

US EPA ARCHIVE DOCUMENT

# Climate Change Indicators – Traits and Taxa



Jen Stamp  
Tetra Tech

March 28, 2008

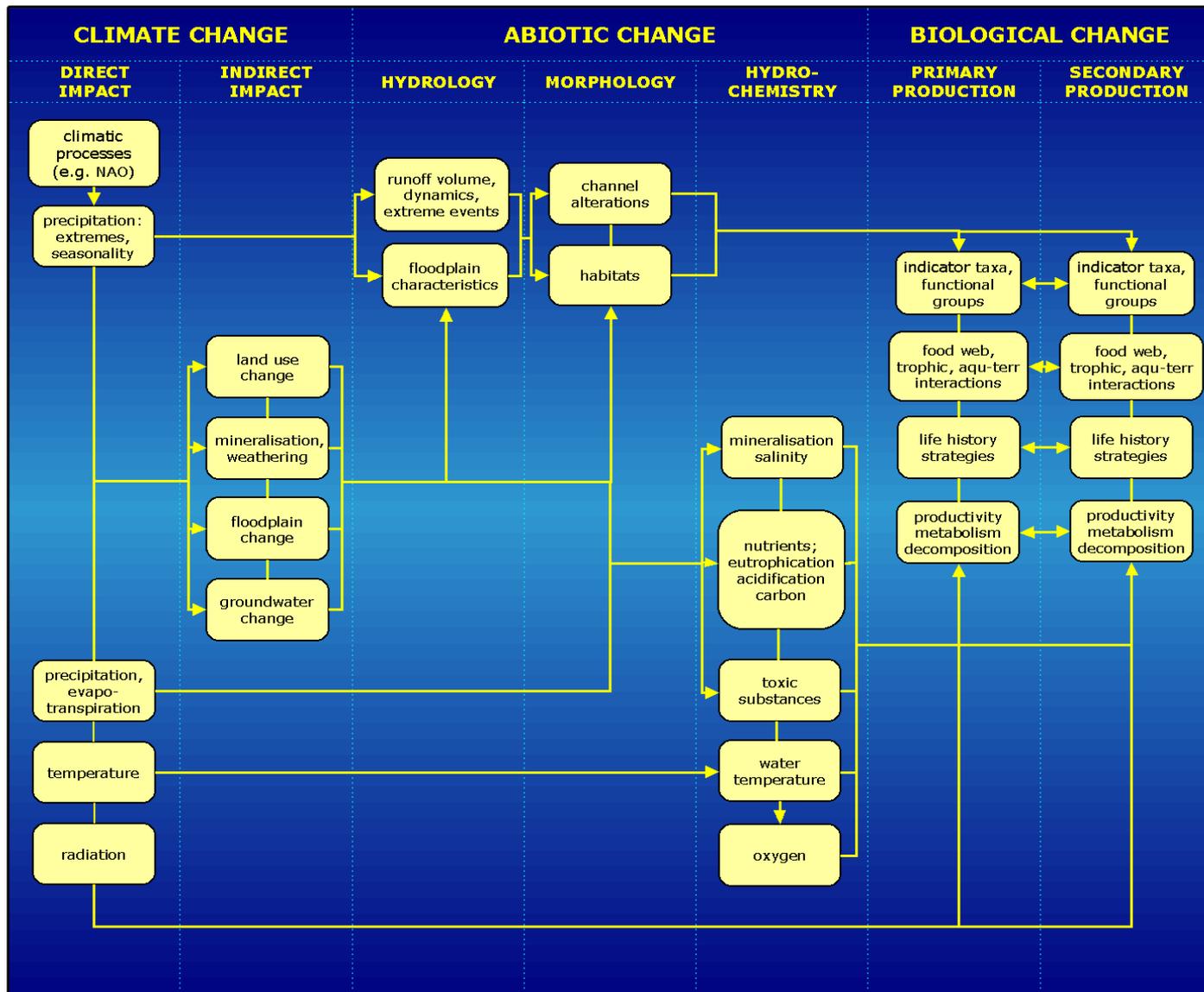
Bartlett, NH



New England Association of Environmental Biologists

# Overview

- Predicted effects of climate change on stream systems
- Preliminary list of traits and taxa that have the highest indicator potential
- Sources of trait information
- Summary of distribution information
- The Attributes database
- Closing thoughts



Euro-limpacs Consortium: Freshwaterecology.info - The Taxa and Autecology Database for Freshwater Organisms. Available from [www.freshwaterecology.info](http://www.freshwaterecology.info)

# What traits are most likely to influence an organism's ability to adapt to the changing conditions associated with climate change?

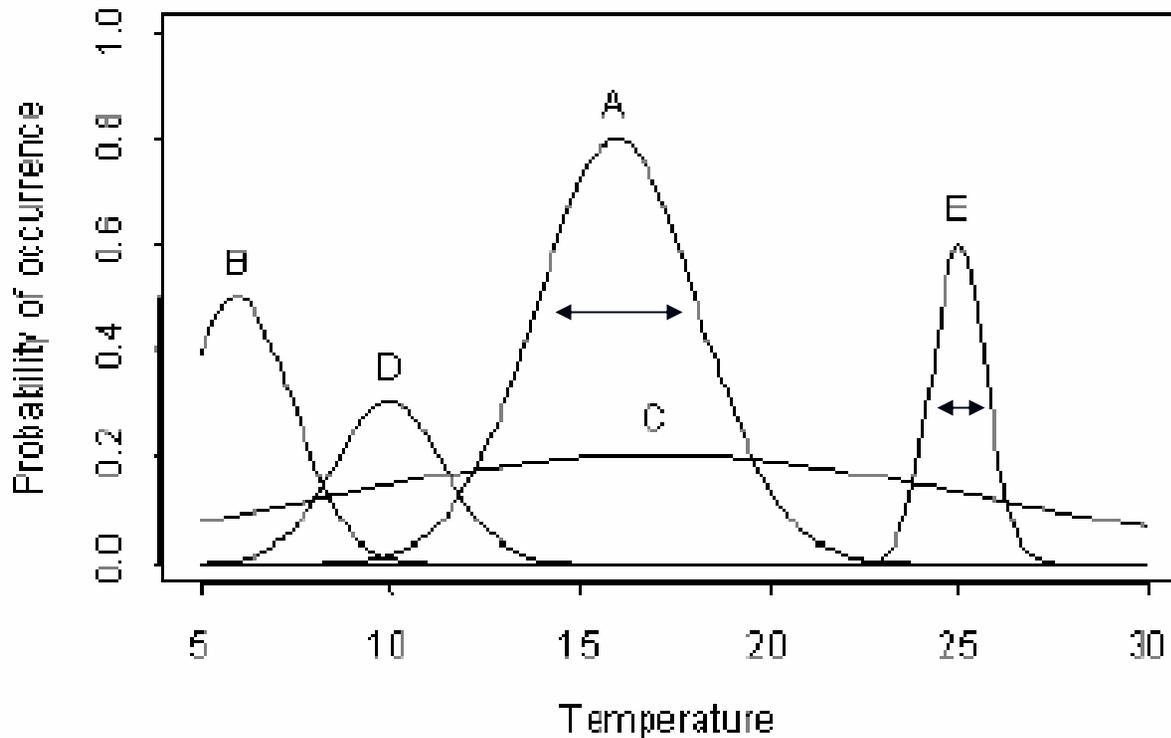
- Temperature Preference and Tolerance – cold stenotherms
- Distribution –isolated populations, high altitudes
- Dispersal Ability – limited mobility=can't migrate
- Dispersal Corridors
- Voltinism – the faster they reproduce the faster they can adapt
- Timing of emergence
- Ability to adapt to disturbance (i.e. flood event)
- Resilience to dessication, drought conditions
- Generalists vs. specialists

# TEMPERATURE SENSITIVITY

## = very complex

- Extremes (max/min), duration of extremes, fluctuations
- Complex interactions with other parameters (i.e. DO, pH, etc.)
- Complex responses among organisms
  - Laboratory experiments are unable to mimic the complexities of the natural stream environment
- Tough to find long-term water temperature data sets for streams
- Tough to capture the true thermal regime of a stream based on instantaneous water temperature measurements

# TEMPERATURE – preference & tolerance



**Figure 2. Different unimodal relationships within a species pool. Letters indicated different species.**

# TEMPERATURE – Sources of Information

- There is limited temperature preference & tolerance information available for benthic macroinvertebrates. More is known about fish.
- There is a lot of information available for some taxa and virtually none for others
- Western states seem to be further along in the development of temperature tolerance values than New England states.
- Temperature preference and tolerance values are mostly derived from weighted average calculations based on instantaneous water temperature measurements. These instantaneous measurements provide limited information about the true thermal regime of a stream reach, but they are the best we have to work with at this point

# **SOURCES OF TEMPERATURE DATA**

## **Macroinvertebrates**

The following are based on analyses of data sets:

- 2006. Yuan, Lester. **Estimation and Application of Macroinvertebrate Tolerance Values** - EPA/600/P-04/116F. (EMAP-West)
- 2001. Brandt, Darren. **Temperature Preferences and Tolerances for 137 Common Idaho Macroinvertebrate Taxa.** (Idaho)
- 2007. Herbst, David. **Anticipating and accounting for the influence of climate change on stream hydrology and biology in the Sierra Nevada.**
- 2008. Weighted average analysis of Maine's database (Lei Zheng, Tetra Tech)

# SOURCES OF TEMPERATURE DATA

## continued...

The following are based on extensive literature searches:

- 1977-78. **EPA Environmental Requirements and Pollution Tolerance Series**
  - Plecoptera (363 species based on 125 sources)
  - Trichoptera (245 taxa based on 294 references)
  - Ephemeroptera (400 species based on 200 sources)
  - Freshwater Chironomidae (262 genus or species based on 33 sources)
  
- 2006. **USGS. A database of lotic invertebrate traits for North America:** U.S. Geological Survey Data Series 187, <http://pubs.water.usgs.gov/ds187>. By Nicole K. M. Vieira, N. LeRoy Poff, Daren M. Carlisle, Stephen R. Moulton II, Marci L. Koski, and Boris C. Kondratieff.
  
- 2006. **N. LeRoy Poff.** Functional trait niches of North American lotic insects: traits-based ecological applications in light of phylogenetic relationships. JNABS 25(4):730-755.
  - 20 traits, 311 genera/tribes in 75 families

# Preliminary list of 'climate change indicator taxa'

based on temperature preferences and tolerances

## ***COLD WATER MACROINVERTEBRATE TAXA***

- Rhyacophila (Trichoptera)
- Parapsyche (Trichoptera)
- Ameletus (Ephemeroptera)
- Epeorus (Ephemeroptera)
- Pteronarcys (Plecoptera)
- Perlodidae (Plecoptera)
- Eukiefferella (Chironomidae)
- Micropsectra (Chironomidae)



These are taxa that were most frequently cited in the aforementioned sources as having a preference for cold water and that were considered to be sensitive to a fairly narrow range of temperatures.

# Preliminary list of 'climate change indicator taxa'

based on temperature preferences and tolerances

## *WARM WATER TAXA*

NOTE: this list was harder to come up with. The majority of taxa appear to have no strong temperature preference and are tolerant to a wide range of temperatures (0-30°C). Here is a short list of genera that appear to favor warm water, and that appear to have a fairly narrow tolerance range.

- **Pseudochironomus** (Chironomidae)
- **Pentaneura** (Chironomidae)
- **Cheumatopsyche** (Trichoptera)



# IMPORTANCE OF SPECIES-LEVEL IDs

## *Baetis* (Ephemeroptera)

### Species that *do not show a strong temperature preference*

- Most *Baetis* fall into this category. A few examples are:
- *Baetis tricaudatus* – Source: EPA pubs (1977-8)
- *Baetis brunneicolor* - Source: EPA pubs (1977-8)

### Species that show a preference for *cold* water

- *Baetis bicaudatus* – Source: Brandt (2001)
- *Baetis parvus* – Source: EPA pubs (1977-8)

### Species that show a preference for *warm* water

- *Baetis australis* - Source: EPA pubs (1977-8)
- *Baetis intermedius* - Source: EPA pubs (1977-8)



# ANOTHER APPROACH TO IDENTIFYING COLD STENOTHERMS (MACROINVERTEBRATES)

Because the presence of cold water fish taxa in a stream is likely a better indicator of the true thermal regime than instantaneous temperature measurements, another approach is to analyze the frequency of co-occurrence with cold water taxa like Brook trout and Slimy sculpin



## **COLD WATER FISH TAXA**

- Brook trout
- Slimy sculpin



# ANOTHER APPROACH...continued

These taxa are considered 'indicator and preferential taxa' in Vermont's 'small high gradient streams,' which are typically inhabited by Brook trout and Slimy sculpin

- **Plecoptera** – *Peltoperla sp.*, *Malerikus sp.*, *Chloroperlidae*,  
*Leuctridae*
- **Trichoptera** – *Symphitopsyche macleodi*, *Parapsyche sp.*
- **Coleoptera** – *Oulimnious sp.*
- **Diptera** – *Eukiefferella brevicalar*

# HYDROLOGY

(=very simplified scenarios)



Increase in the  
number and  
duration of  
droughts and low  
flow events

Increase in the  
number and  
intensity of floods  
and high flow  
events



Hydrologic regime  
stays the same

Also the shift in the timing of ice out/snow melt/spring high flow events

# HYDROLOGY

## Indicator traits – increased probability of low flow/drought

- Current preference

- Respiration - some species (i.e. stoneflies) need flowing water
- Feeding - filter feeders (i.e. black flies, some caddisflies)

- Ability to survive desiccation

- Eggs, aerial adults, desiccation-resistant stages
- Burrowers may do better?

- Habitat availability

- Loss of habitat, such as roots wads and overhanging vegetation
- Clingers may be affected?
- More limited dispersal corridors



# HYDROLOGY

Indicator traits - increased probability of high flow events

- Ability to survive & adapt to disturbance events
  - Short life cycles (voltinism)
  - High mobility (adult and larvae)



# DISTRIBUTION

We expect to see shifts in ranges -

- **Cold stenotherms** will likely shift north or to higher elevations
- There will likely be localized extinctions of **rare taxa** that are already close to their temperature tolerance limits or that occupy rare and vulnerable habitats
- **Warm water** taxa are likely to expand their ranges to the north.

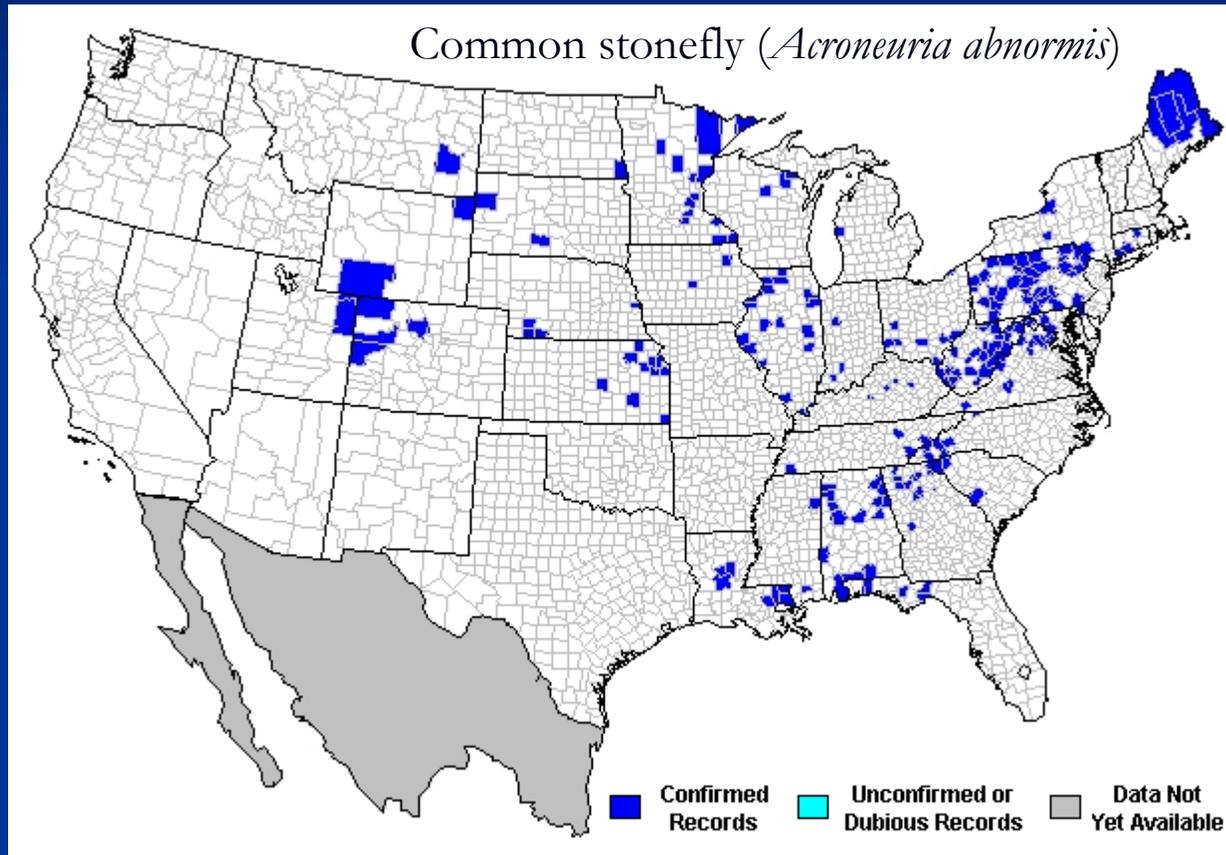
Most vulnerable taxa will likely be –

- Unable to migrate
  - Inadequate dispersal corridor (i.e. impoundments, topography, etc.)
  - Inadequate dispersal mechanism (i.e. limited mobility)
  - Disjunct isolated populations
- Sensitive sites
  - High altitude
  - Ephemeral streams
  - Springs

**QUESTION - At what spatial scale should the distribution data be evaluated?**

# NATIONWIDE

USGS has maps for the lower 48 for stoneflies, mayflies and dragonflies (species level) based on reference publications (USGS Species Distribution Maps website)



Kondratieff, Boris C. and Richard W. Baumann (coordinators). 2000. Stoneflies of the United States. Jamestown, ND: Northern Prairie Wildlife Research Center Online. <http://www.npwrc.usgs.gov/resource/distr/insects/sfly/index.htm> (Version 12DEC2003). <http://www.npwrc.usgs.gov/resource/distr/insects/sfly/usa/361.htm>

# NATIONWIDE – WSA (2004)

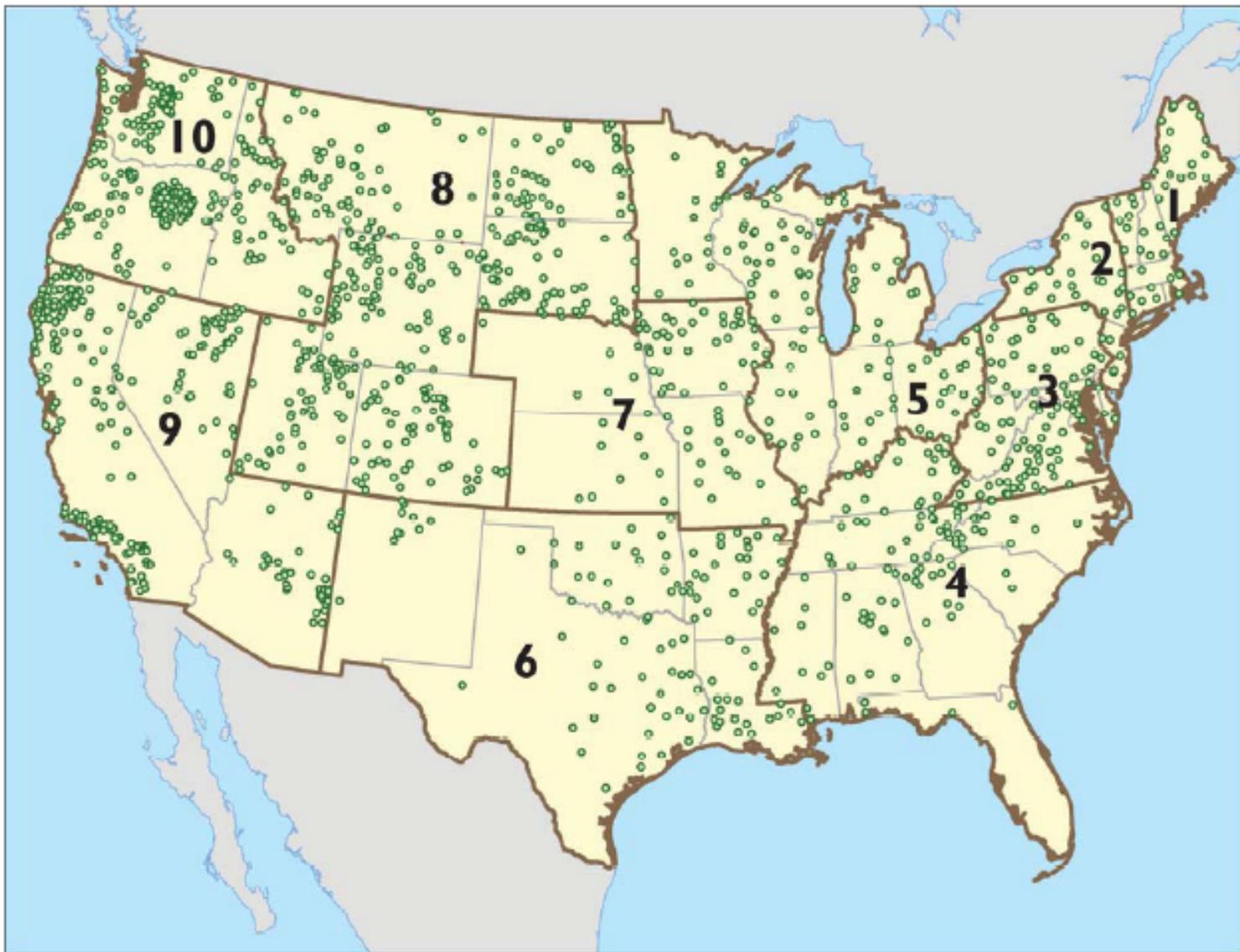
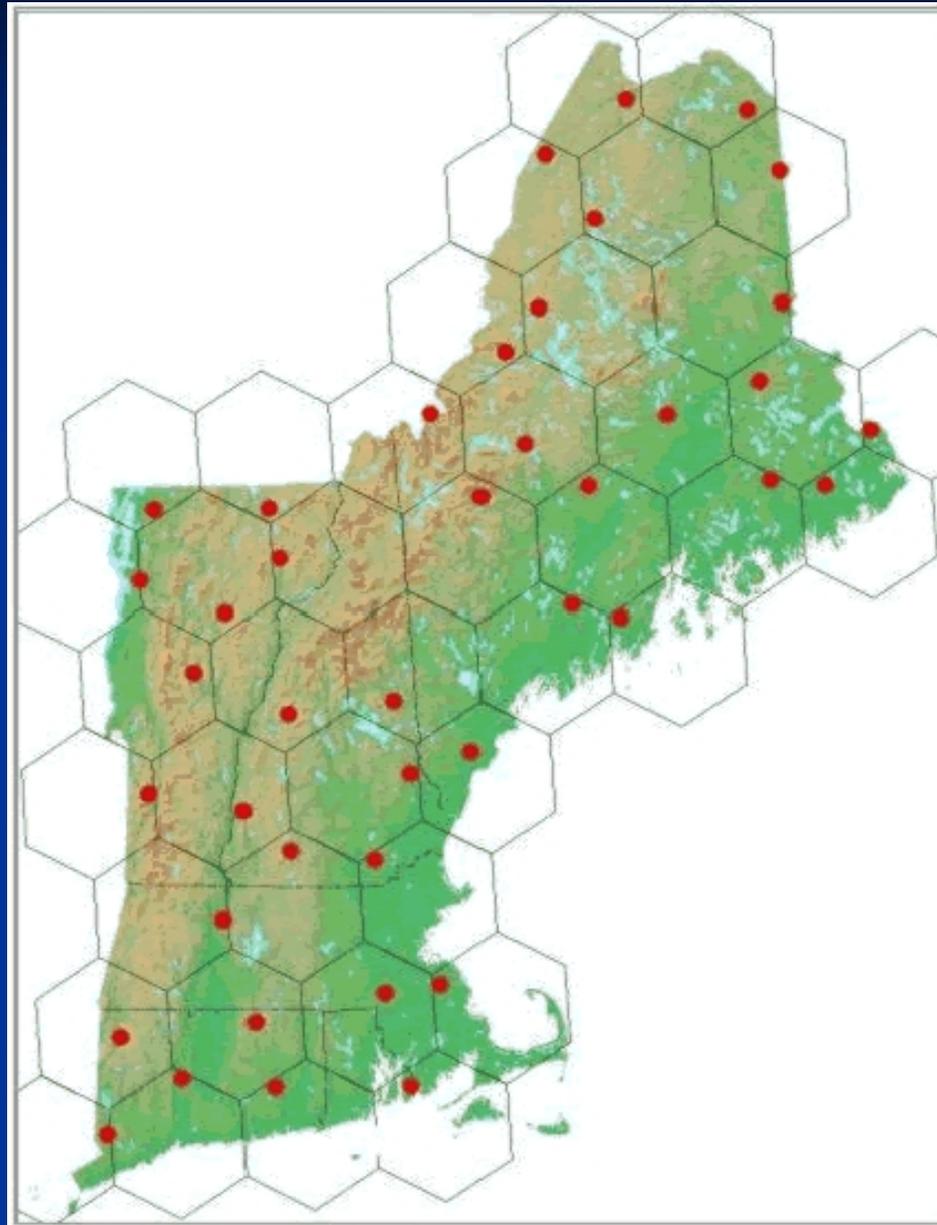
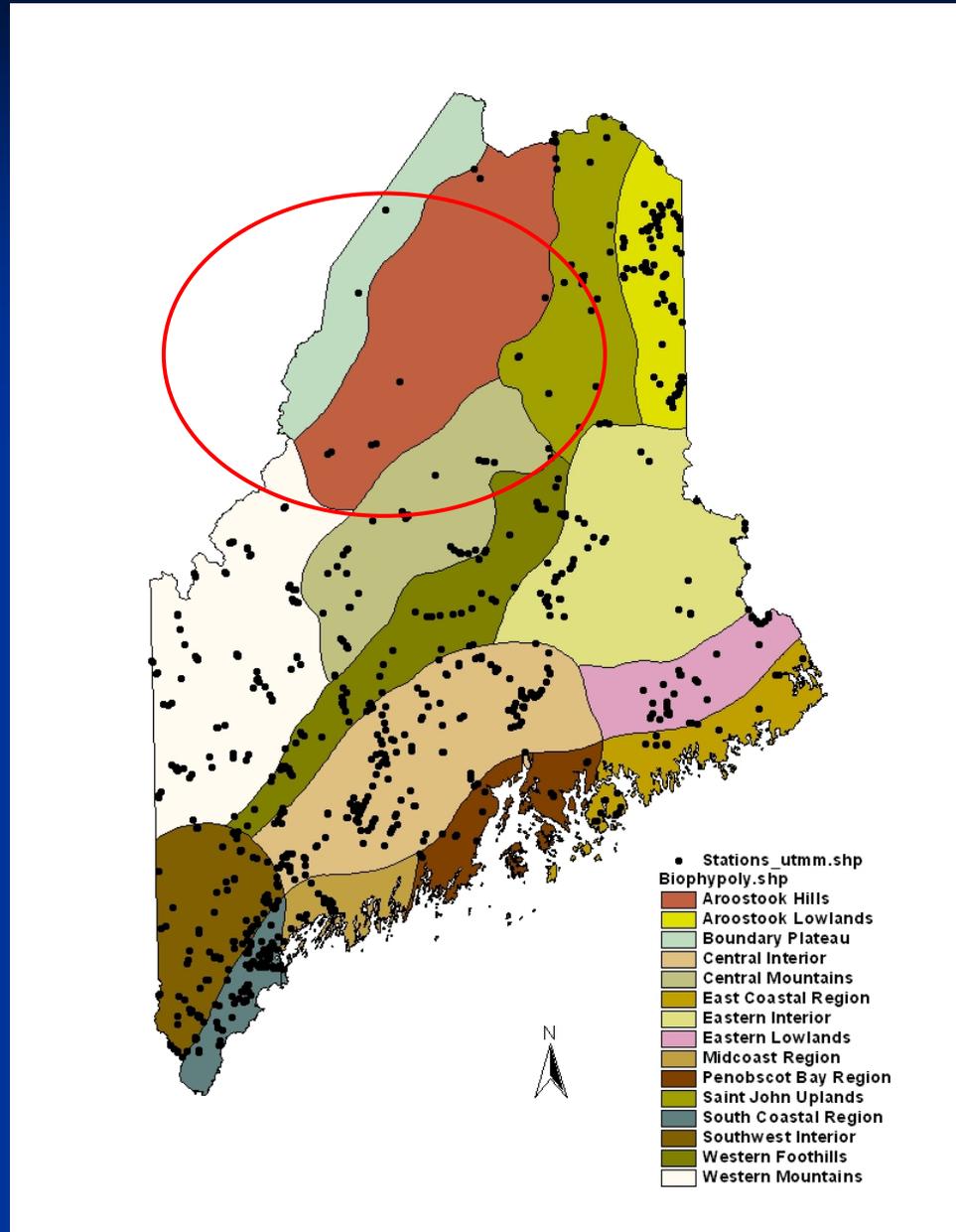


Figure 10. Sites sampled for the WSA by EPA Region (U.S. EPA/WSA).

# REGIONAL - NEWS

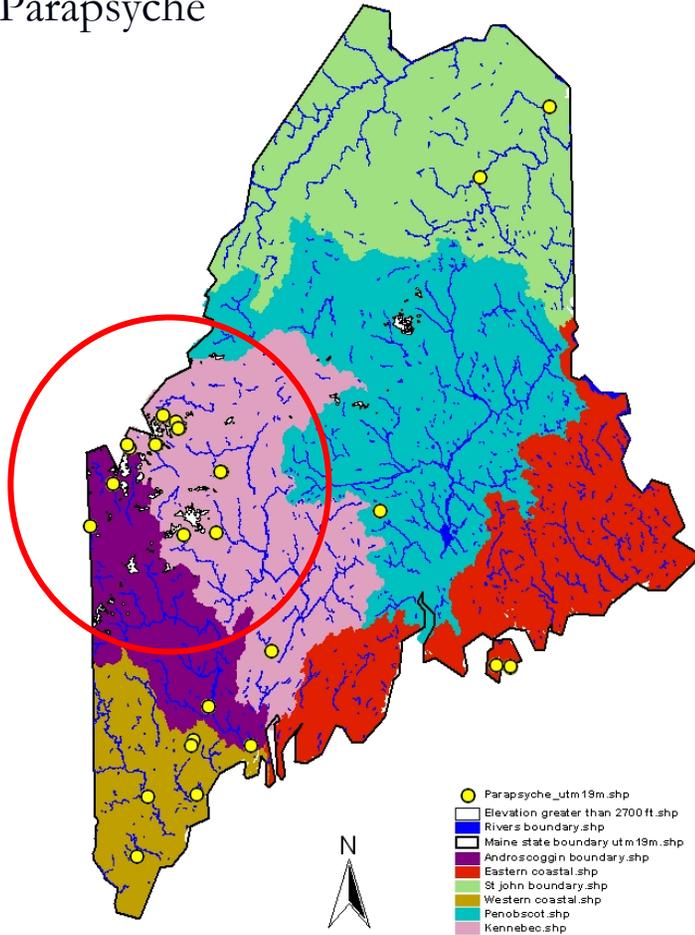


# STATE – Maine's Biomonitoring Database

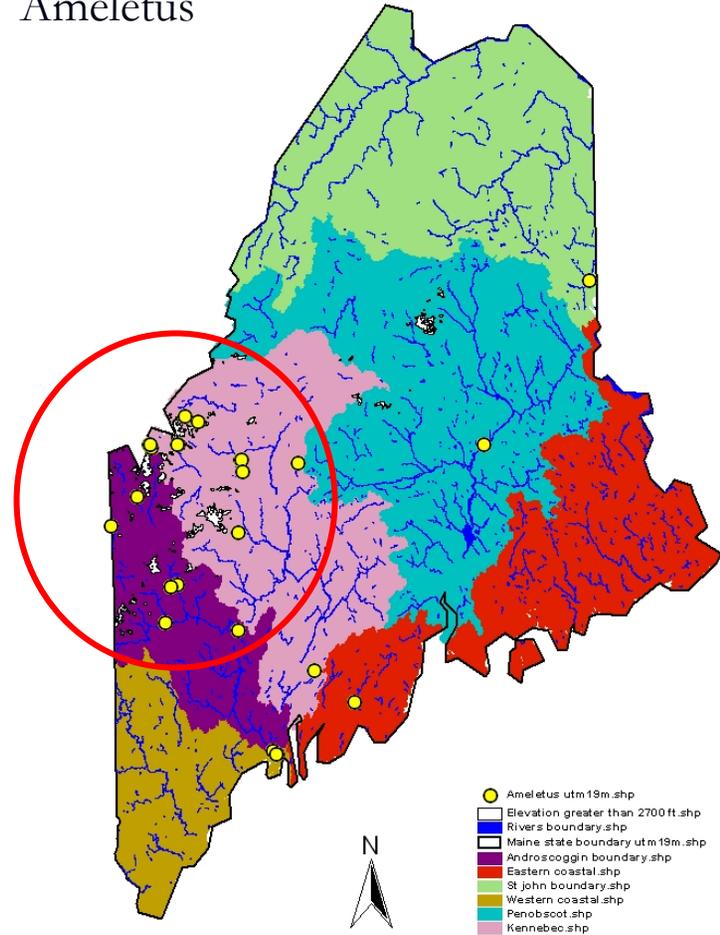


# Examples of taxa with localized populations

Parapsyche



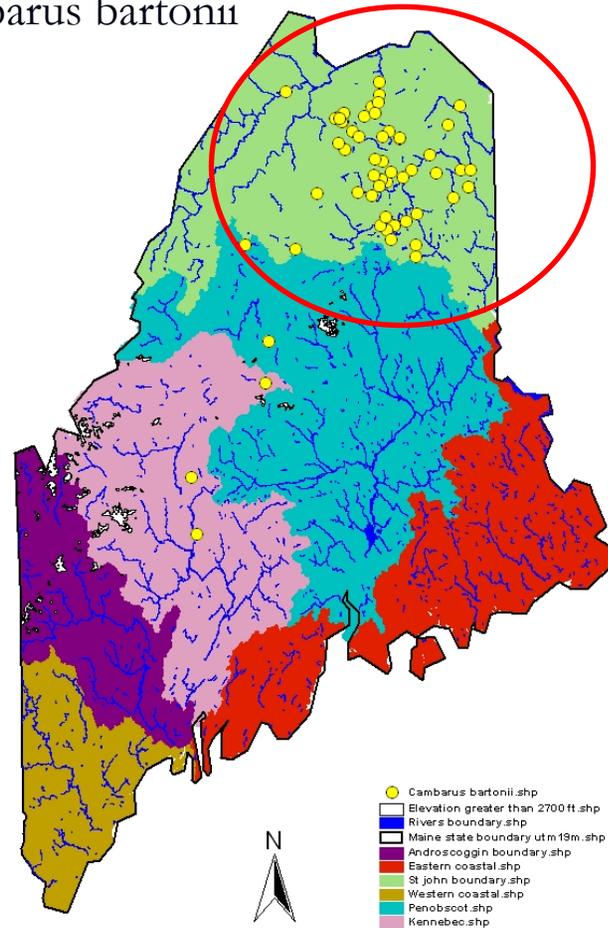
Ameletus



# Another taxa with localized populations...

<http://pearl.spatial.maine.edu/windows/biodiversity/invertebrates.htm>

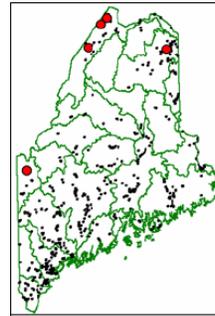
*Cambarus bartonii*



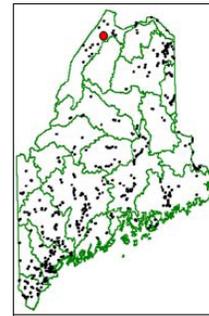
PEARL Biodiversity Project

Once again,  
species-level IDs  
are important...

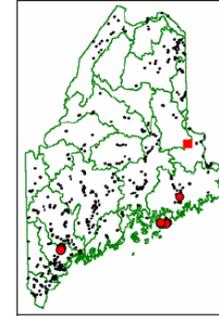
## RHYACOPHILIDAE



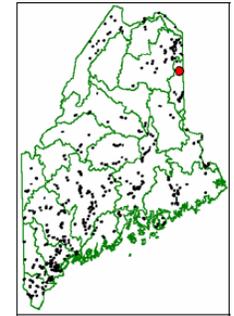
*Rhyacophila acutiloba*



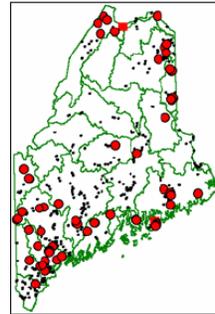
*Rhyacophila brunnea*



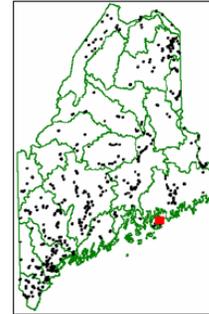
*Rhyacophila carolina*



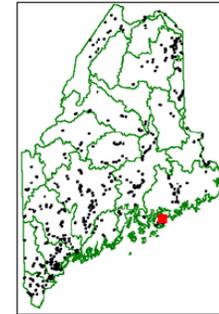
*Rhyacophila fenestra*



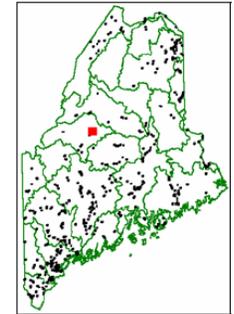
*Rhyacophila fuscula*



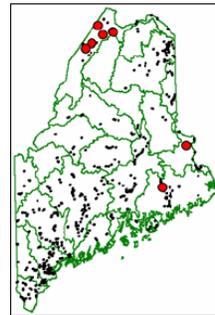
*Rhyacophila glaberrima*



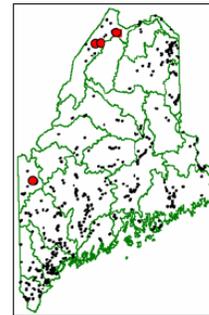
*Rhyacophila invaria*



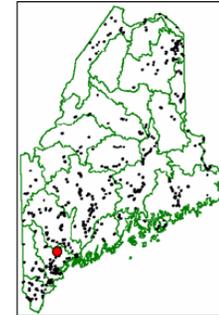
*Rhyacophila mainensis*



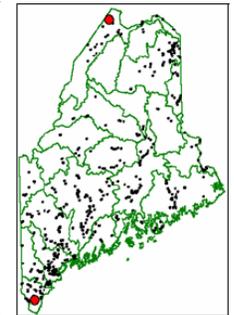
*Rhyacophila manistee*



*Rhyacophila melita*

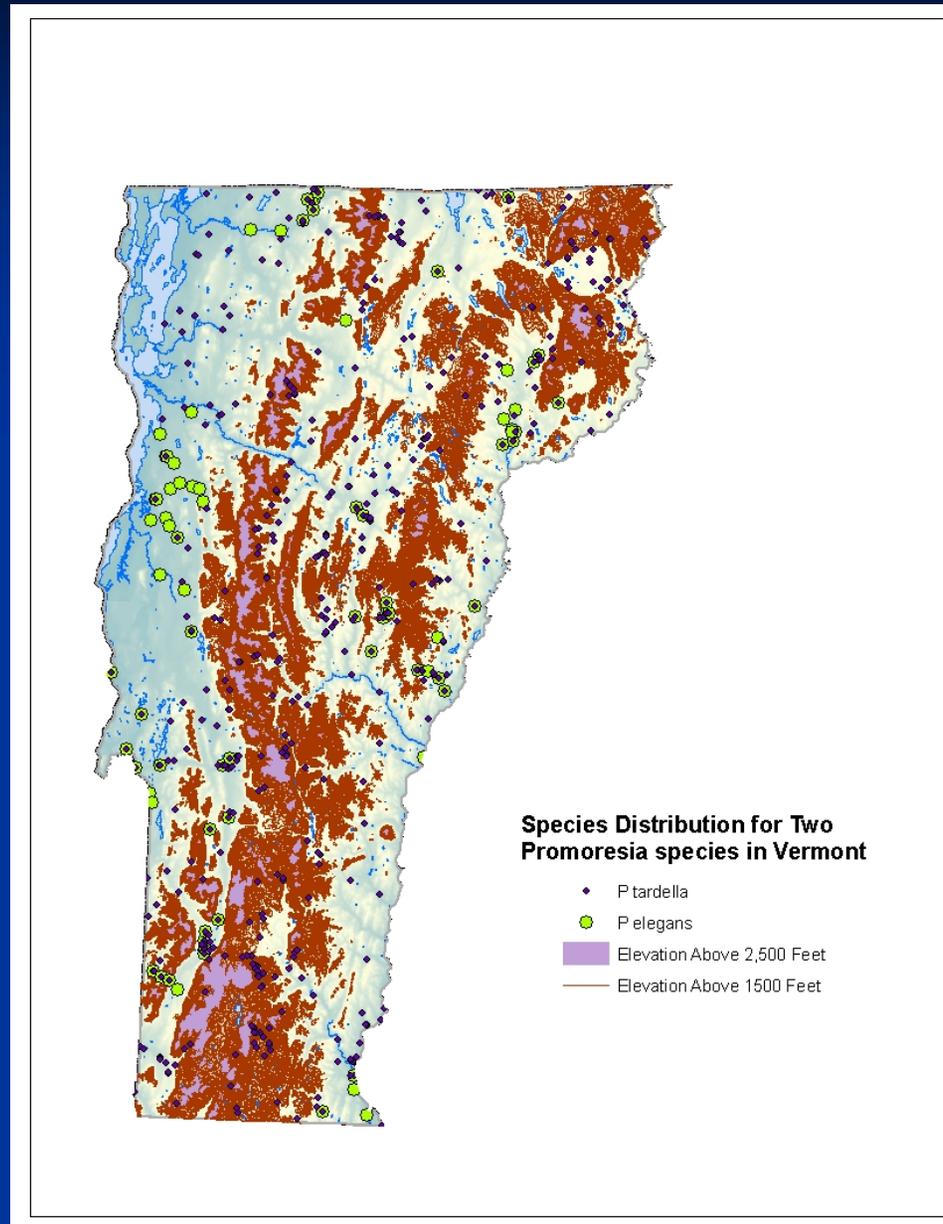


*Rhyacophila minor*



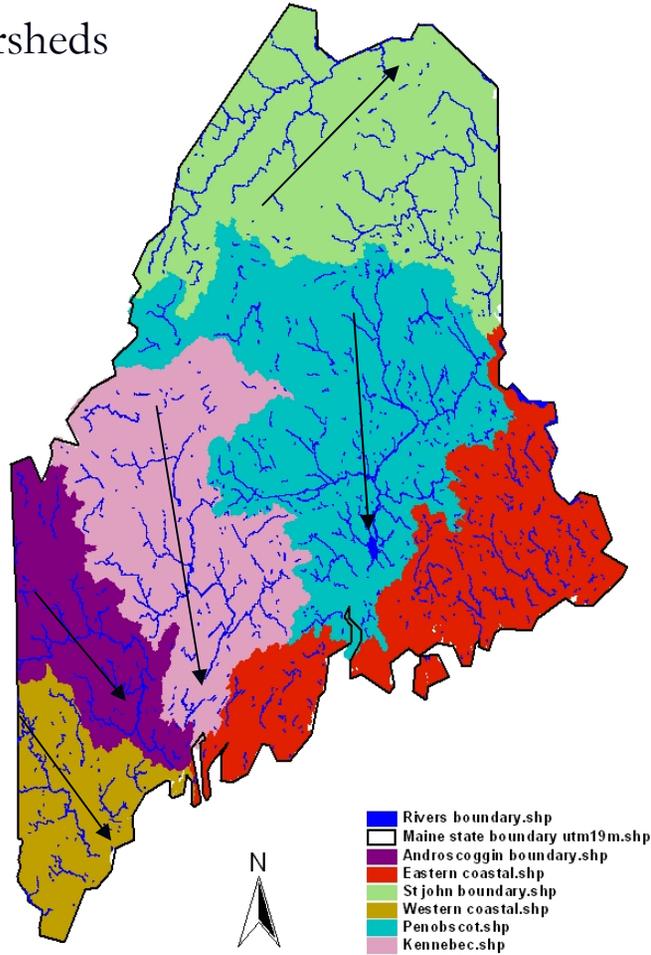
*Rhyacophila nigrita*

# *Promoresia elegans* vs. *Promoresia tardella*

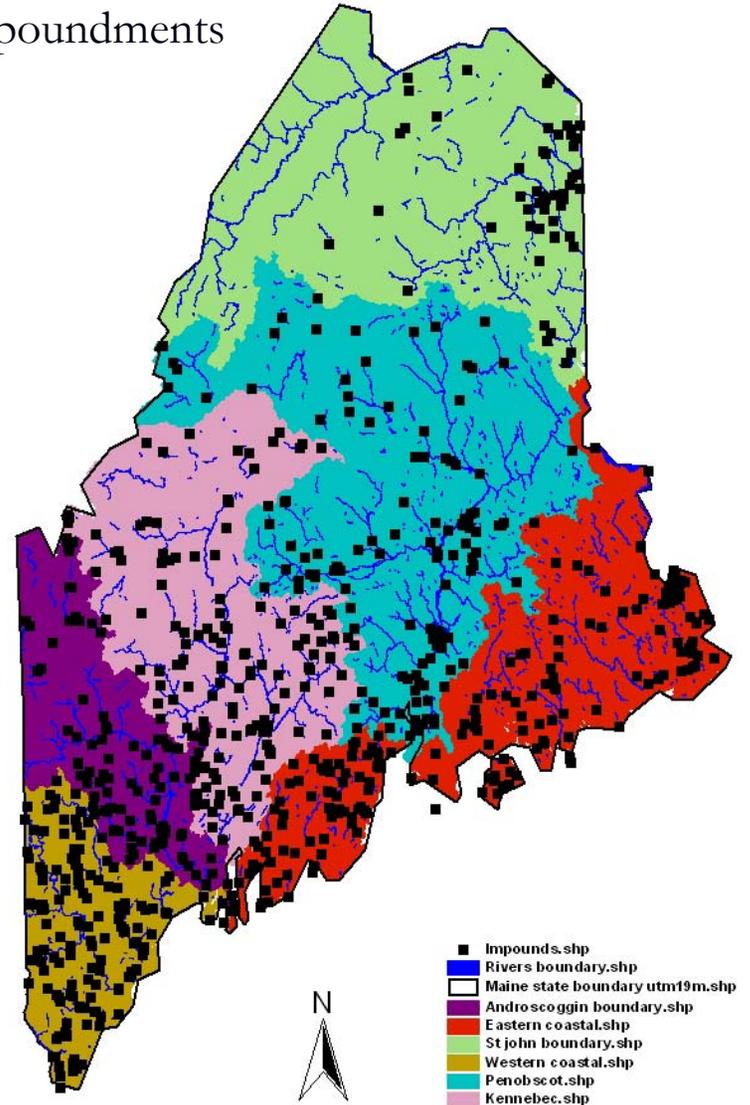


# FACTORS AFFECTING DISPERSAL ABILITY

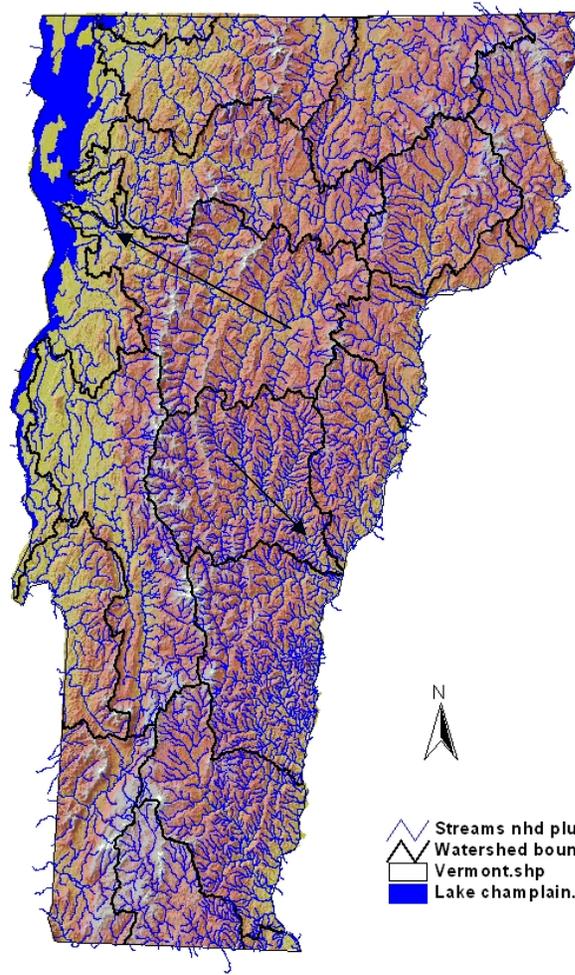
Orientation of watersheds



Impoundments



# FACTORS AFFECTING DISPERSAL ABILITY



Topography, Orientation

# Attributes database

- A compilation of all the trait information in a format that can be analyzed
- This is an Access database that can be linked to taxa lists via FinalID
- Limitation: lots of information on some taxa, virtually nothing on others
- We are documenting where the gaps in the knowledge exist
- Traits-based analyses have a lot of potential

## Example of traits data that has been transformed from a narrative form into numerical values that can be analyzed...

Order	Family	Genus	Code	[1] Volt	[2] Devl	[3] Sync	[4] Life	[5] Disp	[6] Flgt	[7] Exit	[8] Drft	[9] Crwl	[10] Swim	[11] Atch	[12] Armr	[13] Rheo	[14] Desi	[15] Shpe	[16] Size	[17] Habi	[18] Trop	[19] Ther	[20] Resp	
COLEOPTERA	Dryopidae	Helichus	CDrHe	1	2	1	3	1	1	1	1	1	1	1	3	3	1	2	1	4	3	2	3	
		Pelonomus	CDrPe	1	3	1	3	1	1	1	1	1	1	1	3	2	1	2	1	2	3	2	3	3
	Dytiscidae	Agabus	CDyAg	1	2	1	3	2	2	2	1	3	3	1	3	2	1	1	2	5	4	2	3	3
		Hydroporus	CDyHy	1	2	1	3	2	2	2	1	3	3	1	3	1	1	1	2	5	4	2	3	3
		Oreodytes	CDyOr	1	2	1	3	2	2	2	1	3	3	1	3	1	1	1	2	5	4	2	3	3
	Elmidae		CEl--	1	3	1	3	1	1	1	2	2	1	1	2	2	2	2	1	4	1	2	1	1
	Haliplidae	Brychius	CHaBr	2	2	2	3	1	2	2	1	2	2	1	3	3	1	2	1	4	3	1	2	2
	Psephenidae	Ectopria	CPsEc	1	2	2	2	1	1	1	1	1	1	2	3	3	1	1	2	4	3	2	2	2
		Psephenus	CPsPs	1	2	2	2	1	1	1	1	1	1	2	2	3	1	1	2	4	3	2	2	2

VOLTINISM - semivoltine = 1, univoltine = 2, bi- or multivoltine = 3

THERMAL PREF – cold stenothermal =1, cool/warm eurythermal =2, warm eurythermal = 3

ABILITY TO SURVIVE DESICCATION – absent =1, present = 2

2006. **N. LeRoy Poff.** Functional trait niches of North American lotic insects: traits-based ecological applications in light of phylogenetic relationships. *JNABS* 25(4):730-755.

## Euro-limpacs <http://www.freshwaterecology.info/>

- LOTS of ecological parameters (similar to above, plus things like altitudinal preference, etc.)
- Macroinvertebrates, diatoms and fish
- Transformation to numerical values using 10 point system or yes/no



# Closing thoughts...

- We'll need the help and input of taxonomists & experts with long-term knowledge
- Lack of knowledge=major obstacle for analyzing impact of emerging stressors like climate change
- Think about which sites will likely be most sensitive to the effects of climate change in your state (think about ephemeral streams and vernal pools too). Which taxa inhabit these sites? Can these sites be monitored?
- Think about which taxa possess traits that we just discussed
- Long-term data sets are of great importance. We've collected lots of data over the years. We need to gather it and figure out a way to use it.
- Are we recording the right kind of information?
  - Things that might be worth keeping track of that you may not currently be keeping track of –
    - Developmental stage – i.e. instar stage, max/min size of taxa at each site
    - Species-level IDs (especially for possible indicator taxa)
    - Timing of hatches (have a call in number for fly fishermen!)
- Considering degree days as opposed to just calendar days when setting sampling periods
- Keep a close eye on invasives

# Acknowledgments

**Tetra Tech** - Anna Hamilton, Lei Zheng, Jeroen Gerritsen, Erik Leppo, Mike Paul, Michael Barbour, Ben Jessup

**US EPA** - Britta Bierwagen

**Vermont DEC** – Doug Burnham, Steve Fiske, Brian Duffy, Rich Langdon, Jim Kellogg

**Maine DEP** – Leon Tsomides, Tom Danielson

**LeRoy Poff**- Colorado State University

**Piet Verdonschot** – Euro-limpacs

# QUESTIONS?

Jen Stamp

Tetra Tech

Montpelier, VT

[Jen.Stamp@tetrattech.com](mailto:Jen.Stamp@tetrattech.com)

(802) 229-1059

# Process for identifying indicator taxa

## Euro-limpacs

- Cold stenothermic
- Distributions – localized, disjunct, high elevation
- Springs (crenal)
- Specialists

The more of these attributes that a taxa has, the better indicator/more vulnerable it is

# Websites

Euro-limpacs

<http://www.freshwaterecology.info/>

Macroinvertebrates and diatoms

Euro-limpacs Consortium: Freshwaterecology.info - The Taxa and Autecology Database for Freshwater Organisms. Available from [www.freshwaterecology.info](http://www.freshwaterecology.info) (version [insert version number and date\*])

Fish

FAME consortium (2002): Development of a river-type classification system (D1); Compilation and harmonisation of fish species classification (D2). Report by R. Noble and I. Cowx. (Available from [http://fame.boku.ac.at/downloads/D1\\_2\\_typology\\_and%20species\\_classification.pdf](http://fame.boku.ac.at/downloads/D1_2_typology_and%20species_classification.pdf))  
and

Euro-Limpacs Consortium: Freshwaterecology.info - The Taxa and Autecology Database for Freshwater Organisms. Available from [www.freshwaterecology.info](http://www.freshwaterecology.info) (version [insert version number and date\*])

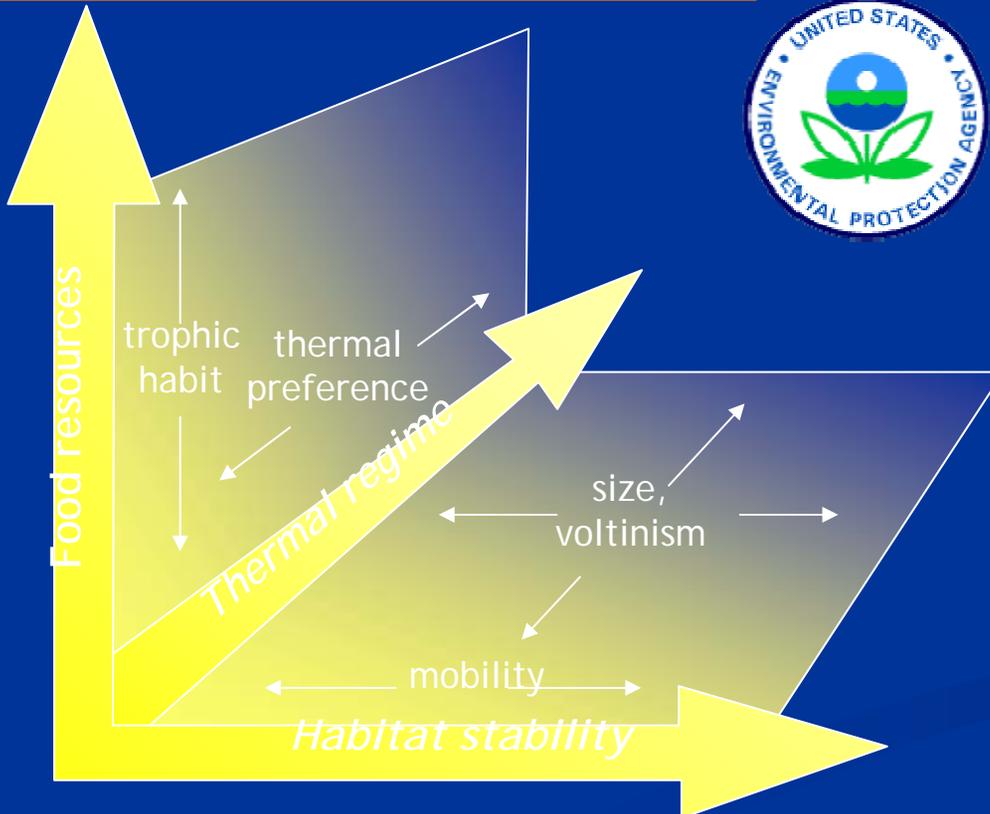
## Key Environmental Drivers

- Habitat structure & dynamics
- Temperature
- Food resources



## Species responses

- What traits should vary “mechanistically”?



Trait responses along environmental gradients

(Poff et al., JNABS, 2006)