Aquatic Insects and Climate Change

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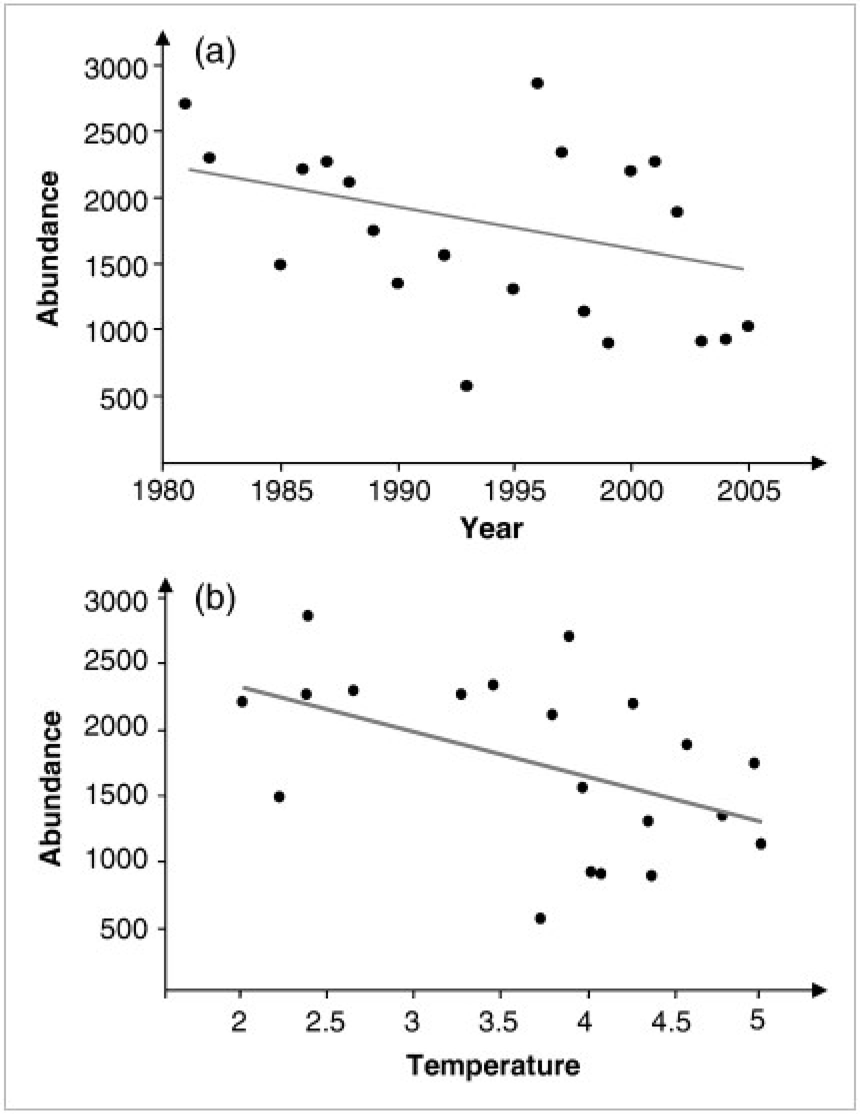
Changing climate has multiple impacts on stream ecosystems

Direct	Multiple Interacting
Temperature	Land use change • Urbanization • Agriculture
Hydrology	Eutrophication
Biodiversity (including invasive species)	Other services
Nutrient cycling and energy flow	

Temperature

- **Numbers and biomass of larvae and adults**
- Life history outcomes
- Species distributions
- Size of adults
- Timing of metamorphosis
- Fecundity
- Sex ratio (?)



Streams in Wales

- Stream invertebrates sampled in spring
- Correlated with temperature from preceding winter

Durance, I., & Ormerod, S. J. (2007). Climate change effects on upland stream macroinvertebrates over a 25-year period. *Global change biology*, *13*(5), 942-957.

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Aquatic Insects and climate change

- **ENDEMIC SPECIES – limited distributions**
- **Habitat specialists – springs and high altitudes**
- **Cold stenothermic species**
- Species with short emergence periods
- Species with restricted niches – food resources

Thermal Tolerance of Select NC Aquatic Insects

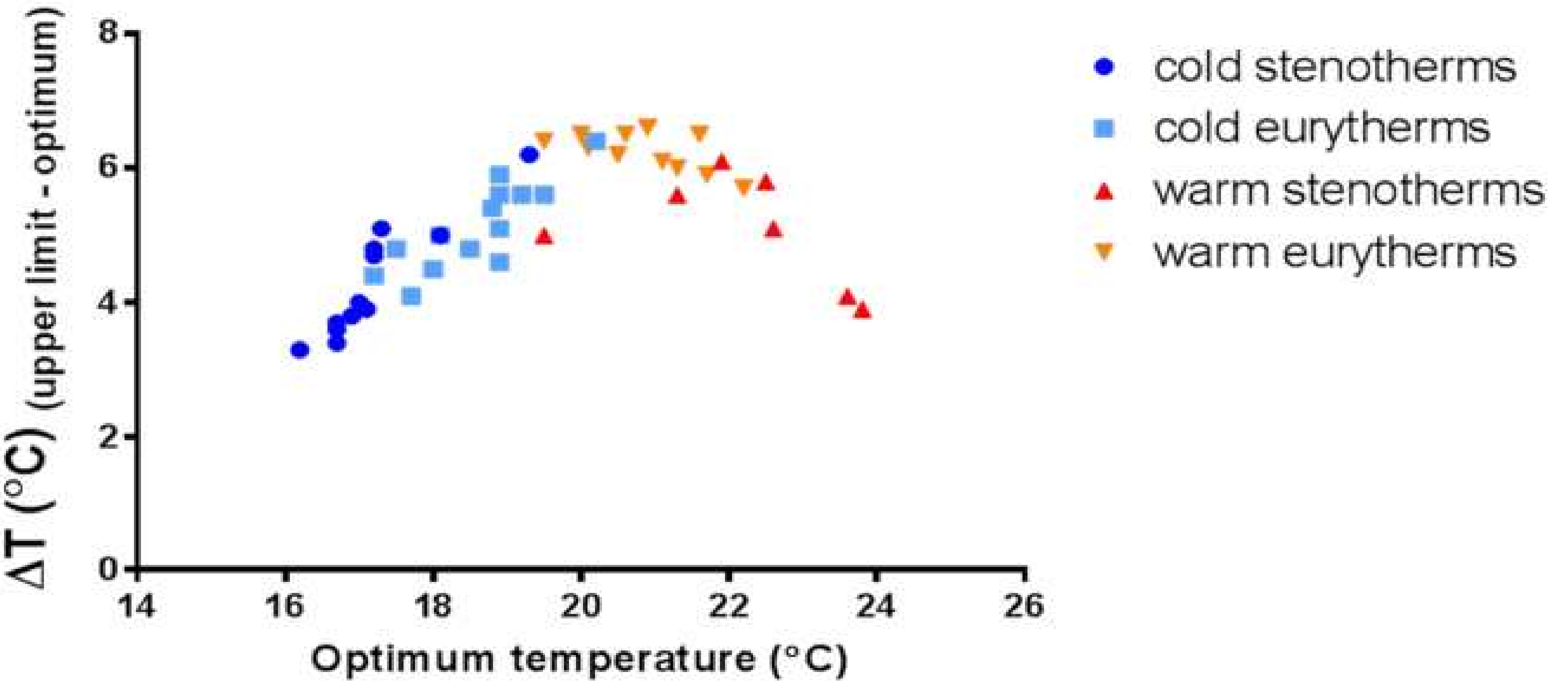

Figure 3: A comparison of ΔT (the °C difference between the upper thermal limit and optimum) and optimum temperatures for each species present in a thermal preference list created by NCDENR.

Buchwalter, D., Camp, A., & Hawkins, C. (2015). *Experimental Approaches to Understanding Temperature Responses of Select North Carolina Macroinvertebrates*. Water Resources Research Institute of the University of North Carolina.

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- **Life history outcomes**
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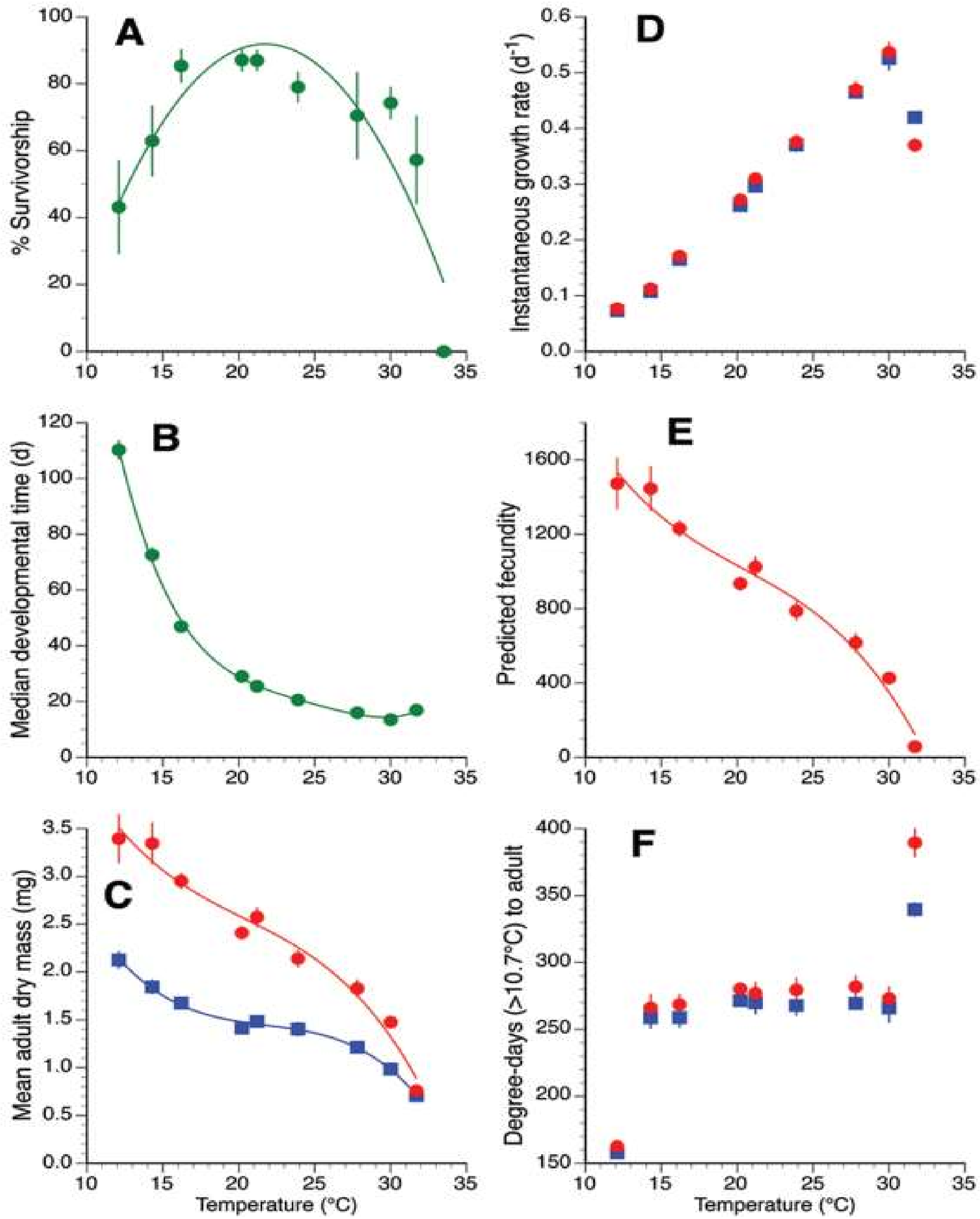


Temperature Effects on C. dipterum

Sweeney, B. W., Funk, D. H., Camp, A. A., Buchwalter, D. B., & Jackson, J. K. (2018). Why adult mayflies of Cloeon dipterum (Ephemeroptera: Baetidae) become smaller as temperature warms. *Freshwater Science*, *37*(1), 64-81.

Adult Mayfly: Field versus Lab

Adult female *Cloeon dipterum*. Specimen on left is from overwintering generation and weighed 4.2 r
atchlings. Specimen on right was reared under laboratory conditions (diel cycle with mean of 27.8°C
weighed 1.4 mg and produced 235 hatchlings.

A mayfly's decision curve as temperature increases

- In laboratory experiments adult mayflies were largest at cooler temperatures and declined as temperature increased
- Fecundity (egg production) decreased with increasing temperatures
- Female mayflies did not produce offspring at 31.7˚C
- Females cannot ingest and process sufficient energy to support body growth and support reproductive tissue at higher temperatures.
- Reduced egg production allows the female to allow for structural growth for successful metamorphosis, flight, mating and oviposition.
- So it’s either produce a limited number of eggs and remain small or increase structural tissue and allow for metamorphosis and flight with no eggs.

Disturbance Important for structuring communities from an ecological perspective

Flooding

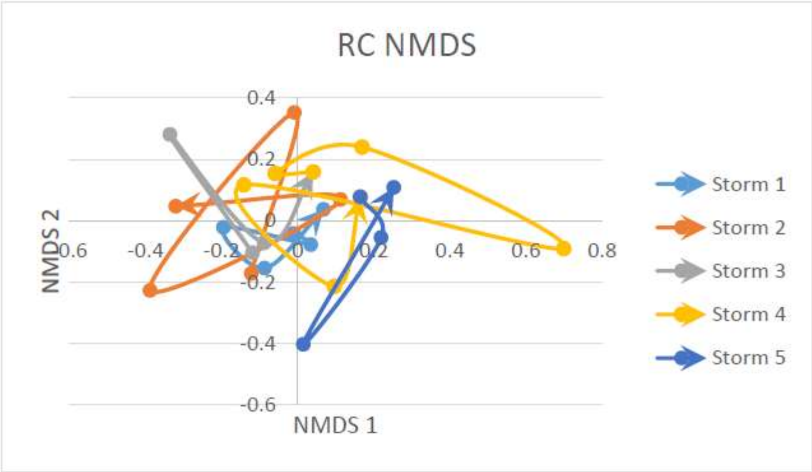
- Timing and magnitude impact rate of colonization after event
- Refugia: surface and hyporheic zone

Low flow/drying conditions

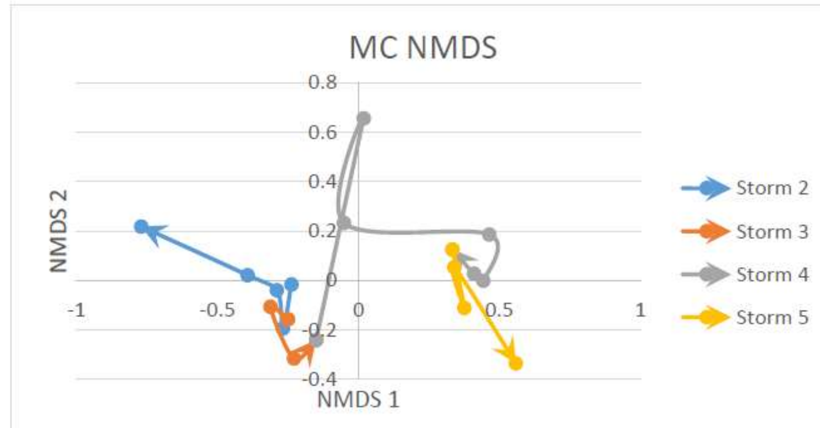
- Physiological adaptations such as aestivation and diapause
- Refugia: migration to permanent water or the hyporheic zone
- Streams with canopy cover will a prolonged drying phase compared to streams with no canopy cover
- Role of perennial upstream: floods can re-connect upstream perennial water to downstream intermittent or dry sites

Colonization

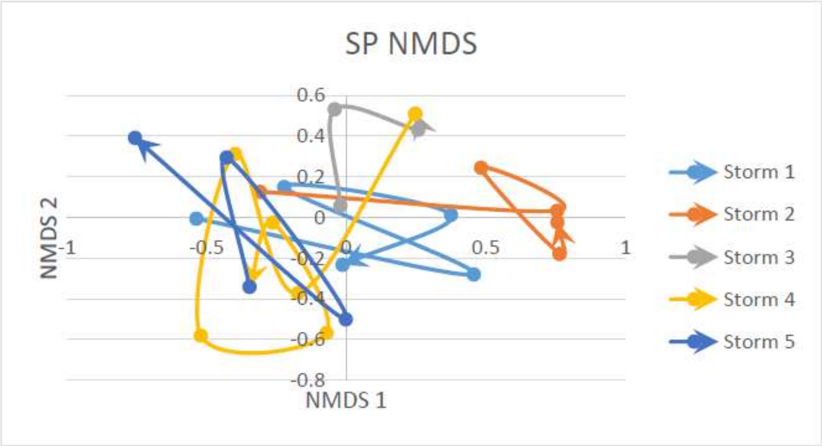
- Drift from upstream
- From refugia: pools, hyporheic zone
- Aerial adults



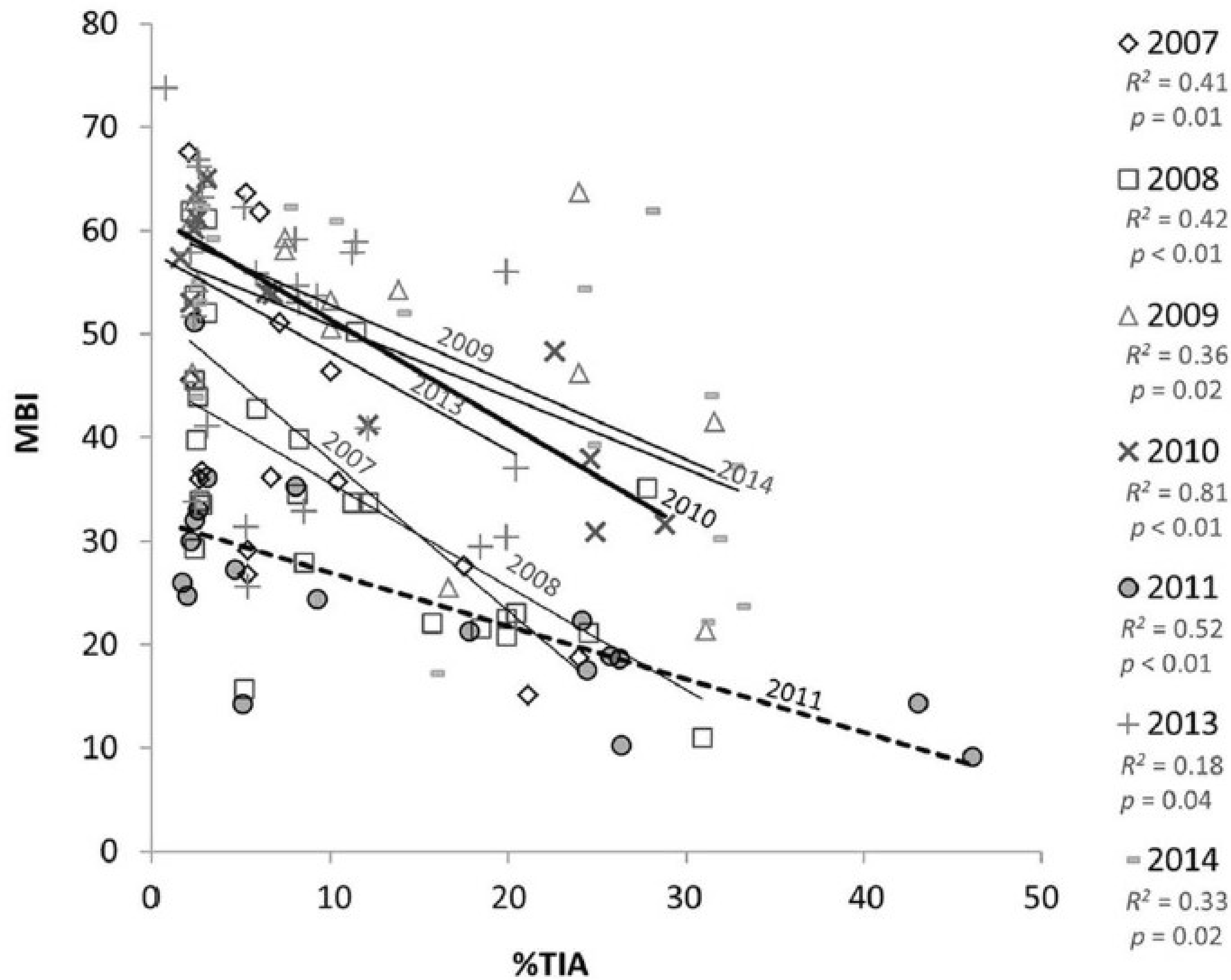
Reedy Creek "conservation"



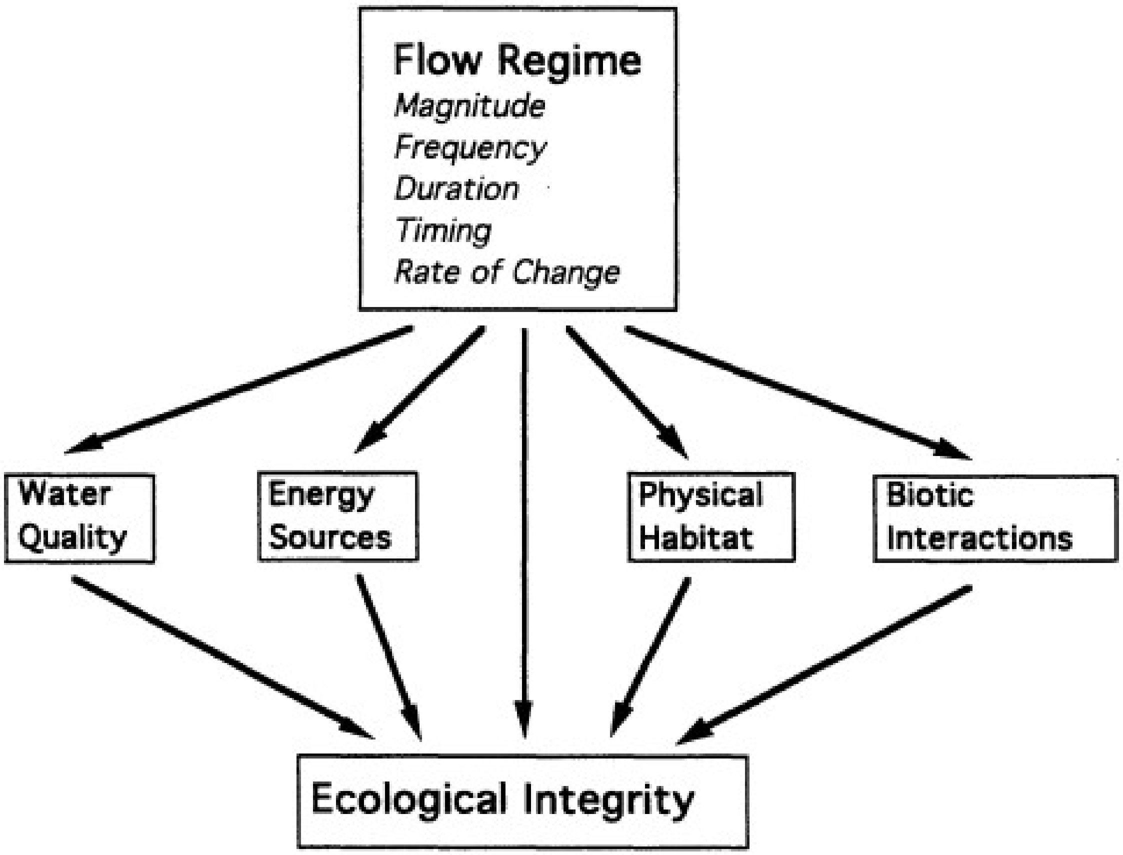
Muddy Creek restored 2 years



Dairy Branch restored 7 years



Hawley, R. J., Wooten, M. S., MacMannis, K. R., & Fet, E. V. (2016). When do macroinvertebrate communities of reference streams resemble urban streams? The biological relevance of Q critical. *Freshwater Science*, *35*(3), 778-794.

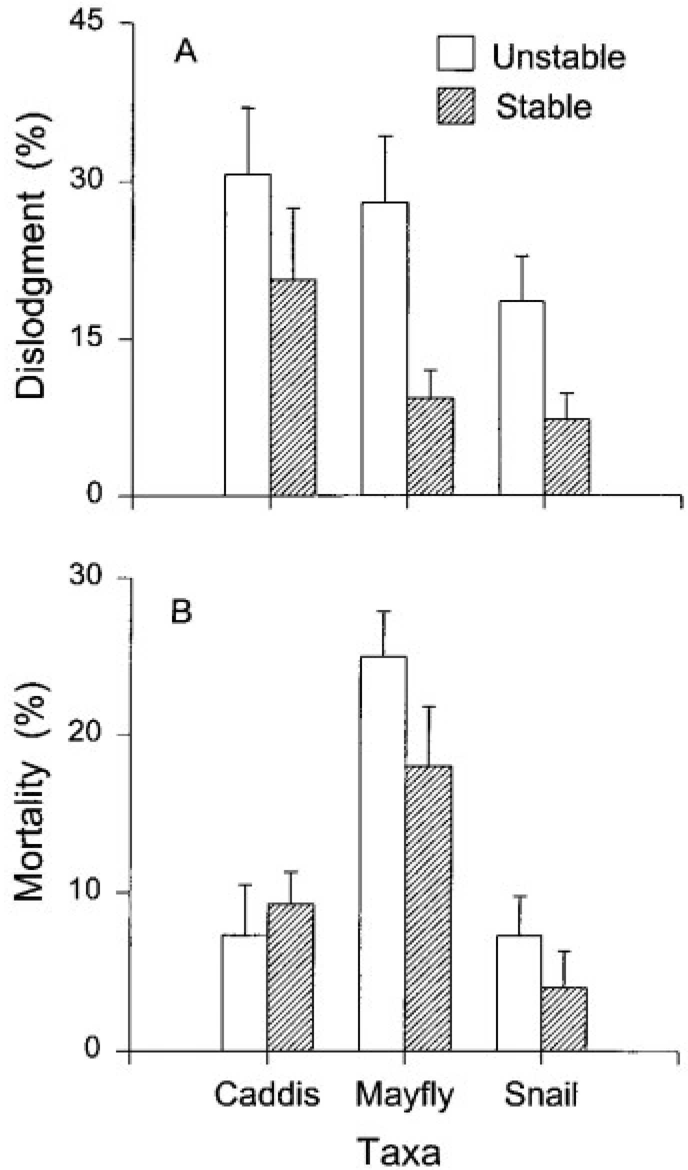


Natural Flow Regime: Organisms have evolved in local flow environments and adapted to perturbations

N. LeRoy Poff; J. David Allan; Mark B. Bain; James R. Karr; Karen L. Prestegaard; Brian D. Richter; Richard E. Sparks; Julie C. Stromberg
BioScience, Vol. 47, No. 11. (Dec., 1997), pp. 769-784.

Use of $Q_{critical}$

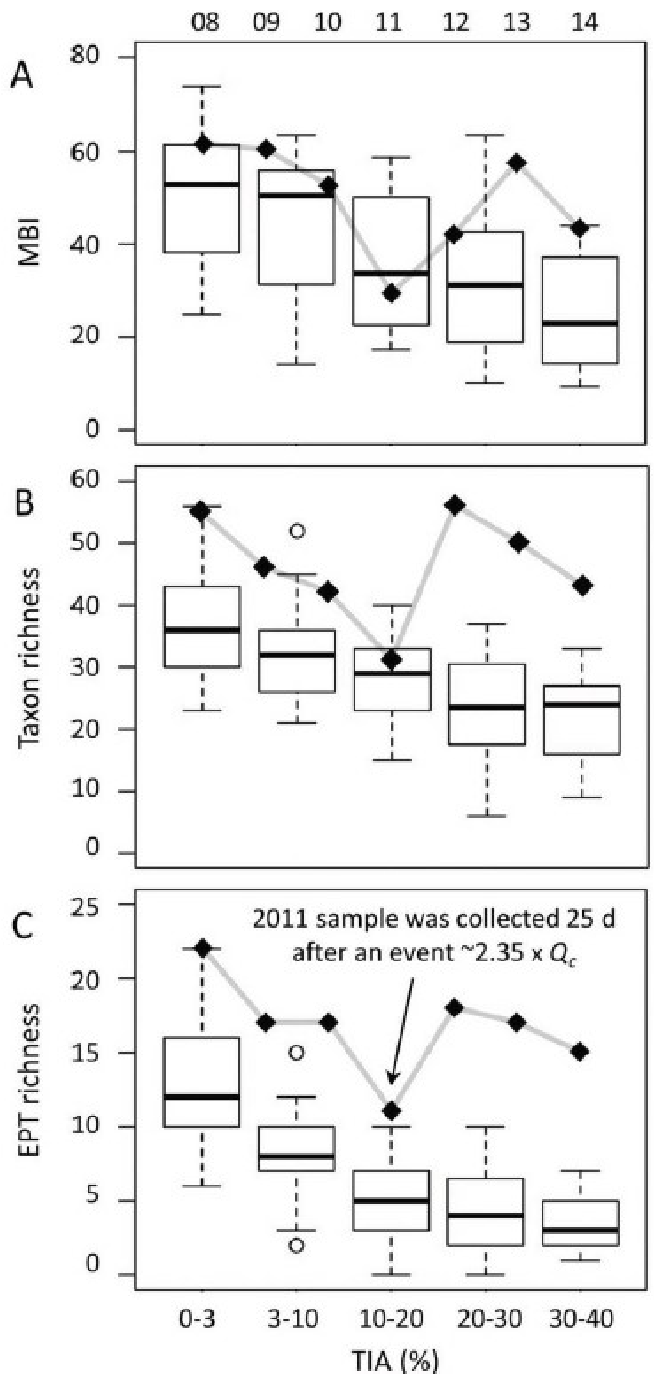
- Critical discharge need to move the streambed
- Links hydrology, geomorphology, biotic integrity
- **Taxa may respond differently to similar Q_c**
  - **caddisflies versus mayflies**
- Most likely need a local (regional?) approach



Taxa specific effects of high flows

Holomuzki, J. R., & Biggs, B. J. (2000). Taxon-specific responses to high-flow disturbance in streams: implications for population persistence. *Journal of the North American Benthological Society*, *19*(4), 670-679.

Importance of understanding how reference systems change over time when designing and evaluating restored systems



BI scores in an excellent stream over years compared to overall BI scores based on TIA

Taxa richness scores in an excellent stream over years compared to overall richness scores based on TIA

EPT richness scores in an excellent stream over years compared to overall richness scores based on TIA

Climate Change

- Hydrology
  - Timing and magnitude of floods
  - Drought/baseflow
  - Seasonal flooding in tropics
  - Change in variability
- Temperature
  - Stream and groundwater
- Eutrophication
- UV light
- Indirect effects → food resources, migration

FUNCTIONAL EVALUATION AND CLIMATE CHANGE

Life History	Mobility
Voltinism Development Synchronization of emergence Adult ability to exit Ability to survive desiccation	Female dispersal Adult flying strength Occurrence in drift Maximum crawling rate Swimming ability
Morphology	**Ecology**
Attachment Armoring Shape Respiration Size at maturity	Rheophily Thermal preference Habit

RESTORATION AND CLIMATE CHANGE: Thoughts from Clinton

- Reconnection of surface and subsurface (refugia and temperature control)
- Diversity of sediment size to create patches of disturbed and not disturbed patches
- Diversity of sediment sizes and structures to offer refugia during flood and drought
- Understand natural changes in local systems as a reference condition for flow
- Incorporate Qc into design? Other flow metrics?

RESTORATION AND CLIMATE CHANGE: Thoughts from Penrose

- Diversity of the reference condition and recovery of restored condition
- Will the restoration/mitigation success rely on thermally threaten species?
- How will the new feature be affected by changes in temperature and drying?
- Can restoration scientists produce cooler streams quickly? Should restoration include temperature?

What are your thoughts?

http://reedycreekrestoration.com/blog/