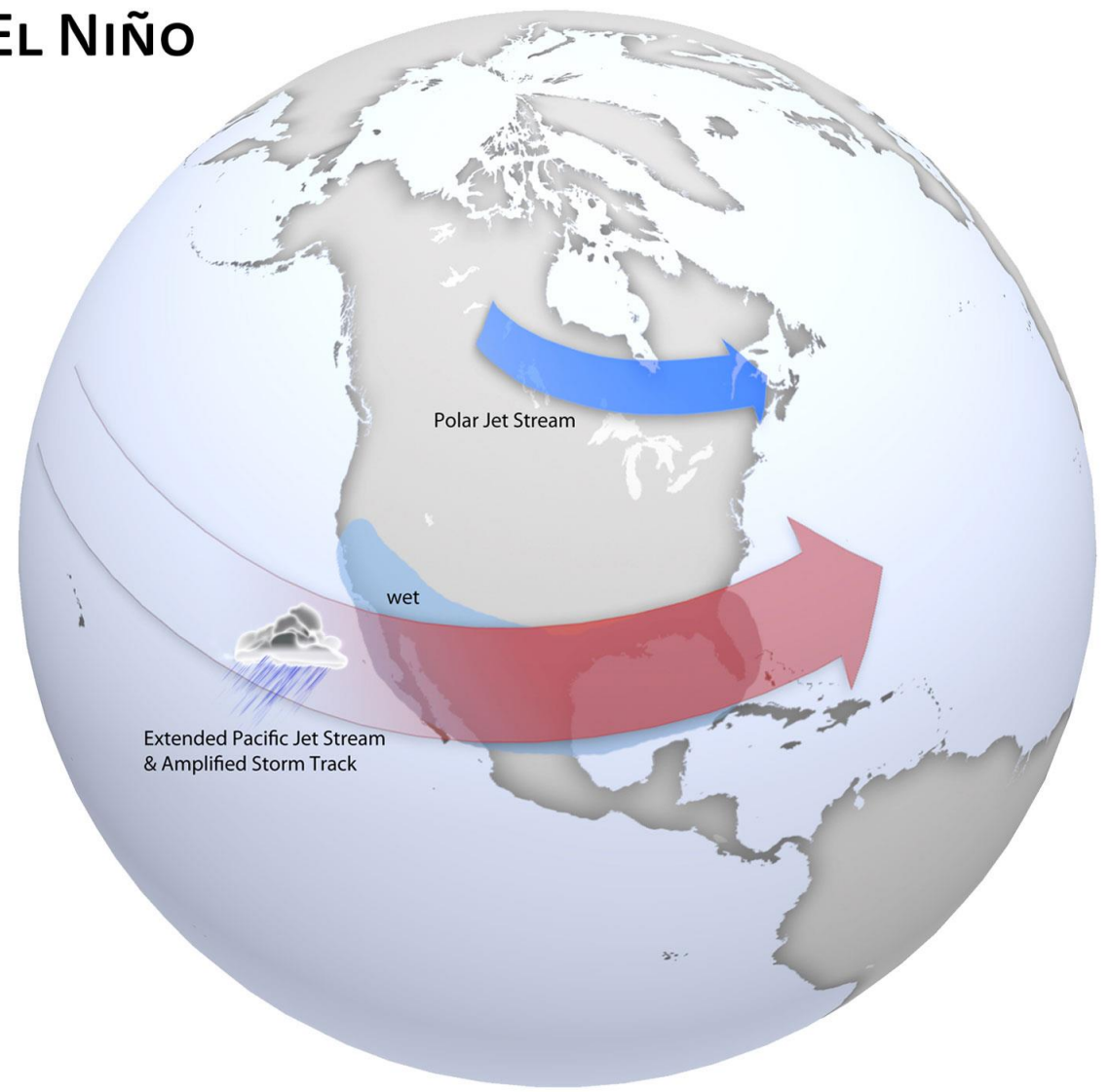
López-Borghesi et al. 2023. Leveraging projection models to evaluate long-term dynamics of scrub mint translocations. Conservation Science and Practice e12947.

Effects of stochasticity

LA NIÑA



EL NIÑO



What now?

- “...this theory implies that great improvements in ecological conditions might be achieved with relatively small reductions in anthropogenic pressures”
- “...if gradual, monotonic changes are the norm, then ecological objectives may only be achieved only with reductions in human pressures commensurate to the degree of change desired”