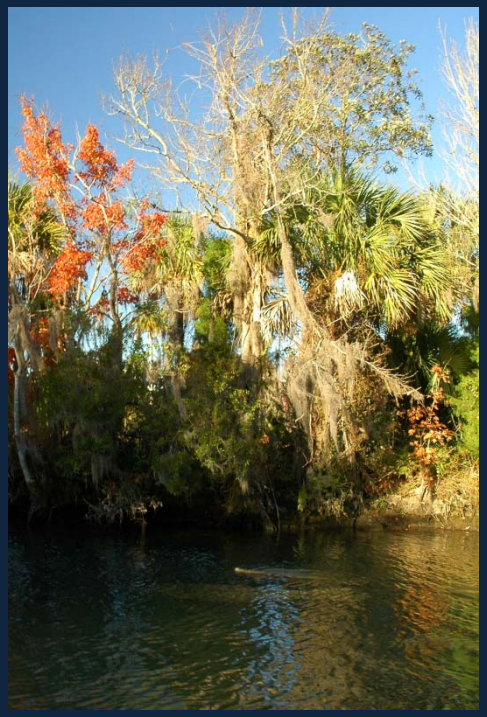
Hydrologic variability and fish life history strategies: Implications for regulated flows

Meryl Mims
UW School of Aquatic and Fishery Sciences

What is hydrologic variability?

high magnitude, unpredictable changes

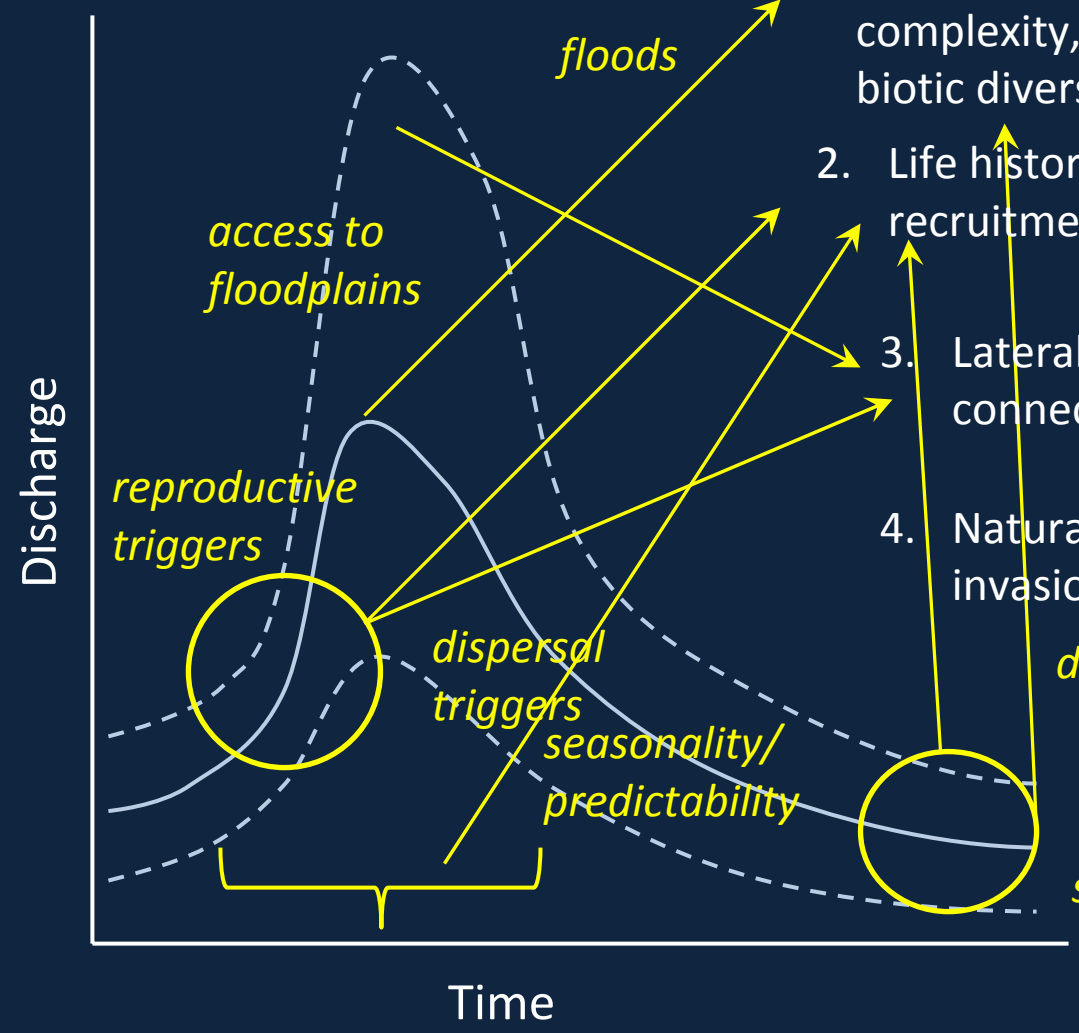
high magnitude, highly predictable changes



low magnitude, highly predictable changes

The magnitude and predictability of changes in flows in a river.

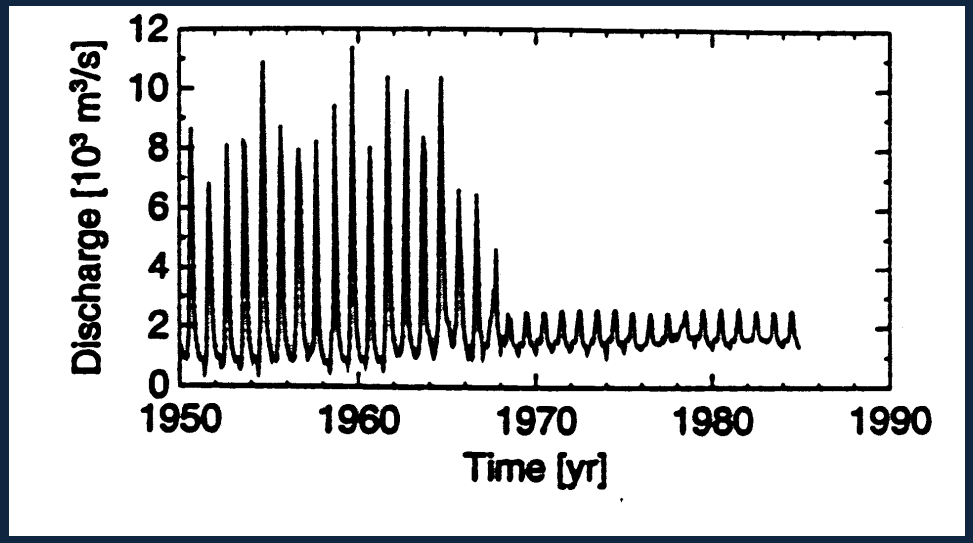
Why does hydrologic variability matter to fish?



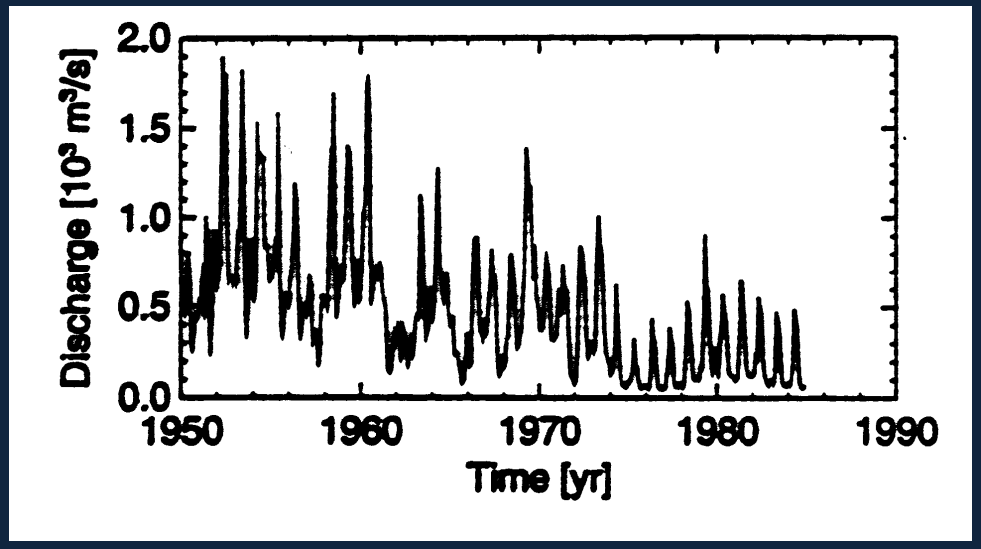
1. Channel form, habitat complexity, patch disturbance – biotic diversity
2. Life history patterns (spawning, recruitment cues)
3. Lateral and longitudinal connectivity
4. Natural regime discourages invasions

Adapted from Bunn and Arthington 2002.

Hydrographs are altered by human water use.

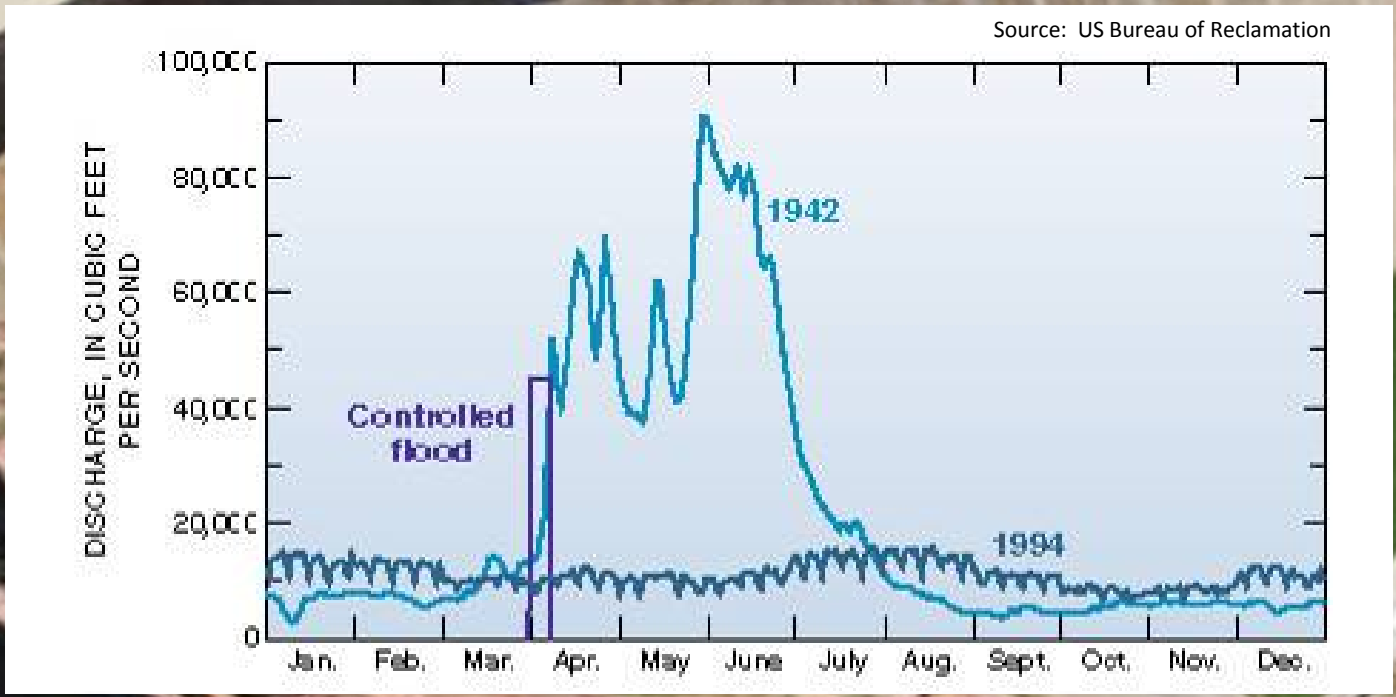


Dam (hydroelectric)



Increasing irrigation

Glen Canyon Dam, Colorado River, USA



Have changes in hydrologic variability altered fish communities downstream of dams?

Hypotheses:

1) Predictable relationships exist between flow regimes and dominant life history strategies of fishes.

2) Dominant life history strategies downstream of dams are consistent with the new (regulated) flow regimes.

Methods:

-Use existing fish surveys, hydrologic gauges, and dam data throughout the United States.

-First examine pairs of fish surveys and gauges to establish relationships in unregulated flow regimes.

-Then, examine ‘trios’ of fish surveys, gauges, and dams to examine fish communities in regulated flows.

Data sources:

USGS flow gauges

>22,000 gauges throughout the US with >1300 on unimpounded rivers

EPA EMAP and REMAP

>5000 surveys throughout the US from 1990-2001

National Inventory of Dams

>79,000 dams throughout the US

Using data from throughout the US provides large sample size, but…

-How can different climate types be examined?

-How can fish assemblages with completely different species be compared?

Assign gauges to flow regimes to account for climate variation.

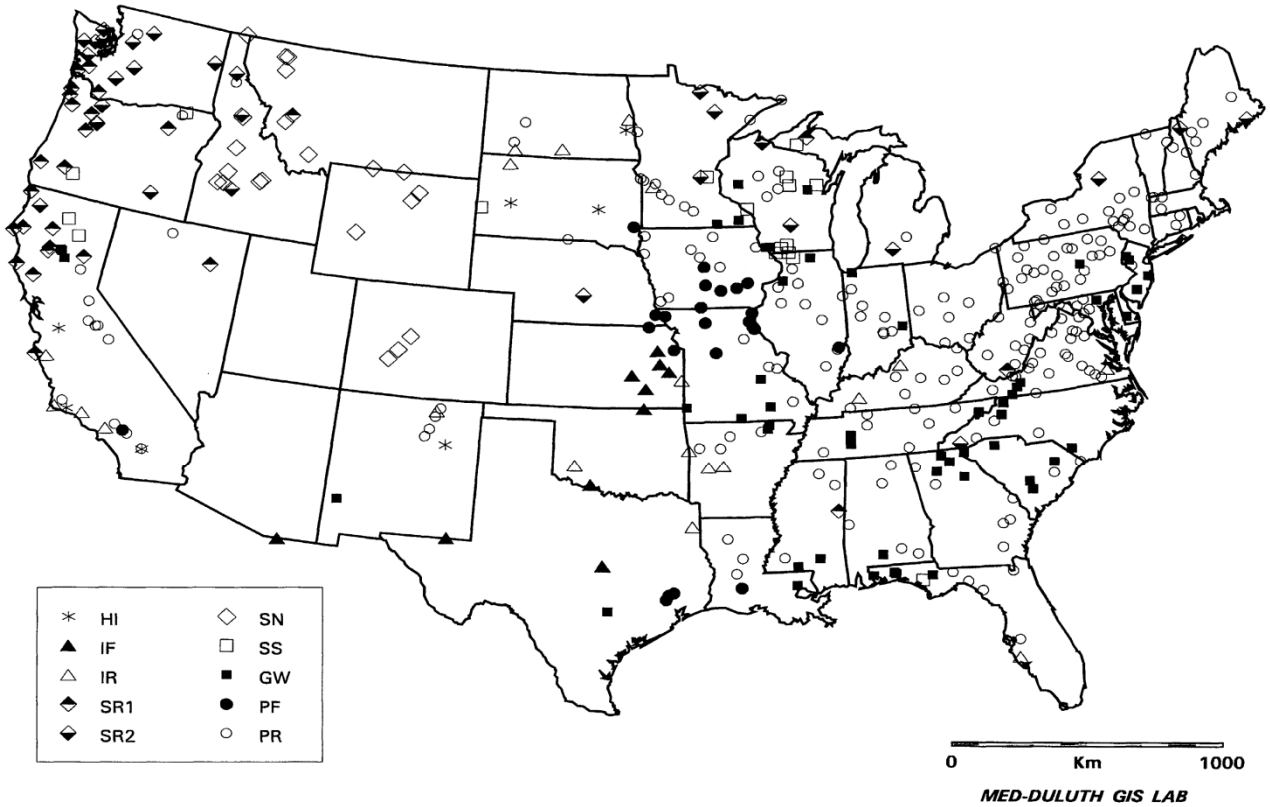


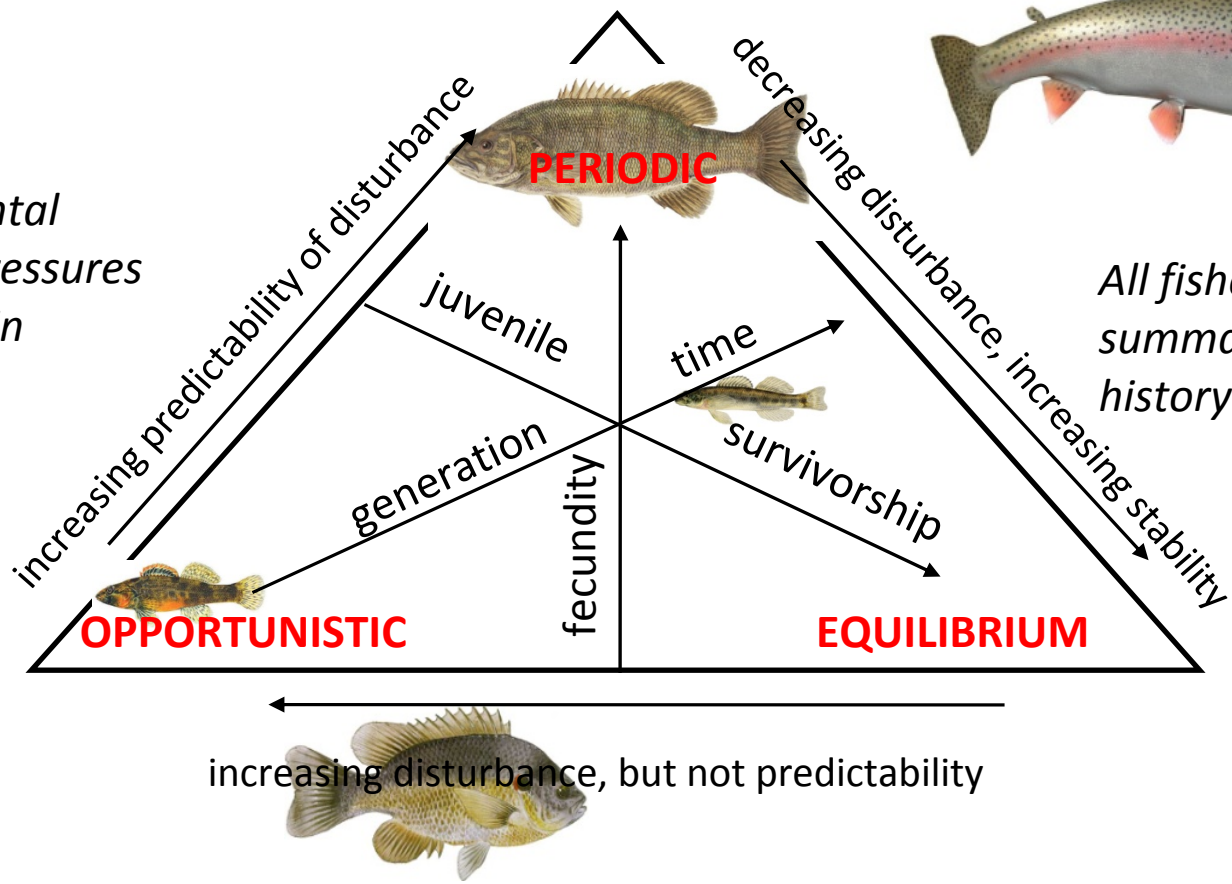
Fig. 2 Geographical locations of 'best' 420 gauged streams grouped into ten clusters based on ten hydrological descriptors. HI = harsh intermittent, IF = intermittent flashy, IR = intermittent run-off, SR = snow + rain (types 1 and 2), SN = snowmelt, SS = superstable groundwater, GW = stable groundwater, PF = perennial flashy, PR = perennial run-off.

Poff 1996

Life history strategies allows for comparison of assemblages with little taxonomic similarity.

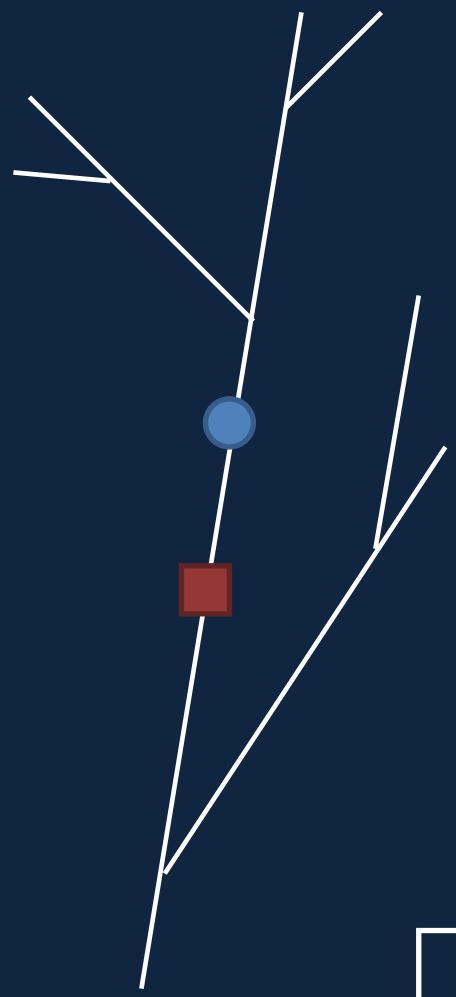
Environmental selection pressures favor certain strategies.

All fishes can be summarized by 3 life history strategies



Adapted from Winemiller 1995.

Site selection: Unaltered



>15 years continuous gauge data?

YES

Gauge-survey pair within 10 river km?

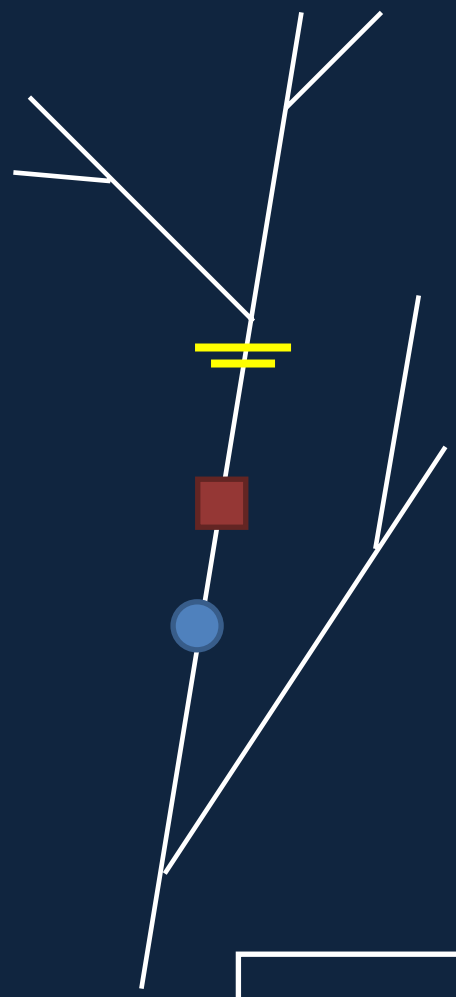
YES

Any tributaries between the pair?

NO

Acceptable pair.

Site selection: Altered



Gauge-survey-dam trio <20km apart?

>15 years gauge data pre- and post-dam?

YES

Survey taken after post-dam gauge record?

YES

Upstream dams constructed prior trio dam?

Any tributaries between trio?

NO

Acceptable trio.

Testing Hypothesis 1:

Relationships between flow regimes and life history strategies exist.

-Compute % life history strategies (Opportunistic, Equilibrium, or Periodic) at each site.

-Assign each gauge to a flow regime by cluster analysis.

-Examine correlation of life history strategies with flow regimes.

-Compare relationships to life history model to see if relationships are predicted by model.

Testing Hypothesis 2:

Dominant life history strategies downstream of dams are consistent with the new (regulated) flow regimes.

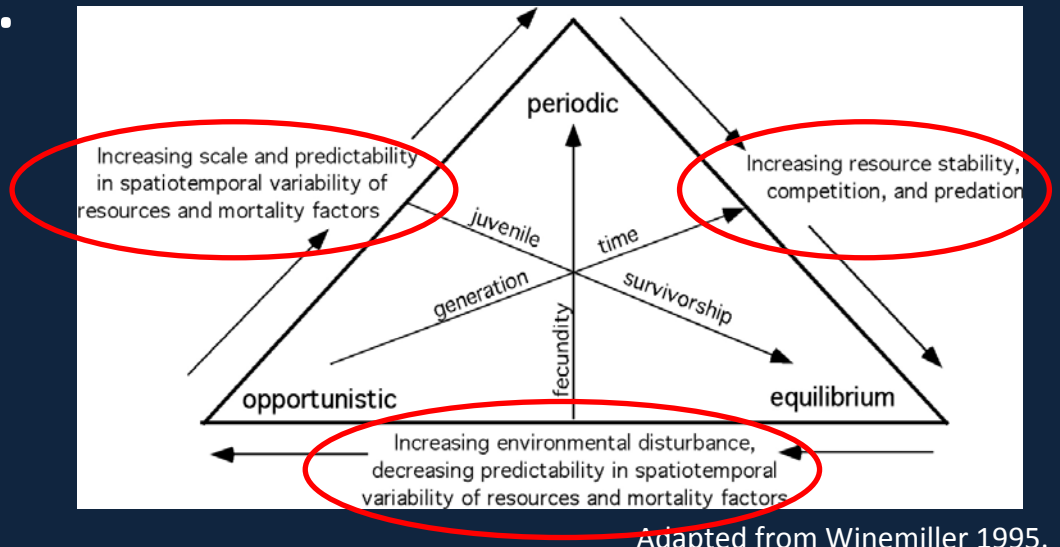
-Compute % life history strategies (Opportunistic, Equilibrium, or Periodic) at each site.

-Assign each PRE- and POST-dam gauge to a flow regime by cluster analysis.

-Examine correlation of life history strategies with POST-post flow regimes.

-Compare relationships to life history model to see if relationships are predicted by model.

Anticipated Results:



Adapted from Winemiller 1995.

-Relationships will exist and will be predicted by life history model.

-Post-dam fish surveys will show expected relationship with POST-dam (not pre-dam) flow regimes.

-Patterns and relationships will differ by flow regime, but we may see influence of local processes – e.g. land use, basin shape, and dam operation.

Important considerations for this study:

-Lacks a sense of temporal variability in assemblages by examining ‘snapshot’ survey

-Communities downstream of dams could also be influenced by other factors (ex/ introduced species, landuse patterns, and changes in the thermal regime)

-Trait-based studies do not account for intraspecific variation; thus, adaptation to a new flow regime cannot be examined

But… this study is much more detailed than any other in both site selection and . *If trends emerge from the noise, it is pretty convincing!*

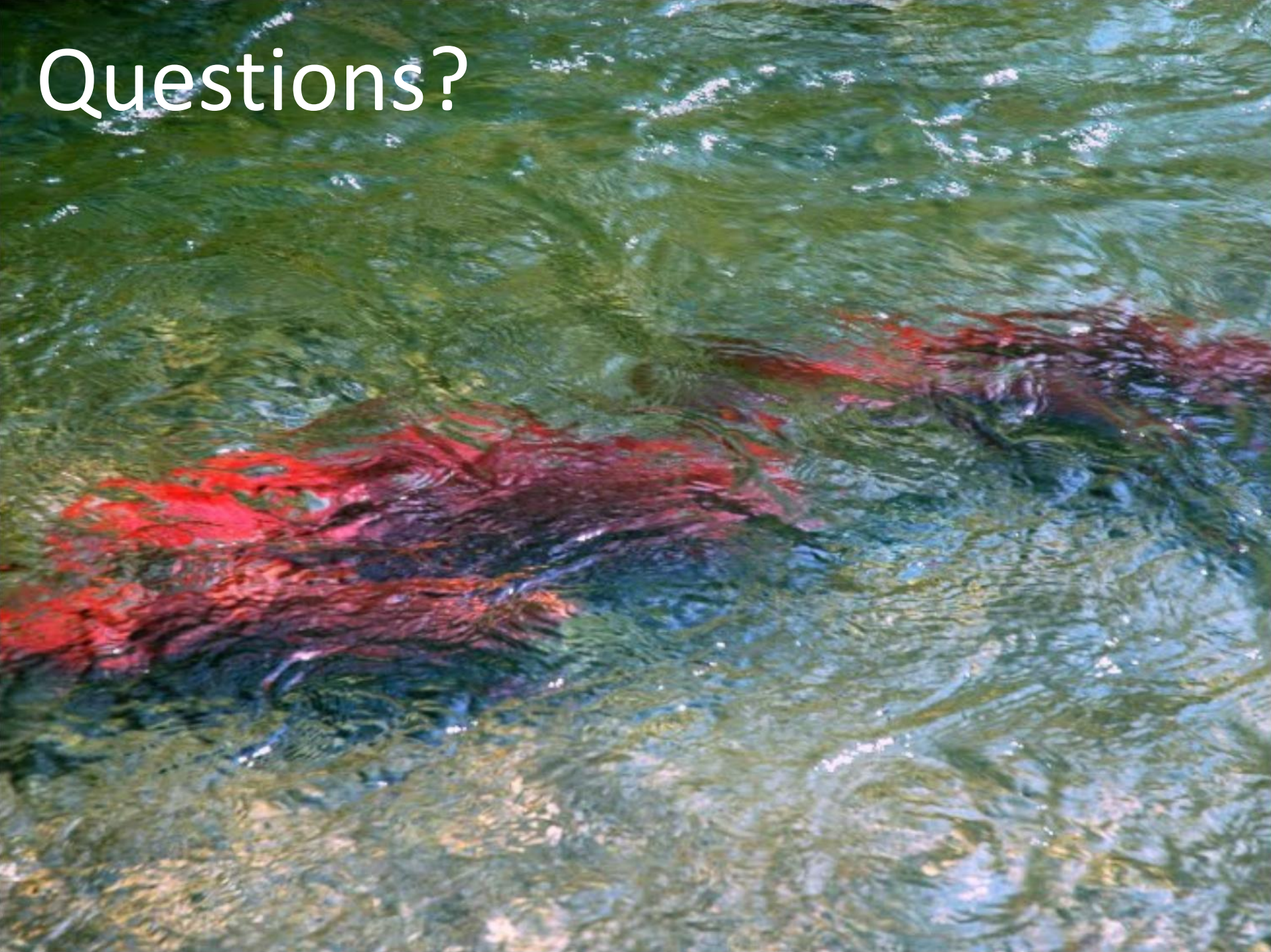
Impacts:

-Provide baseline understanding of relationship between flow regimes and fish assemblages.

-Help identify species most likely threatened by altered flow regimes.

-Also guide future research at regional or local scales that may result in ‘ecological’ flow regulation.

Questions?



References

Bunn, S. E., and A. H. Arthington. 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental Management 30:492-507.

Magilligan, F. J., and K. H. Nislow. 2005. Changes in hydrologic regime by dams. Geomorphology 71:61-78.

Nilsson, C., C. A. Reidy, M. Dynesius, and C. Ravenga. 2005. Fragmentation and flow regulation of the world's large river systems. Science 308:405-408.

Poff, N. L. 1996. A hydrogeography of unregulated streams in the United States and an examination of scale-dependence in some hydrological descriptors. Freshwater Biology 36:71-91.

Winemiller, K. 0. 1995. The structural and functional aspects of fish diversity. Bull. Fr. Peche Piscic. 337:23-45.

US Army Corps of Engineers: National Inventory of Dams

US Environmental Protection Agency

US Geological Survey

Hydrograph examples from Cathy Reidy-Liermann, UW.