Quantifying ecological responses to flow alteration: a literature review

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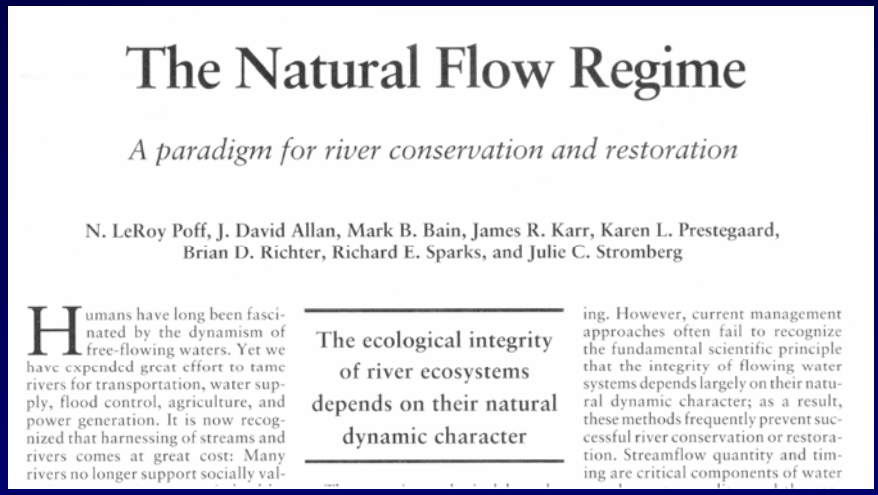


The Natural Flow Regime

A paradigm for river conservation and restoration

N. LeRoy Poff, J. David Allan, Mark B. Bain, James R. Karr, Karen L. Prestegaard, Brian D. Richter, Richard E. Sparks, and Julie C. Stromberg

Humans have long been fascinated by the dynamism of free-flowing waters. Yet we have expended great effort to tame rivers for transportation, water supply, flood control, agriculture, and power generation. It is now recognized that harnessing of streams and rivers comes at great cost: Many rivers no longer support socially valing. However, current management approaches often fail to recognize the fundamental scientific principle that the integrity of flowing water systems depends largely on their natural dynamic character; as a result, these methods frequently prevent successful river conservation or restoration. Streamflow quantity and timing are critical components of water

The ecological integrity of river ecosystems depends on their natural dynamic character

BioScience 1997

Ample evidence for ecological consequences of flow alteration

Can we develop quantitative relationships that can be applied generally (i.e., unmonitored sites?)

Are there thresholds?

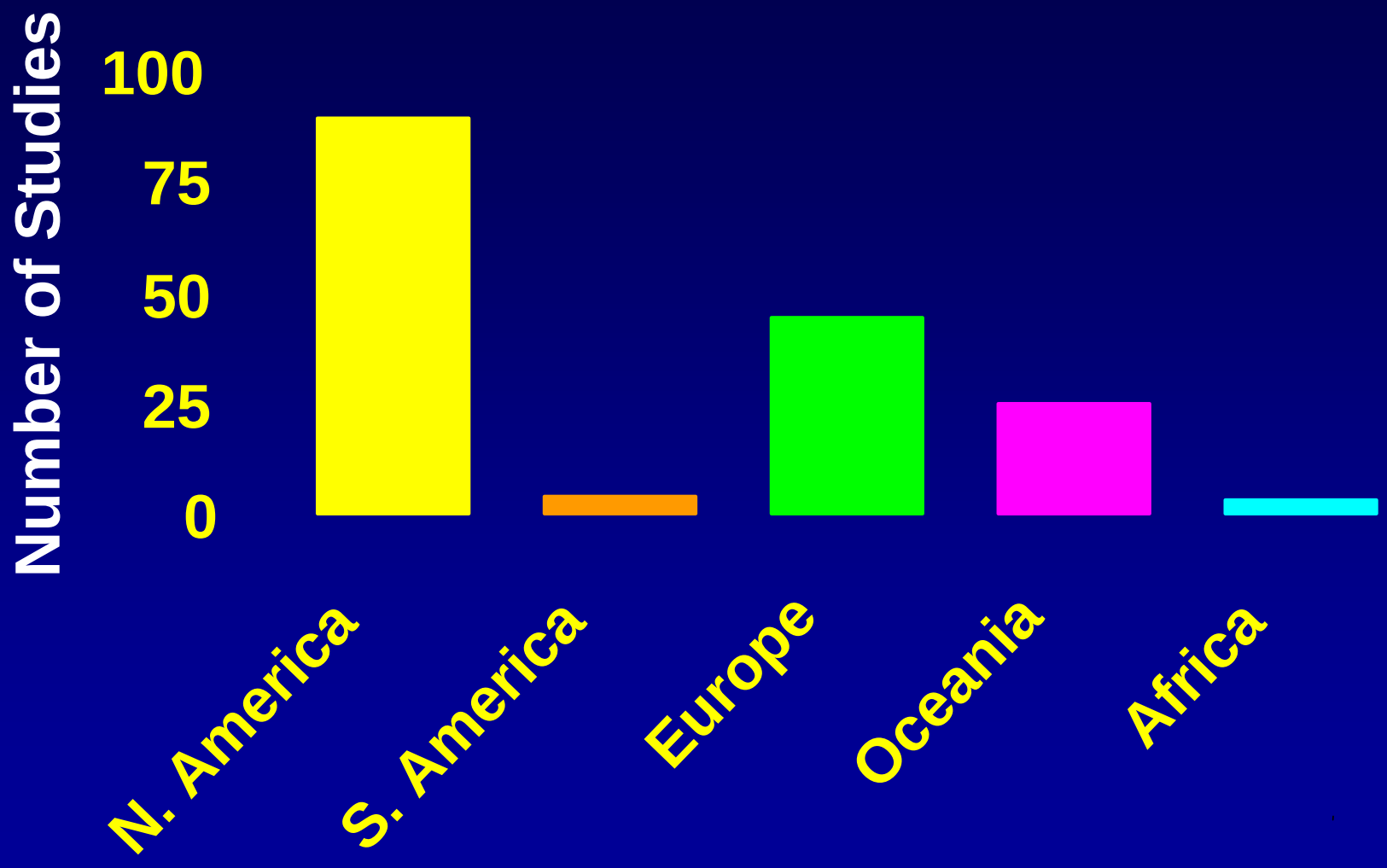
Literature Review

165 published papers … mostly published in last 10 years

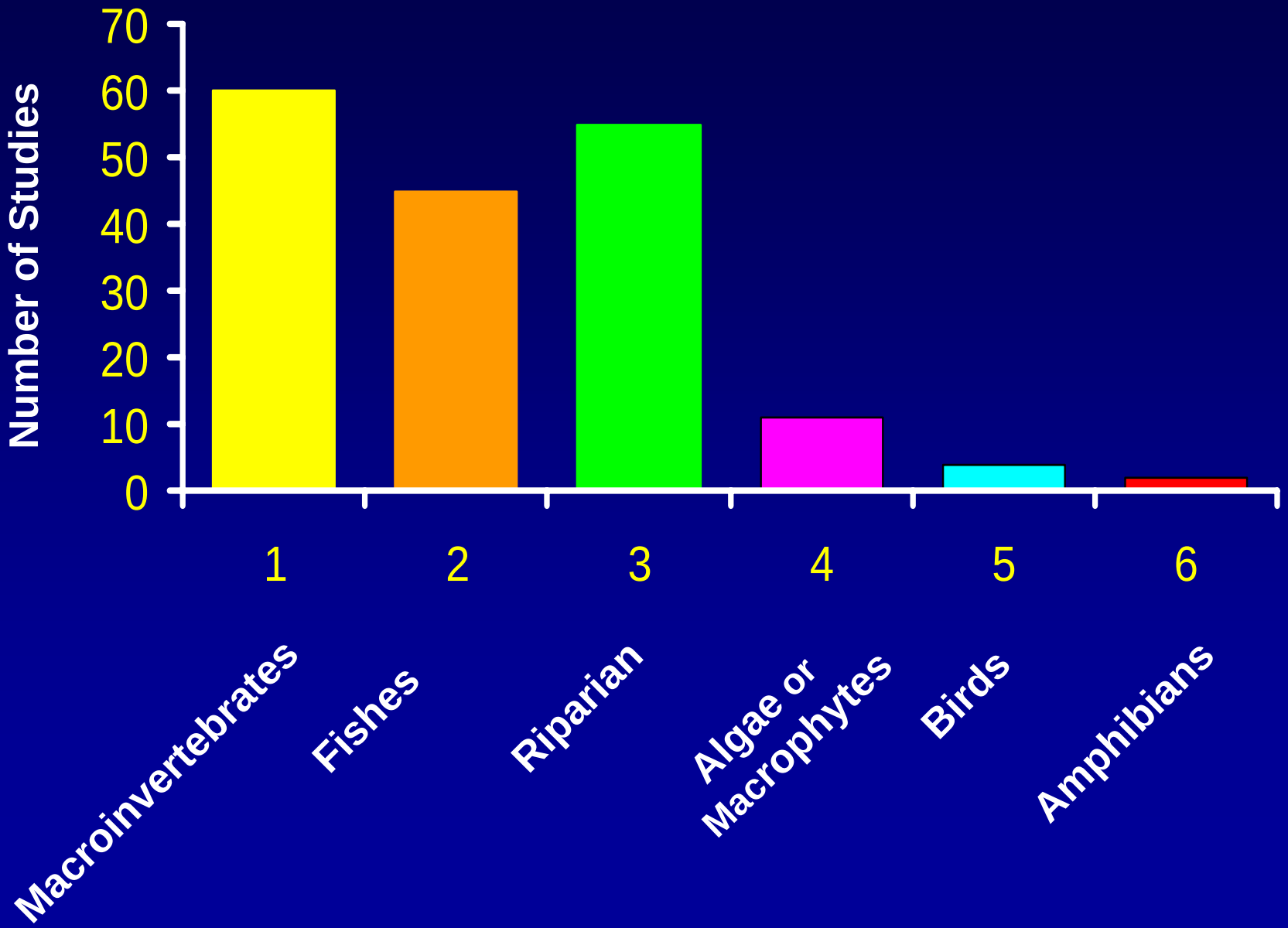
Characterized by:

- Type of flow alteration
- Ecological response
  - Diversity/Ecosystem function
  - Flora/fauna
  - Channel/floodplain
- Source of flow alteration
  - Dams, diversion, groundwater pumping

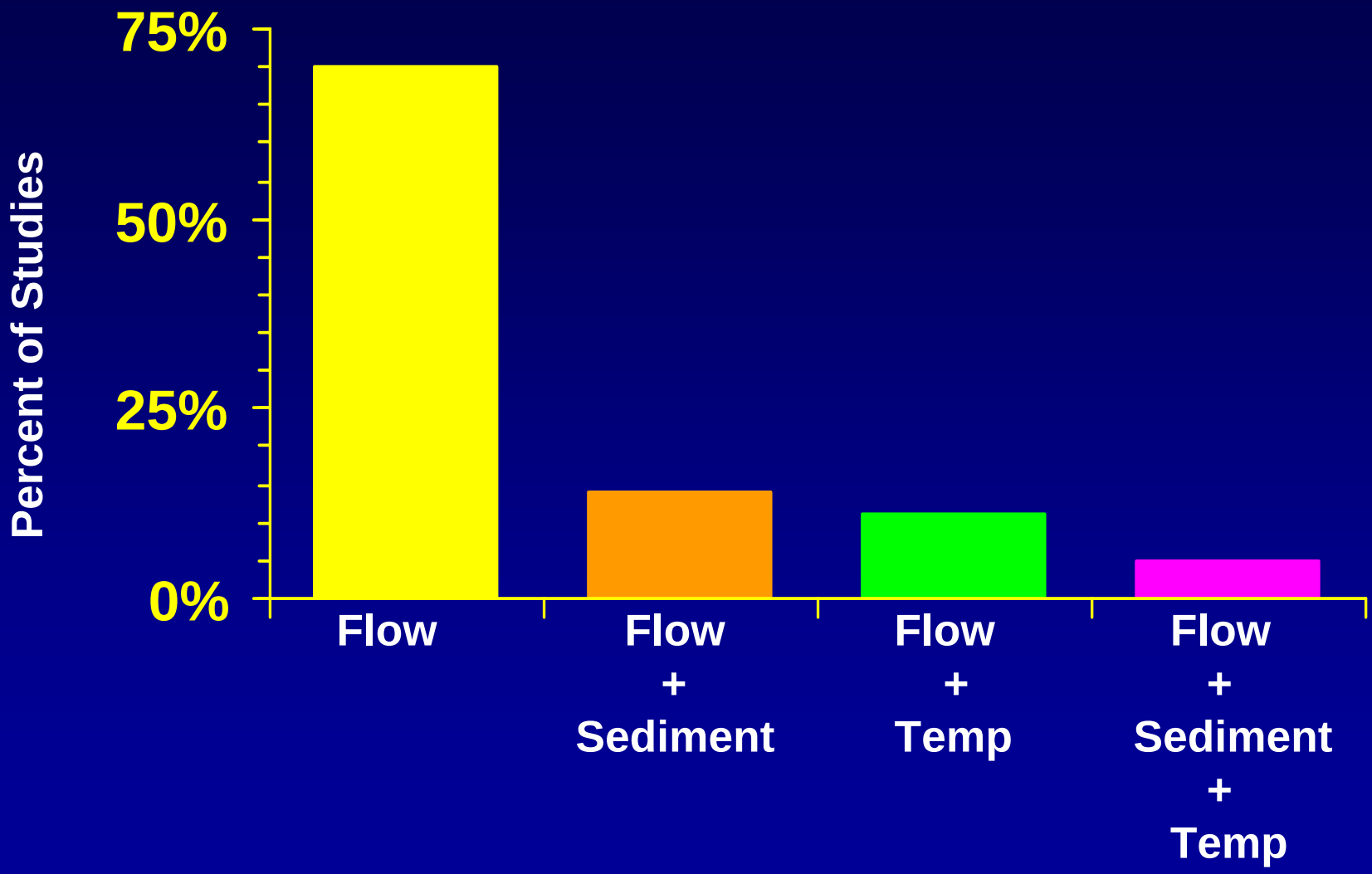
Geographic Distribution of Studies on Flow Alteration



Ecological Responses



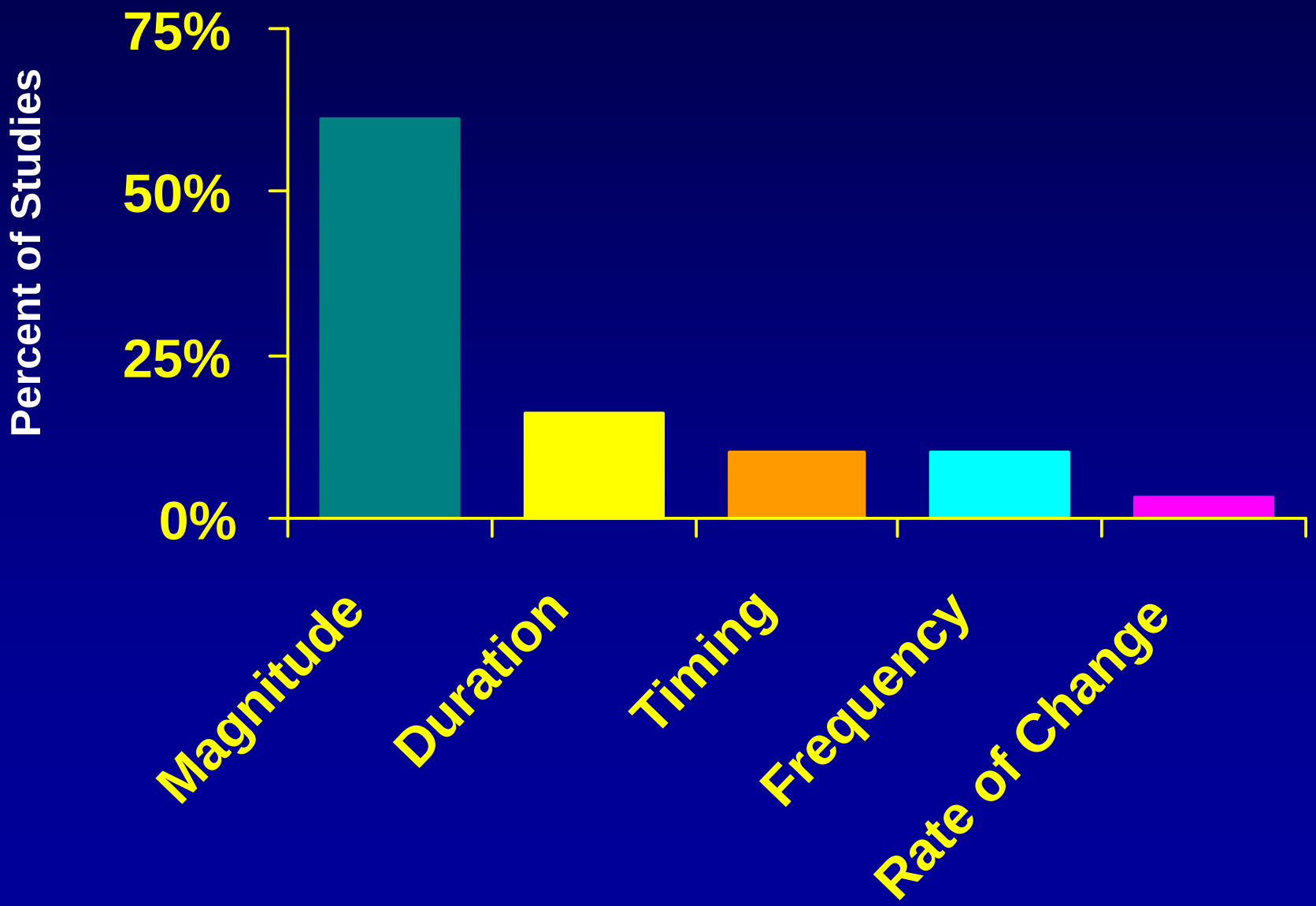
Environmental Drivers



Ecologically Relevant Components of the Flow Regime

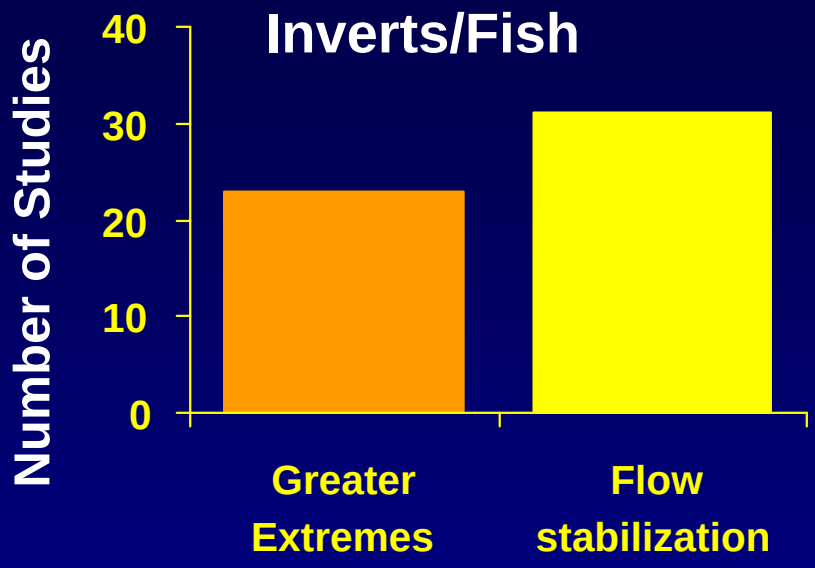
- ***Magnitude*** **of discharge**
- ***Frequency*** **of occurrence**
- ***Duration*** **of a given flow condition**
- ***Timing*** **or *Predictability* of flows**
- ***Rate of Change*** **or *Flashiness* of flows**

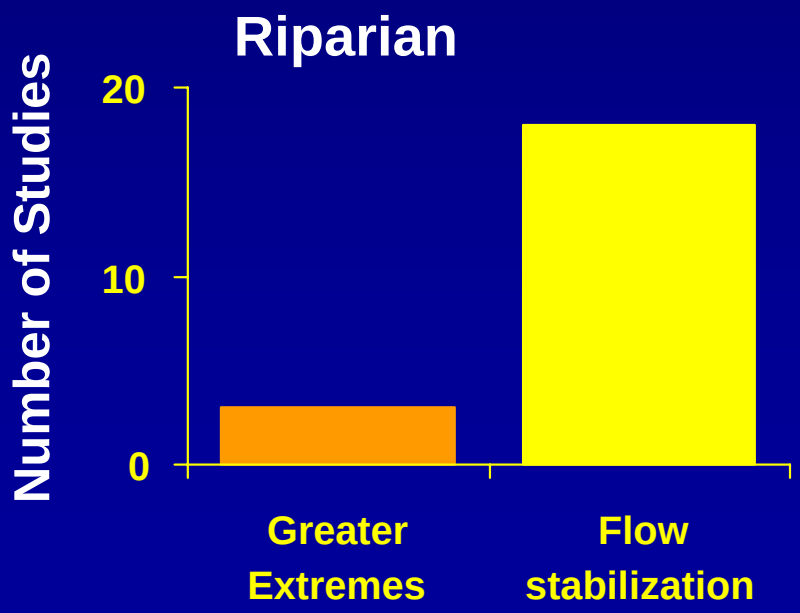
Flow components



Part 1. Qualitative Results

Magnitude of Flow (61%)





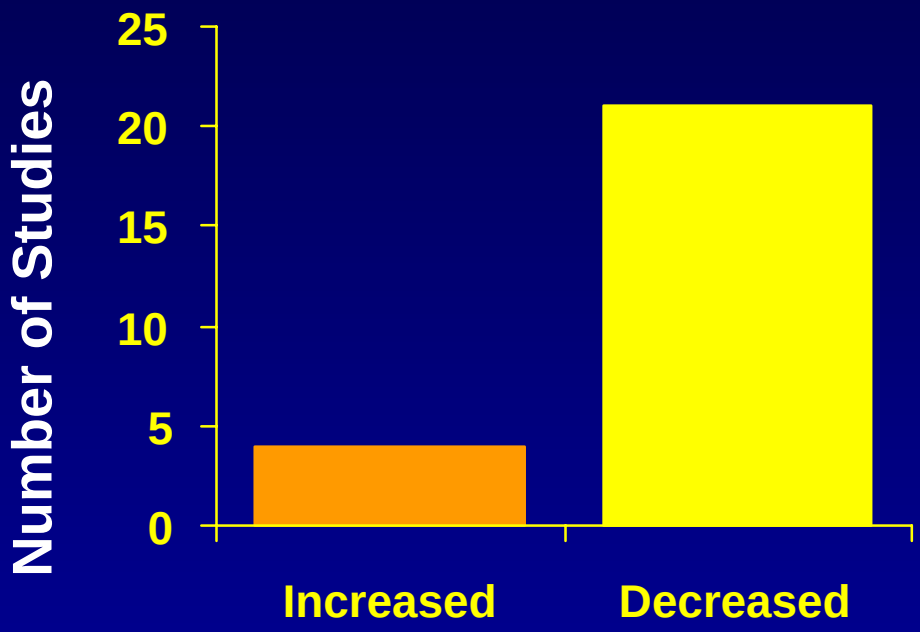
Within-channel responses:

- *Loss sensitive species*
- *Reduced diversity*
- *Invasives*

Riparian responses:

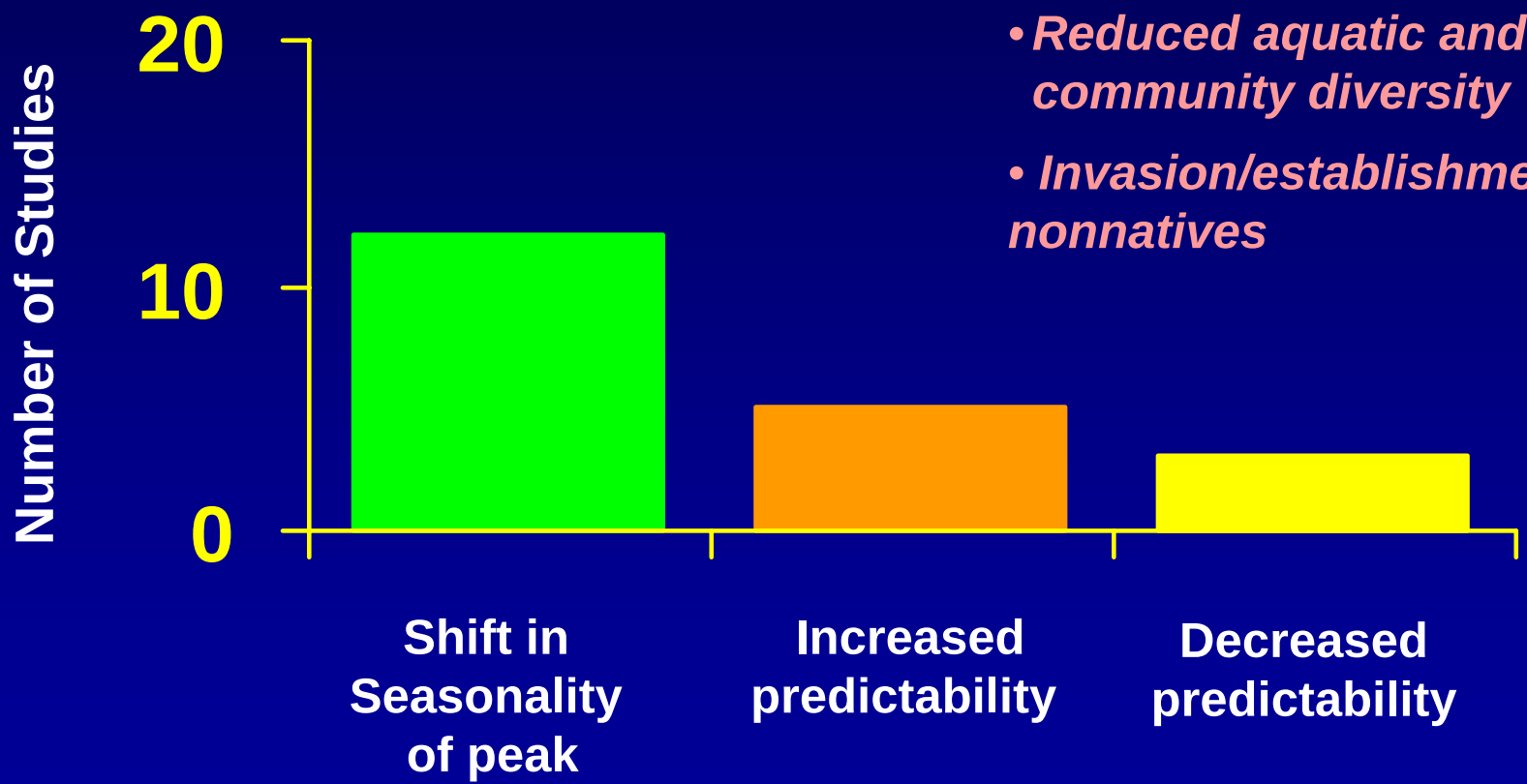
- *Altered recruitment*
- *Nonnative success*

Duration of Floodplain Inundation (16%)



- *Terrestrialization of riparian and wetland communities*
- *Reduced biomass aquatic organisms*
- *Loss of floodplain-dependent fish species; shift in assemblage structure*

Timing of Flow (10%)



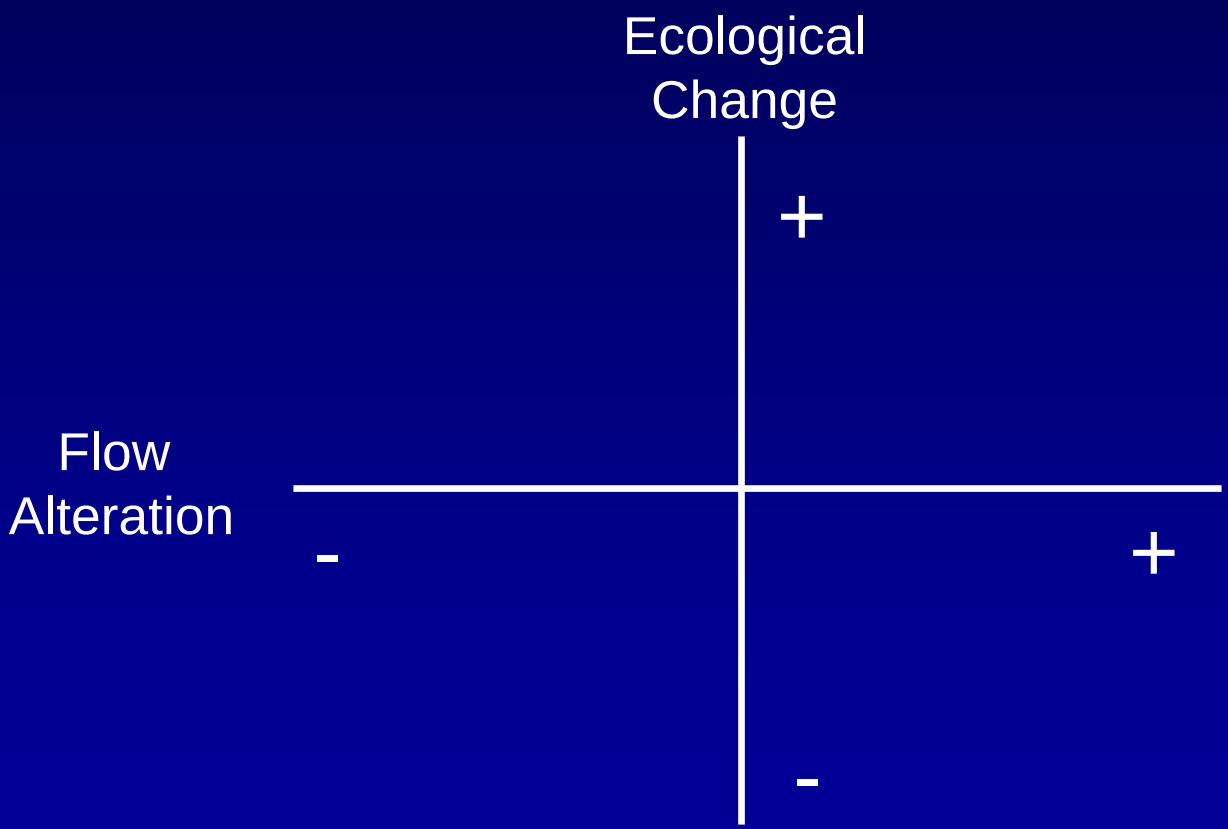
- *Disrupt life cycle cues*
- *Reduced aquatic and riparian community diversity*
- *Invasion/establishment of nonnatives*

What can we conclude from this qualitative analysis?

Further demonstration of the ecological consequences of flow alteration

Interactions among many drivers (e.g., flow, temperature, sediment) not reported in literature)

Part 2. Quantitative Results



Calculation of Flow Alteration (Magnitude)

Includes any of 4 categories reported:

1) % change in discharge
2) % change in peak flow
3) % change in baseflow
4) % change in short-term variation

Calculation of Ecological Responses

% change relative to “reference”

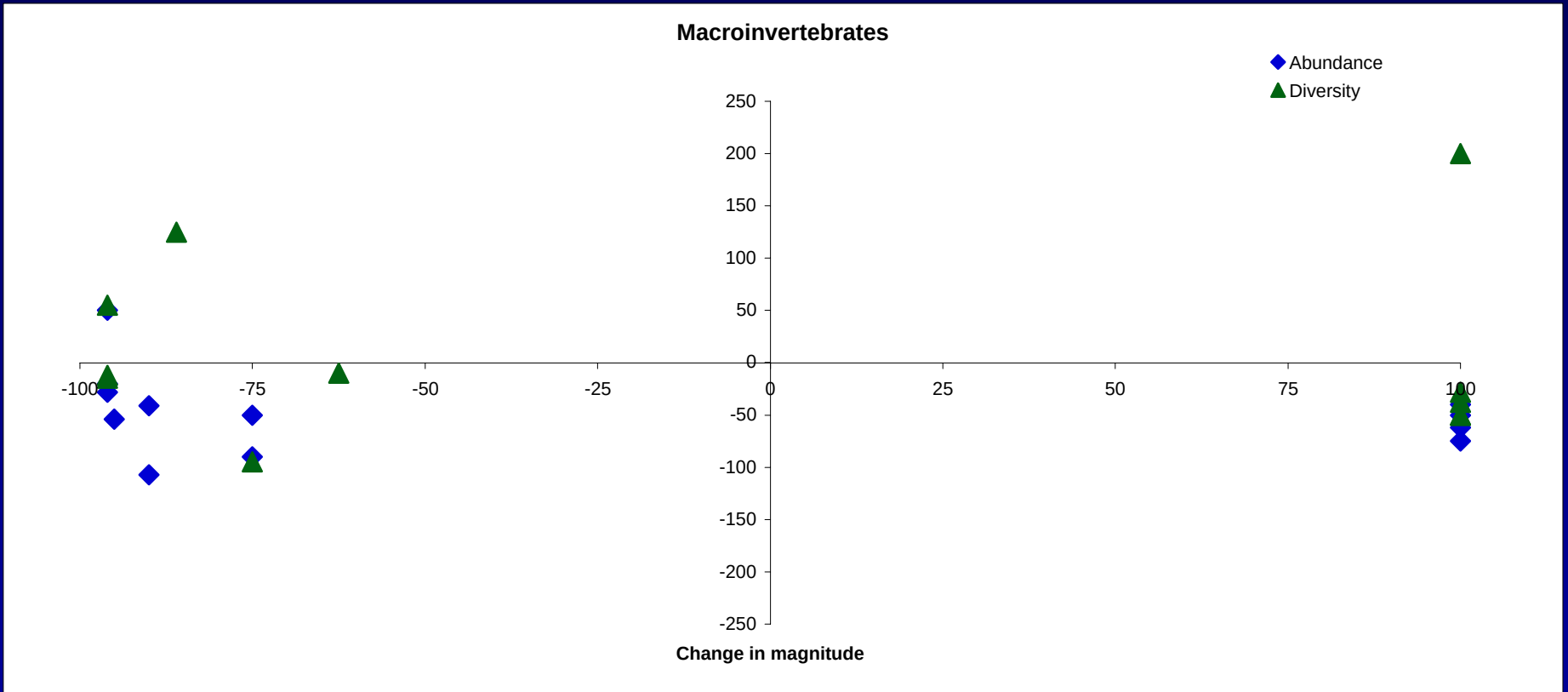
(before/after; upstream/downstream)

1) Macroinvertebrates, Fish, Riparian
2) Abundance, Demographic, Diversity

N = 34 studies

Quantitative Results

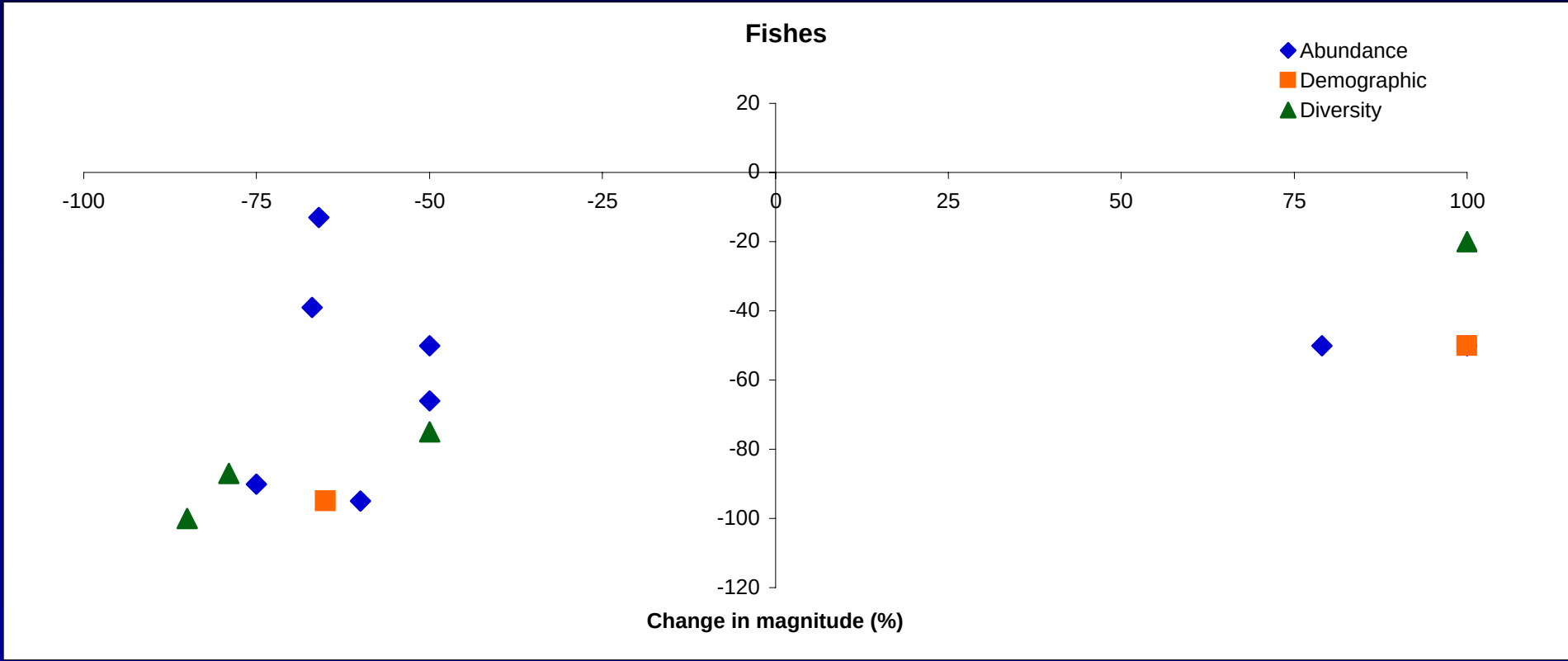
Macroinvertebrates



Abundances reduced, Diversity variable

Quantitative Results

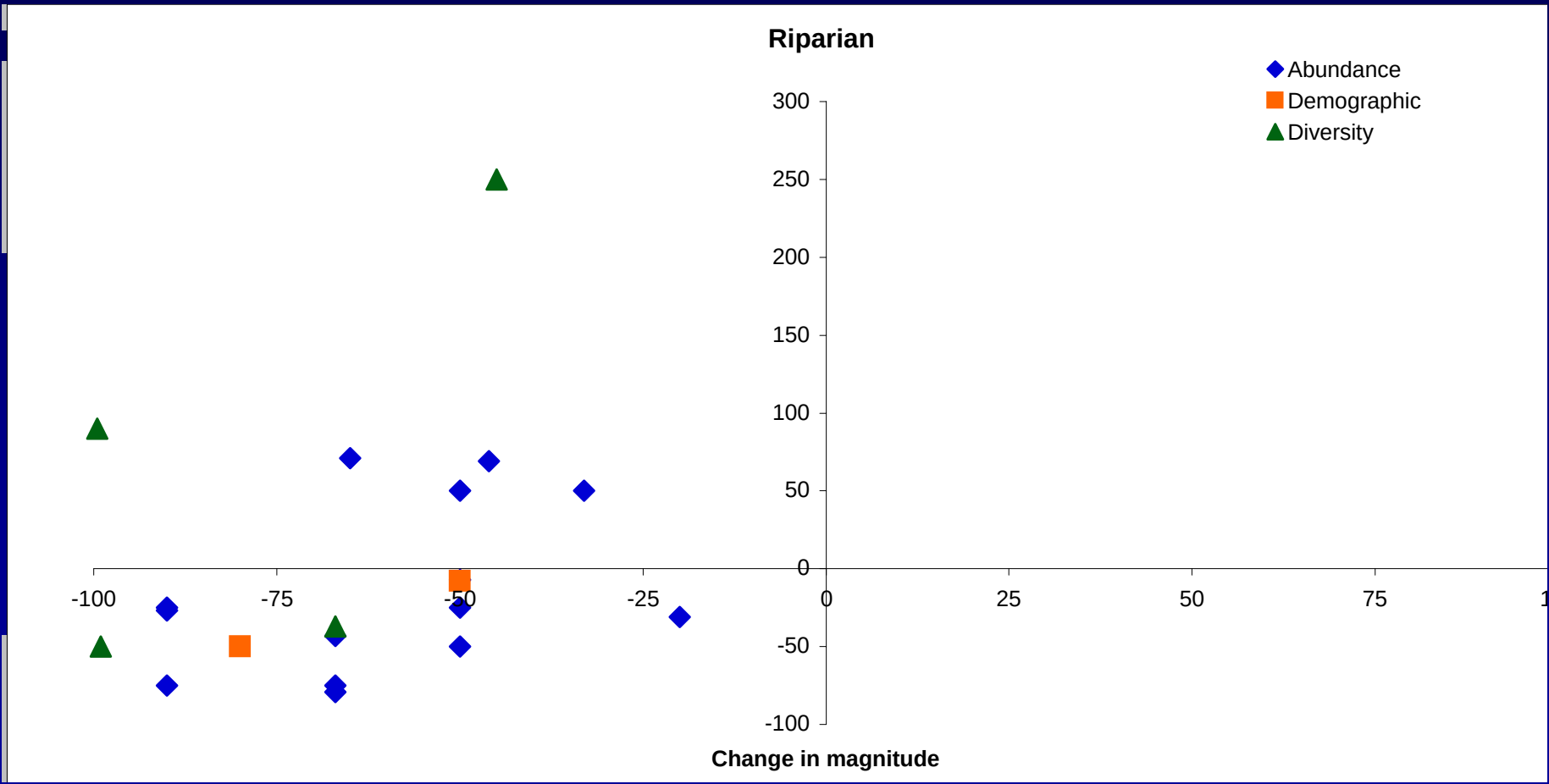
Fish



All responses negative

Quantitative Results

Riparian



Mixed responses

What can we conclude from this analysis?

General, quantitative patterns not strongly evident in data we were able to extract …

Why?

- Individual studies not designed to address our hypothesis.
- We have not separated tolerant or native species from others.
- Other, confounding variables not included (e.g., channel size, constraint, temperature, etc.).

Part 3. Qualitative Results

ELOHA-type approach for developing quantitative flow alteration - ecological relationships

For 108 gauged river sites across the USA

Developed 2 stream classes:

1) Snowmelt (9 reference, 22 regulated)
2) Perennial Runoff (33 reference, 44 regulated)

Estimated degree of alteration for each class

Hydrologic variables used:

1) 10 components of natural flow regime
2) Focus here 1-day maximum, 90-day minimum

Biological response variables -- *a priori* sensitive to flow alteration

1) Abundance in drift
2) Small size at maturity

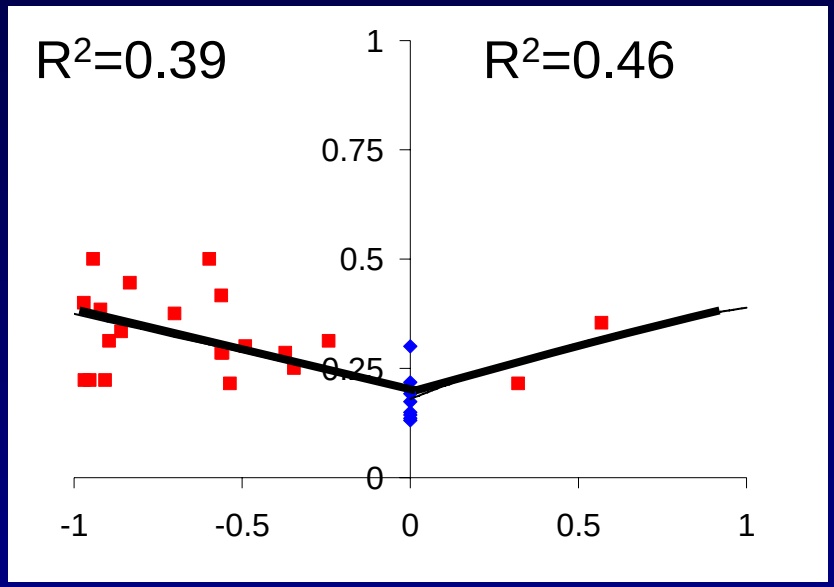
Abundant in drift

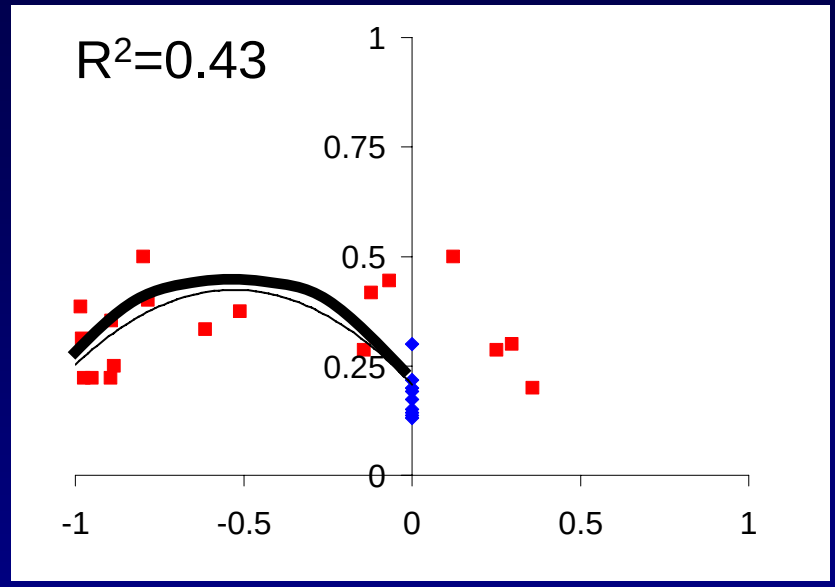
1-day maximum

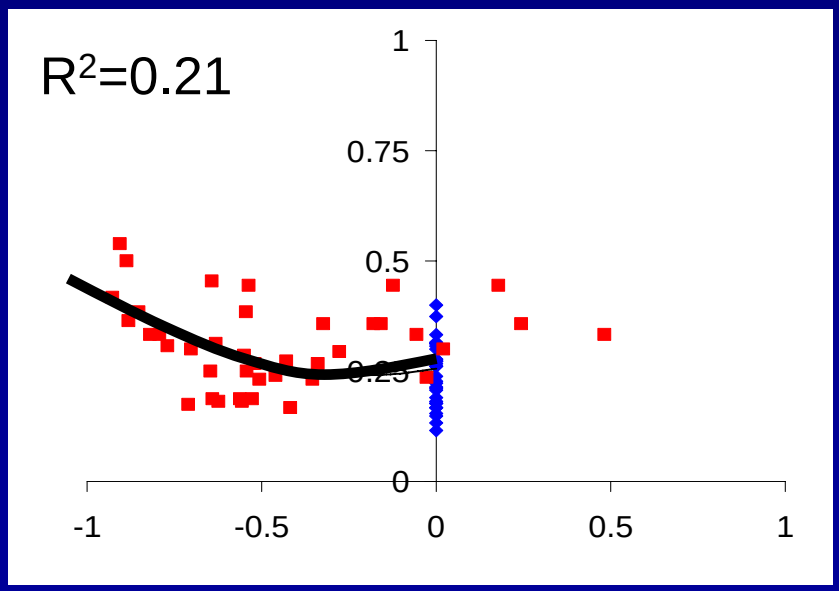
90-day minimum

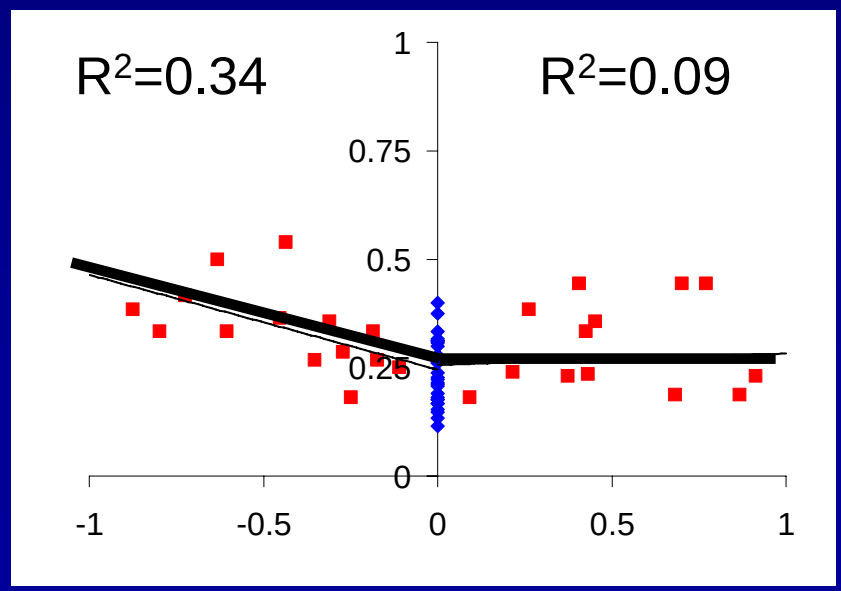
Snowmelt

Perennial









Conclusions, Prospectus

Use other response variables (e.g., fish).

Better modeling of flow alteration.

Apply at more regional scale (snowmelt vs. perennial)

Should follow this approach with other regional data sets.

Need to account for interactions with other site factors (temperature, substrate, etc.).