An Intermittent Stream Bioassessment Tool for the Arizona-New Mexico Mountains Ecoregion of Arizona

David C. Richards, Cramer Fish Sciences, West Sacramento, CA

and

Patrice Spindler, Arizona DEQ

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Introduction and Background

Intermittent streams differ functionally and ecologically from perennial streams

(Anna et al. 2008, Bogan et al. 2013)

Water quality standards for intermittent streams should probably be substantially different than standards developed for perennial streams

(URS 2006)

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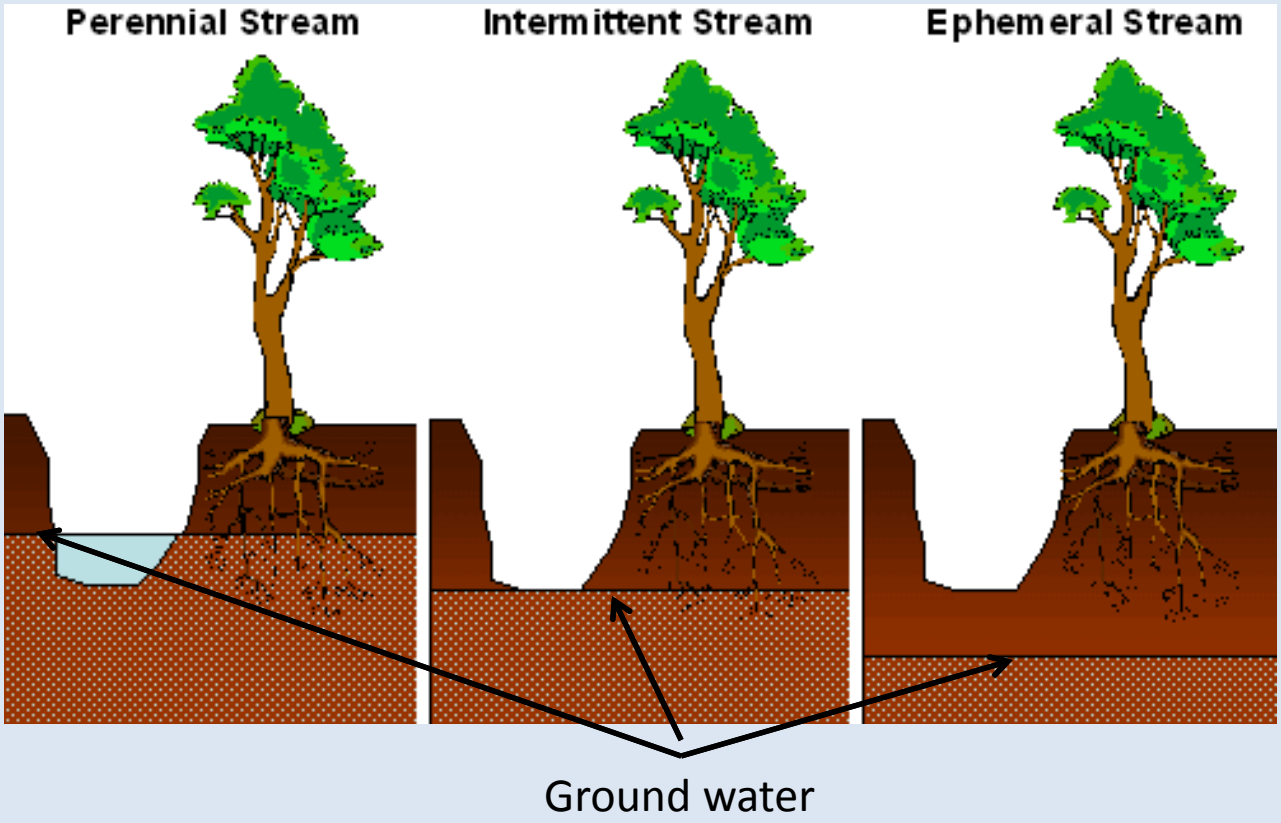
Perennial vs. Intermittent vs. Ephemeral



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- Perennial
  - Year-round flow
  - Base-flow maintained by ground-water discharge
  - Ground-water elevation higher than streambed elevation

- Ephemeral
  - Flow briefly in direct response to precipitation in the immediate vicinity
  - Channel is at all times above groundwater

- **Intermittent**
  - Flow continuously only at certain times of the year
    - such as melting snow (i.e. seasonal)
  - At low flow there may be dry segments alternating with flowing segments
  - Channel and ground water elevation similar

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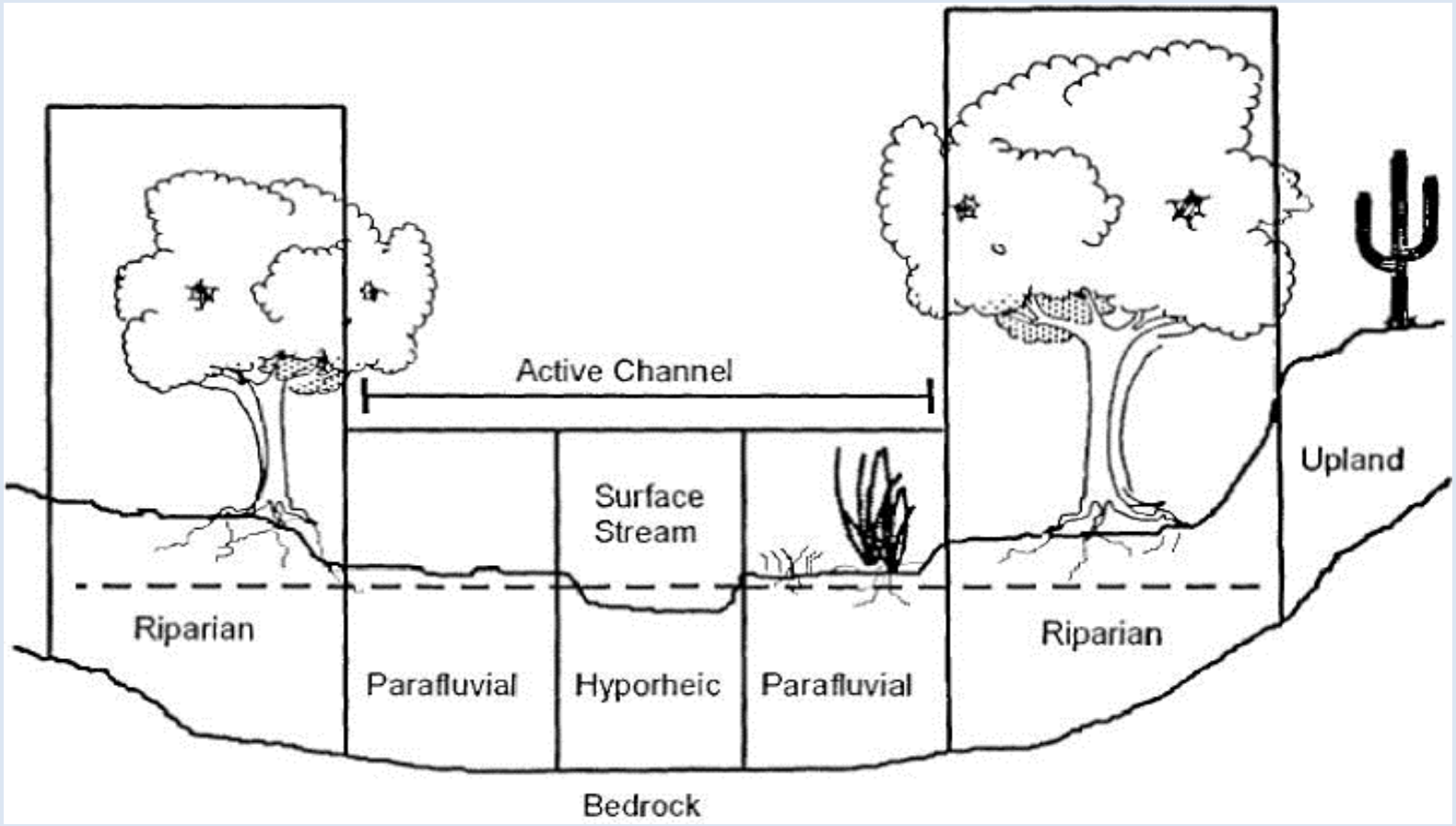
Hyporheic and Parafluvial Zones Important



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Intermittent Stream Habitats

- Riffles
  - Similar to perennial streams
- **Pools**
  - Persist longer than riffle habitats during intermittency
  - Provide temporary refugia for riffle biota
  - Likely to have taxa not found in riffles
  - Community structure and functioning: abiotic to biotic
  - Biotic interactions become more intense as the surface area and volume of the wetted habitat decreases
- **Hyporheic zone**
  - Area between the surface stream and alluvial ground water
- **Parafluvial zone:**
  - Part of the active channel without surface water during intermittency

Perennial vs. Intermittent Stream Benthic Macroinvertebrate Assemblages (BMAs)

- Significantly lower richness despite connectivity to upstream species-rich perennial reaches
- Not a subset of perennial taxa but a suite of taxa with adaptations to intermittency
- Unique or locally rare taxa
- Seasonal variability and duration of intermittency important

Bogan et al. 2013

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Intermittent Stream BMI Traits (Resistance and Resilience)

- Body armor
- Voltinism-short lived taxa
- Respiration adaptations
  - E.g. aerial breathers
- Desiccation resistance
- Non-seasonal development
- High crawling rate
- Strong dispersal ability
  - e.g. adult flyers
- Burrowers

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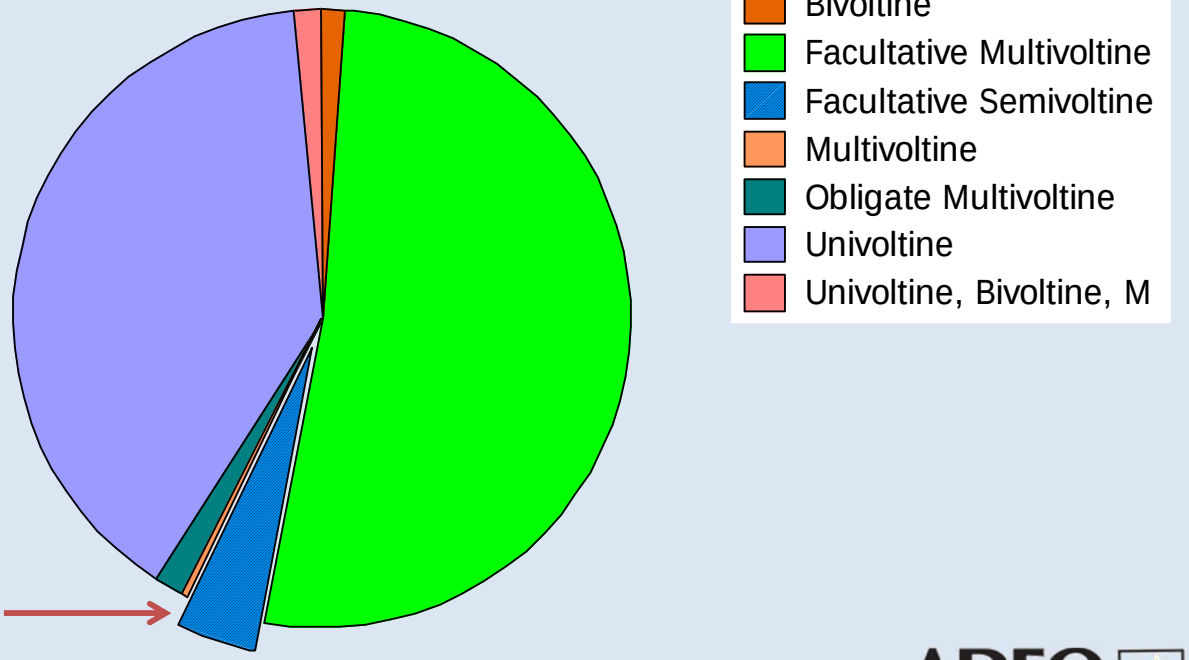
Voltinism: Intermittent vs. Perennial

- Semivoltine (long lived)
  - Intermittent = 4%
  - Perennial = 19%

AZ Intermittent Streams



Semivoltine

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FFGs

- Functional Feeding Group (FFG) shifts ?
  - Perennial vs. intermittent ?
    - Not enough data/understanding
  - Seasonal Intermittent FFGs
    - High flow to low flow:

↑ Predators

↓ Collector-filterers and Shredders

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Bogan and Lytle 2007


Perennial Stream MIBI not useful for classifying intermittent stream impairment

- > 95% of streams in AZ are intermittent or ephemeral
  - Disproportionate focus on perennial stream MIBIs
  - Bioassessment tool needed for Intermittent streams

- 61 intermittent streams evaluated using AZ perennial stream MIBIs
  - 92% were classified as either in violation or inconclusive
    - Taxa Richness (and its associated affects on other metrics)
    - HBI scores

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Intermittent IBI Development

- Round 1:
  - Exploratory analysis with existing datasets
  - Determine if perennial index can be adjusted to assess intermittent streams
  - Identify best metrics for intermittent streams
- Round 2:
  - Focused on one ecoregion
  - Multihabitat samples
  - Develop tool to differentiate reference from sediment stressed samples

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Round 1: The Beginning

Belostomatid bug attacking snake

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Original AZ Data Set

- 136 intermittent stream samples:
  - 79 cold water
  - 57 warm water
- *A priori* condition categories:
  - Reference
  - Non-reference
  - Stressed
    - Sedimentation

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Ecoregion Sites

Ecoregion	Riffle Sites	Multihabitat Sites	Source	Basins
AZ/NM Mountain	11	Cold = 8 Warm = 8	Snowmelt, Spring, Regulated	Salt and Verde
Arizona/NM Plateau	3	0		
Southern Basin and Range	3	0		
Southern Desert	6	0		
Total	23	16 (32 samples)		

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Statistical Methods

- Non-Metric Multidimensional Scaling (NMS)
- Mantel tests and Multi-response permutation procedure (MRPP)
- Indicator Taxa Analysis
- Metric comparisons (N = 12)

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Results

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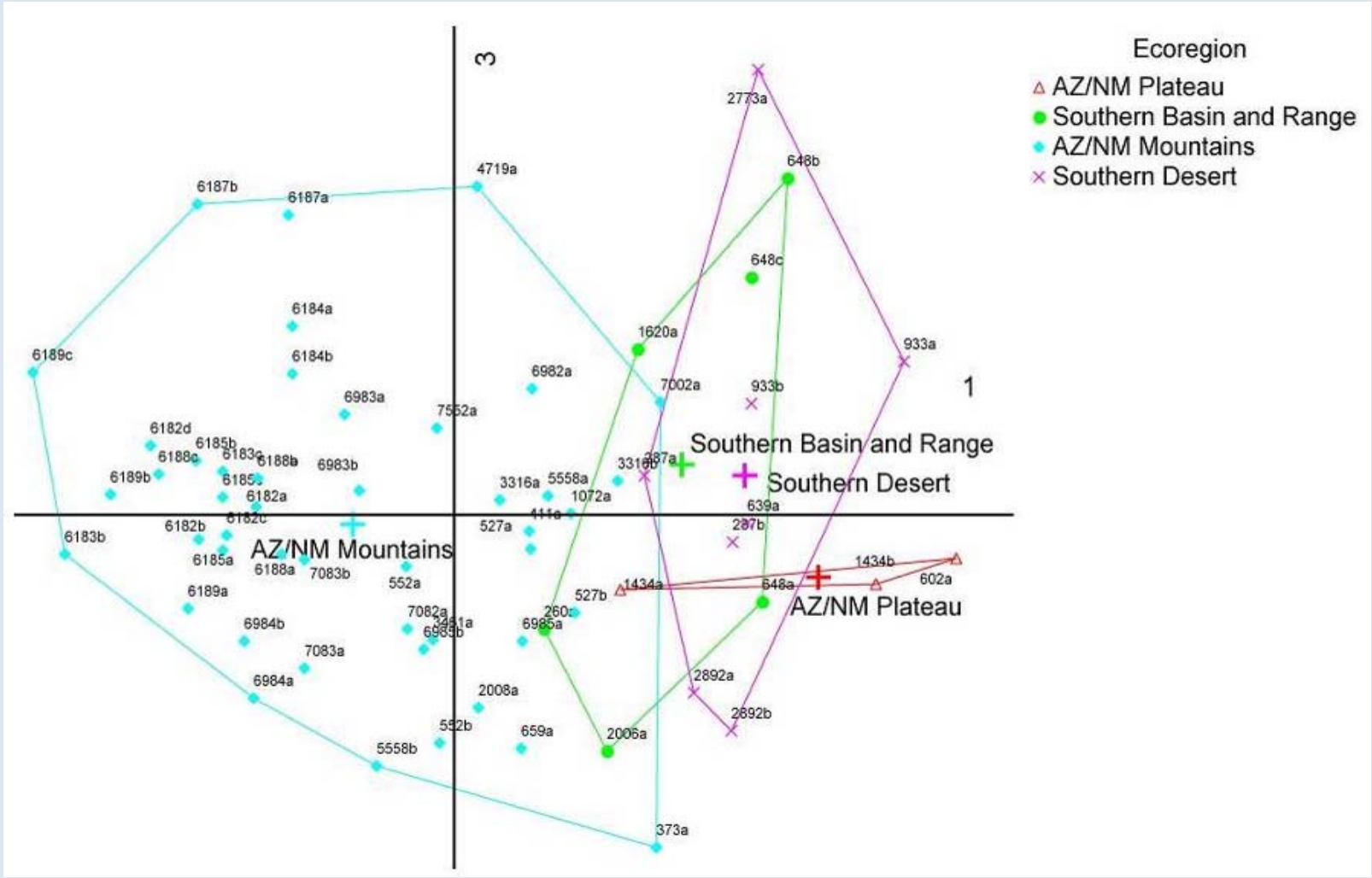
Ecoregion



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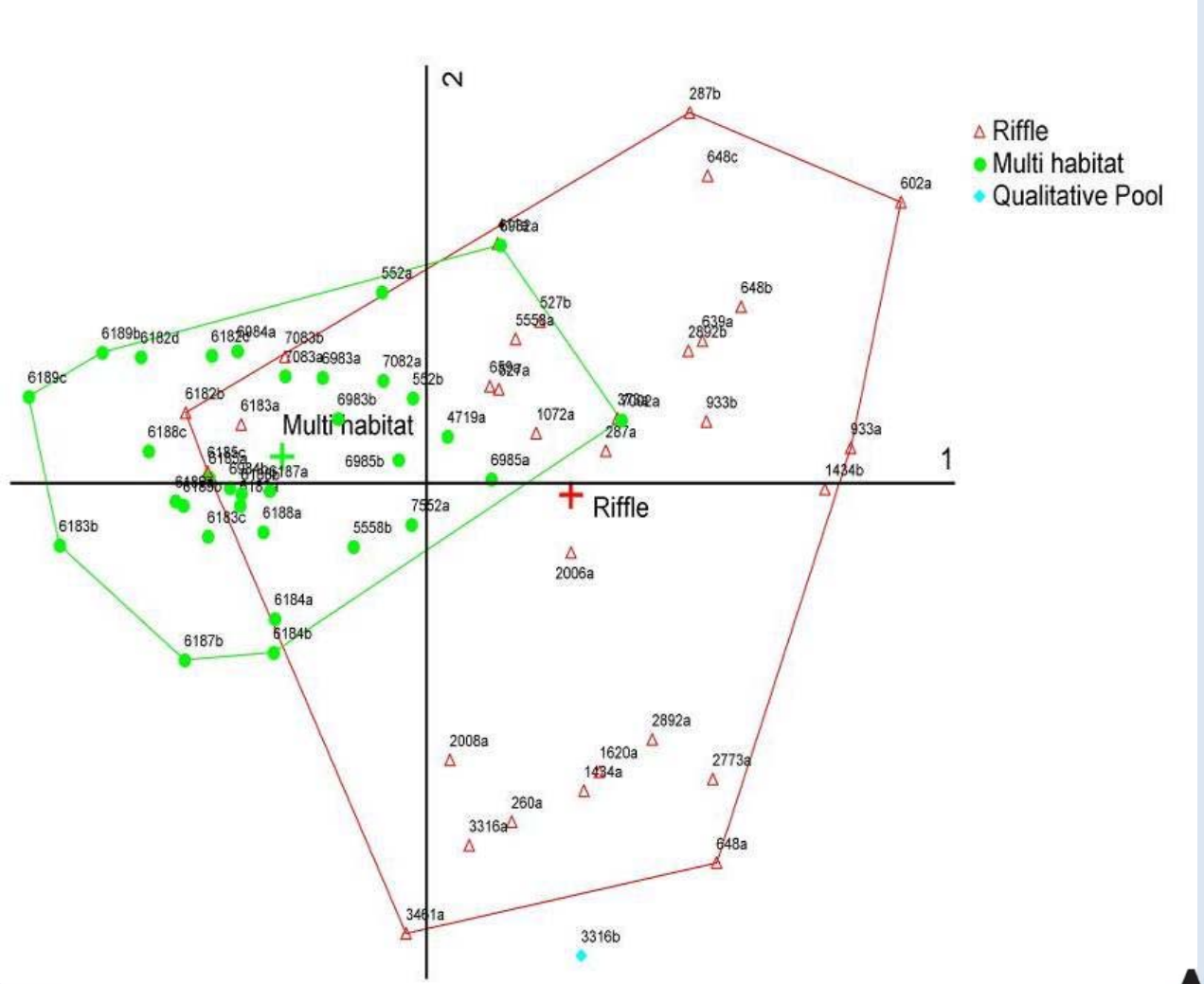
Riffle vs. Multi Habitat



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BMAs and Environmental Variables

- Significant correlations:
  - **Ecoregion**
  - **Condition: r**eference, non-reference, and stressed
  - **Elevation**
  - Straight line **Distance** to perennial
  - **Temperature** (Cold vs. Warm)
  - **Sediment** metrics: % Embeddedness, % Fines
  - **Source**: spring fed, snowmelt, snowmelt-regulated, and regulated-altered
- No correlation:
  - **Watershed size** (unknown if this is a true relationship or a bias of the dataset used)

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Potential Ecoregion Indicator Taxa

Ecoregion	Order	Family	Genus/species	p-value
Arizona/New Mexico Plateau	Diptera	Stratiomyidae	*Euparyphus* sp.	0.01
	Odonata	Libellulidae	*Paltothemis lineatipes*	0.01
	Coleoptera	Dytiscidae	*Neoclypeodytes* sp.	0.01
	Coleoptera	Hydrophilidae	*Laccobius* sp.	0.01
	Odonata	Coenagrionidae	*Argia* sp.	0.01
	Diptera	Chironomidae	*Larsia* sp.	0.04
	Trichoptera	Philopotamidae	*Chimarra* sp.	0.04
	Diptera	Chironomidae	*Nilotanypus* sp.	0.08
Southern Basin and Range	Basommatophora	Physidae	*Physa* sp.	0.01
	Coleoptera	Elmidae	*Heterelmis* sp.	0.01
	Hemiptera	Naucoridae	*Ambrysus* sp.	0.01
Arizona/New Mexico Mountains	Diptera	Chironomidae	*Hydrobaenus* sp.	0.02
	Diptera	Chironomidae	*Krenosmittia* sp.	0.04
	Plecoptera	Taeniopterygidae	*Taenionema* sp.	0.05
	Diptera	Chironomidae	Diamesa sp.	0.05
	Plecoptera	Capniidae	NA	0.08
	Diptera	Chironomidae	*Orthocladius* sp.	0.08
Southern Deserts	Ephemeroptera	Leptophlebiidae	*Thraulodes* sp.	0.01
	Diptera	Chironomidae	*Lopescladius* sp.	0.01
	Trichoptera	Polycentropodidae	Polycentropus sp.	0.01
	Ephemeroptera	Leptohyphidae	*Homoleptohyphes* sp.	0.01
	Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	0.01
	Megaloptera	Corydalidae	*Corydalus* sp.	0.02
	Diptera	Chironomidae	*Tanytarsus* sp.	0.02
	Trichoptera	Hydrobiosidae	*Atopsyche sp.*	0.02
	Ephemeroptera	Tricorythidae	*Tricorythodes* sp.	0.04
	Trichoptera	Hydropsychidae	*Hydropsyche* sp.	0.04
	Trichoptera	Lepidostomatidae	*Lepidostoma* sp.	0.05
	Trichoptera	Hydroptilidae	*Neotrichia* sp.	0.05
	Diptera	Tipulidae	*Limonia* sp.	0.07
	Coleoptera	Hydraenidae	*Hydraena sp.*	0.08
	Trombidiformes	Sperchonidae	NA	0.08
	Diptera	Chironomidae	*Stempellinella* sp.	0.09
	Diptera	Chironomidae	*Rheotanytarsus* sp.	0.09
	Diptera	Chironomidae	Polypedilum sp.	0.10
	Coleoptera	Dytiscidae	*Liodessus* sp.	0.10
	Trichoptera	Helicopsychidae	*Helicopsyche* sp.	0.10

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Stream Condition Indicators

Condition	Taxon	p-value
Reference	*Atrichopogon* sp.	0.08
Non-reference	*Hydrochara* sp.	0.03
Stressed	Calopterygidae	0.04
	Helochares sp.	0.04
	Unidentified Chironomidae	0.05
	Stratiomyidae	0.07

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Sedimentation Indicators

Sedimentation measure		Taxon	p-value
Embeddedness	< 70%	*Caenis bajaensis*	0.07
		Polypedilum sp.	0.07
		Hydropsyche sp.	0.08
		Taenionema sp.	0.08
		Krenosmittia sp.	0.01
		Hydraena sp.	0.02
		Platysmittia sp.	0.06
	≥70%	*Orthocladius* sp.	0.05
Fines	< 45%	*Tvetenia bavarica* group	0.01
		Krenosmittia sp	0.07
		Eukiefferiella sp.	0.07
	≥ 45%	Calopterygidae	0.02
		Unidentified Chironomidae	0.02
		Apedilum sp.	0.04
		Physa sp.	0.05
		Ostracoda	0.06
		Micropsectra sp.	0.07
		Phaenopsectra sp.	0.07

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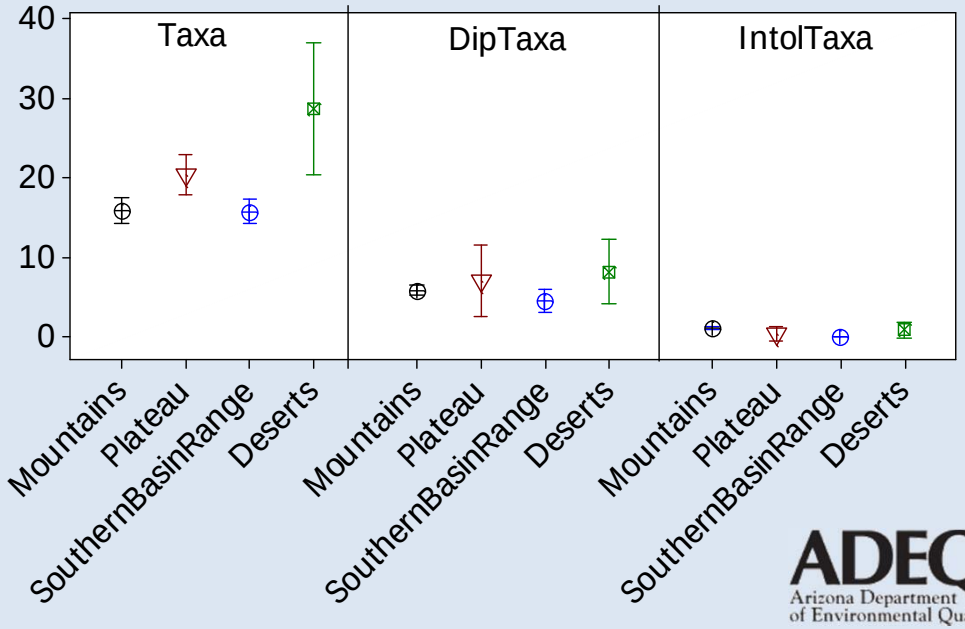
Metric Comparisons

- Compared AZ suite of 12 metrics by:
  - Ecoregion
  - Riffle vs. Multihabitat
  - Condition: Reference, Non-reference, Stressed
  - Temperature



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Proposed Metrics

- In addition to AZ metrics for perennial streams
  - **Voltinism and Short Lived Taxa**
  - **Distance or Dispersal**
  - **Hyporheic and Parafluvial**
  - **Flow Intermittency**
  - **Non-Native Taxa**
  - **Rare and Uncommon Taxa**

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- ***Importance of Invasive Taxa***
  - Invasives are stressors
  - Invasives are indicators of impairment: ↑ due to reduced R and R or loss of diversity?
  - Empty niche due to impairment? Etc.
    - Ex. NZMS

- ***Importance of Rare and Uncommon taxa***
  - Unique
  - Contribute much more to ecosystem function than previously acknowledged (Bracken and Low 2012)
  - Better indicators than cosmopolitan tramp species (e.g. *Baetis* sp.)

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Rare and Uncommon Taxa

Family	Taxon
Aeshnidae	Oplonaeschna armata sp.
Baetidae	Acentrella sp.
	Camelobaetidius sp.
Belostomatidae	Abedus sp.
Calopterygidae	Calopterygidae
Chironomidae	Alotanypus sp.
	Chaetocladius sp.
	Dicrotendipes sp.
	Epseudomontana group
	Nanocladius sp.
	Pagastia sp.
	Psilometriocnemus sp.
	Reomyia sp.
	Saetheria tylus
	Stictochironomus sp.
	Stilocladius sp.
Dryopidae	Postelichus sp.
Dytiscidae	Laccophilus sp.
	Liodessus sp.
Empididae	Clinocera sp.
Glossosomatidae	Culoptila sp.
Heptageniidae	Epeorus longimanus
Hydrophilidae	Enochrus sp.
Hydropsychidae	Hydropsyche sp.
Leptohyphidae	Leptohyphidae
Leptophlebiidae	Choroterpes sp.
	Thraulodes brunneus group
Lestidae	Lestidae
Limnephilidae	Hesperophylax sp.
Naucoridae	Ambrysus sp.
Nemouridae	Malenka sp.
Sperchontidae	Sperchonopsis sp.
	Sperchon sp.
Stratiomyidae	Hedriodiscus/Odontomyia
Tipulidae	Gonomyia sp.

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Recommendations

- Sample at one season: Spring
- Focus on AZ/NM Mountain Ecoregion
- Use Multihabitat Sampling Method

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Why Multi-habitat

- Intermittent streams often have; very low flows, no riffles, and only pool habitats during portions of the year
  - Multi-habitat sampling is more representative
- Mixed responses of riffle vs. multihabitat metrics to impairment
  - Couldn't combine the two data sets

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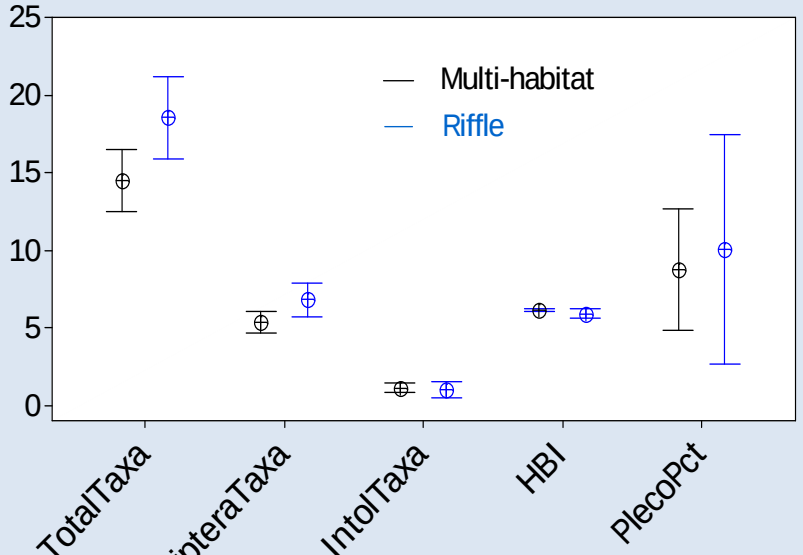
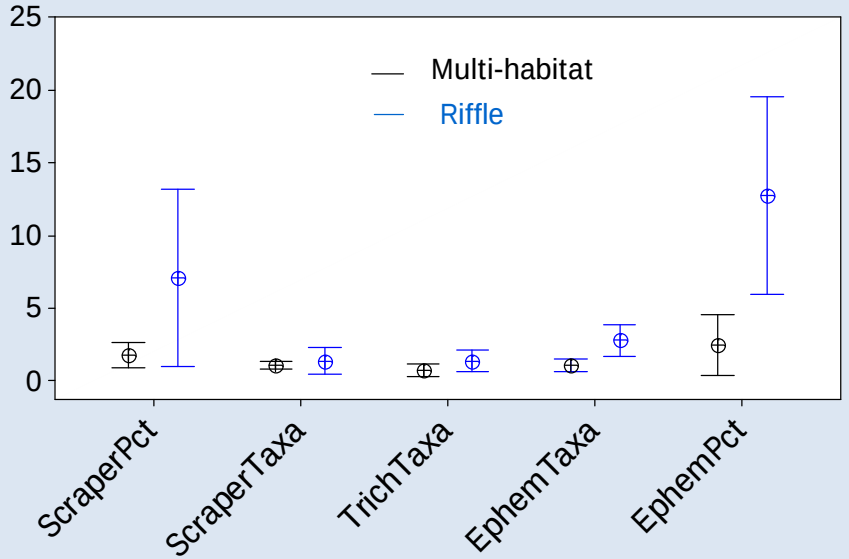
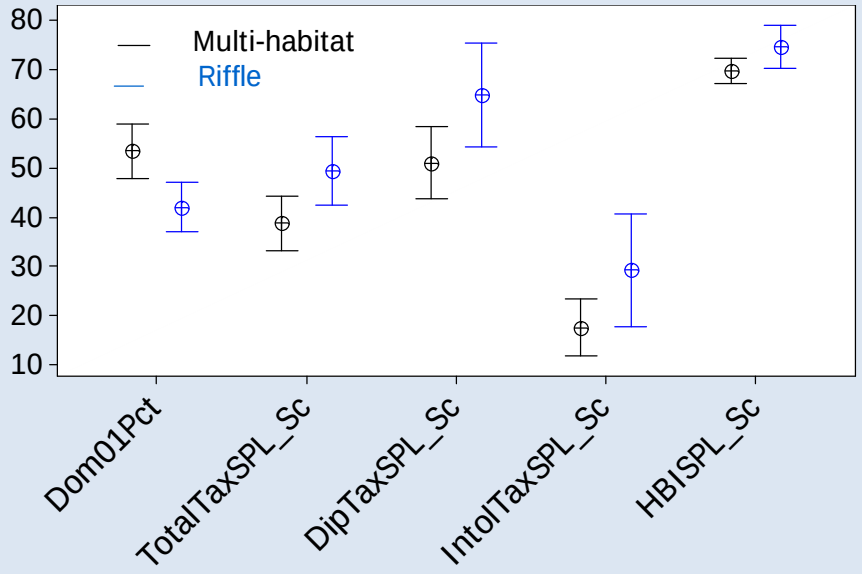
Riffle vs. Multi Habitat Metrics







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Round 2: Index Development

Belostomatid bug attacking turtle

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GOALS

- Develop AZ Intermittent stream MIBI, given the limited data sets
- MIBI should be able to:
  - Discriminate:
    - Reference vs. Stressed (= sedimentation)
    - Warm and Cold water
  - Testable and Modifiable

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Second Round Data

- AZ/NM Mountain Ecoregion only
- Multi-habitat samples:
  - 7 cold water sites: N = 11 samples
  - 8 warm water sites: N = 21 samples
- Spring index period only

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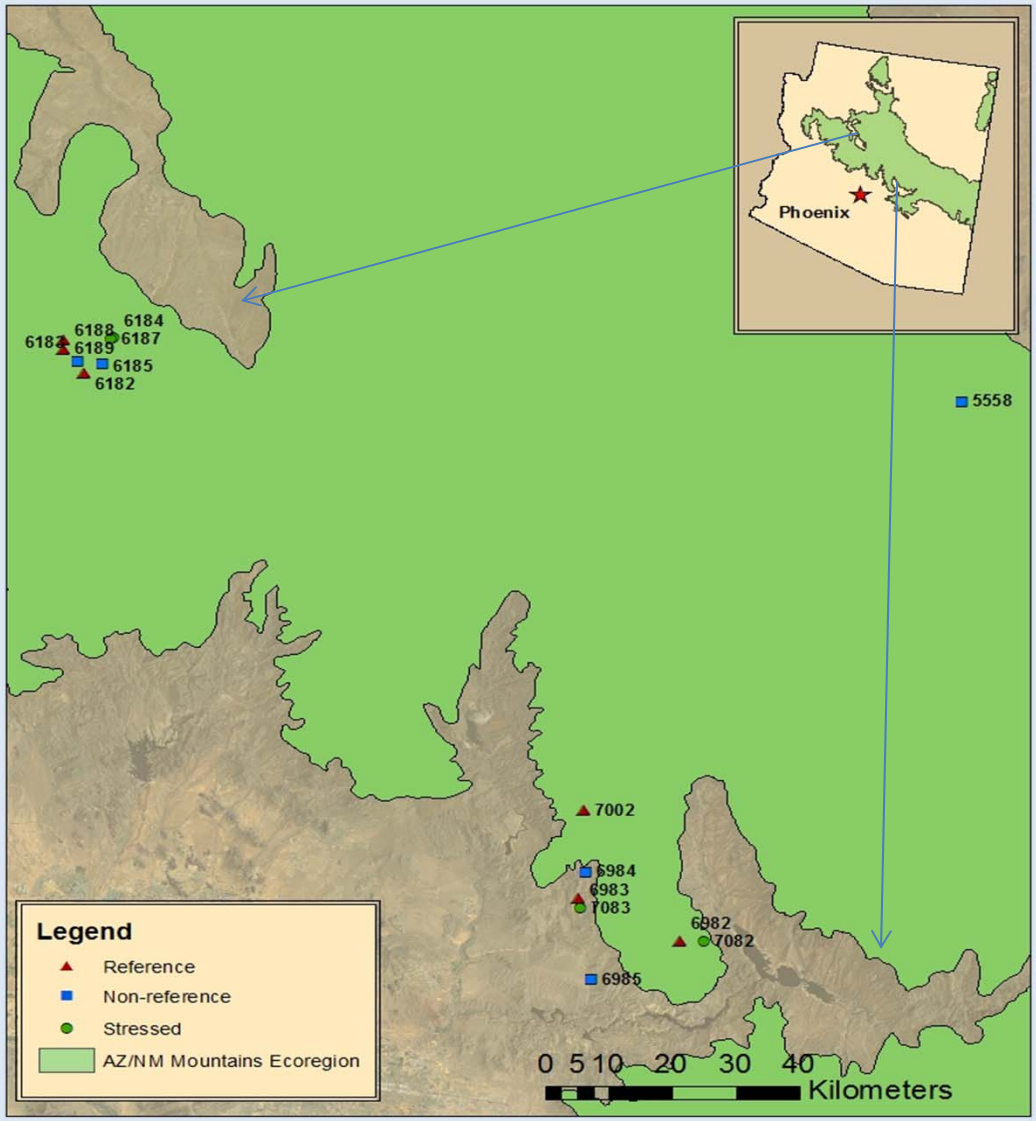
AZ/NM Mountain Ecoregion



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Statistics

- BMAs
  - Hierarchical Clustering
  - Non Metric Multidimensional Scaling (NMS)
    - Mantel correlations
  - Multi-Response Permutation Procedure (MRPP)

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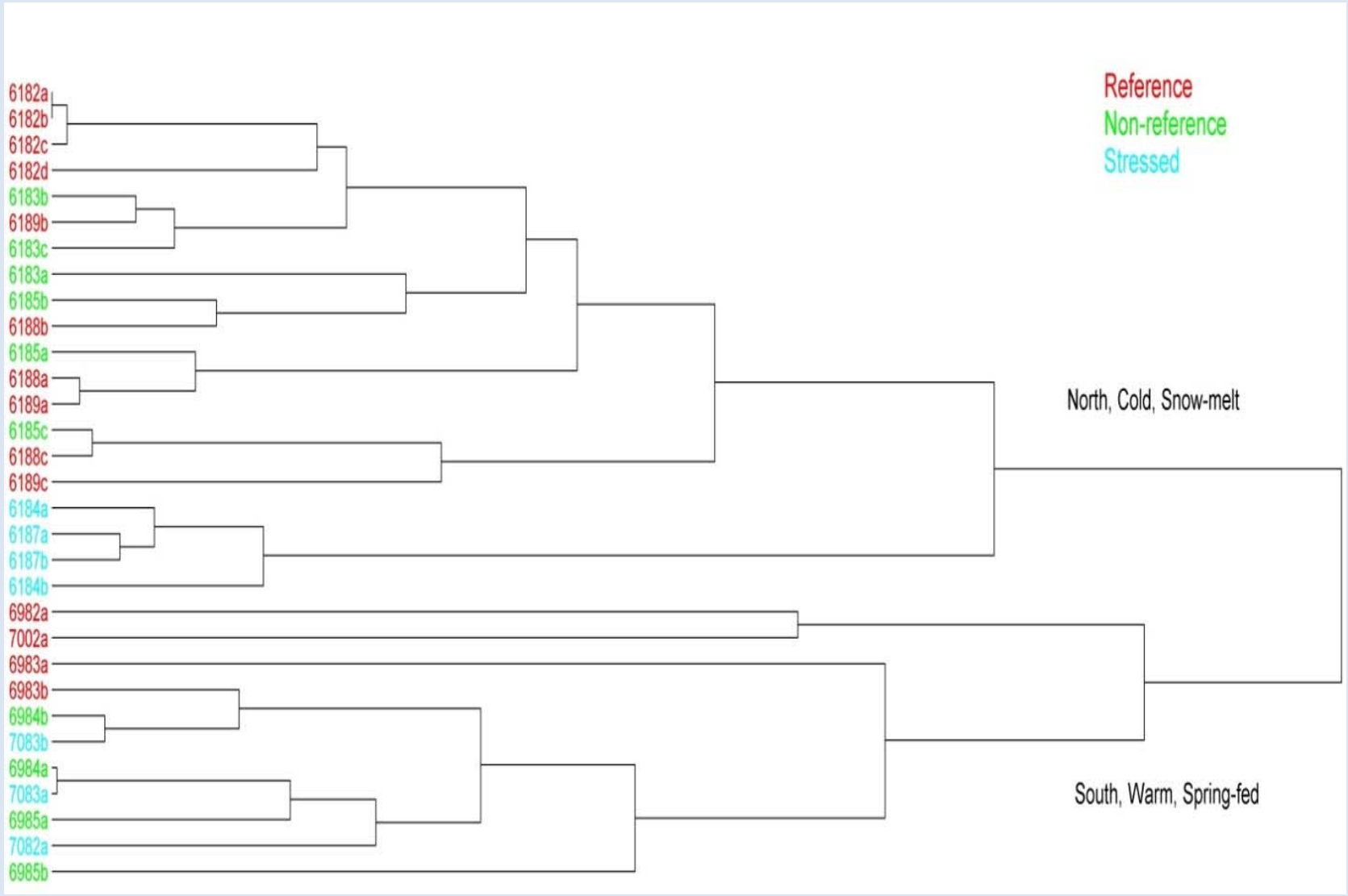

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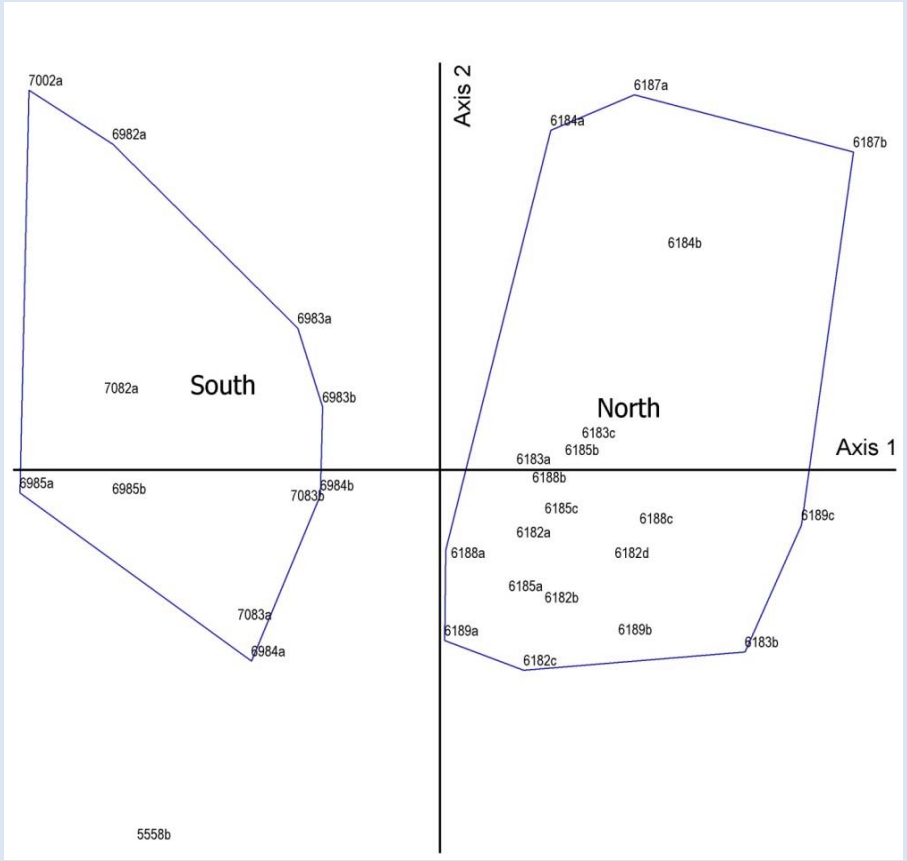
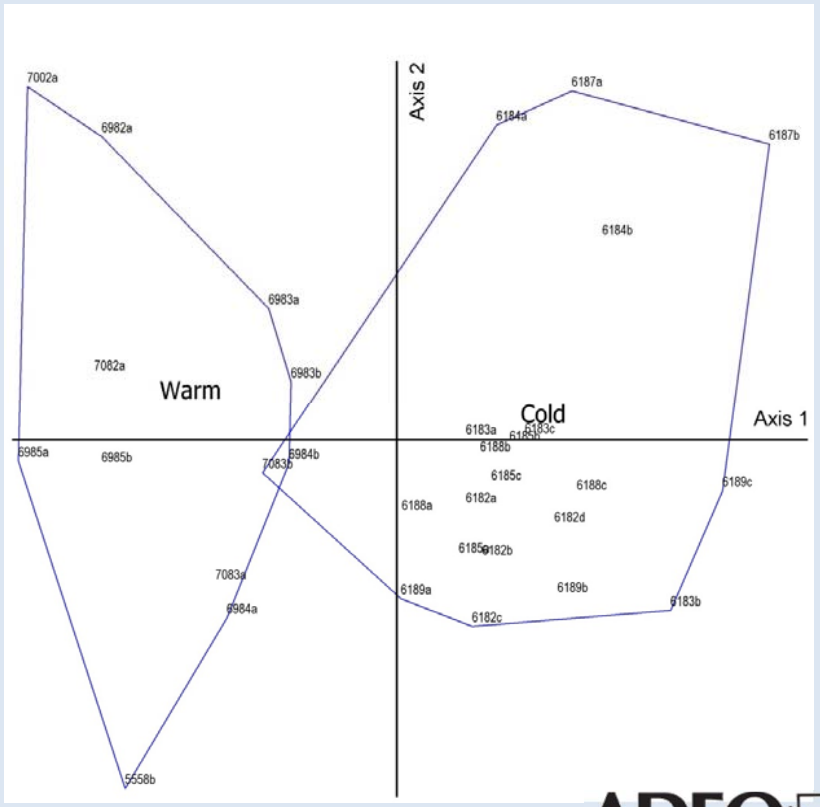
North vs. South



Warm vs. Cold



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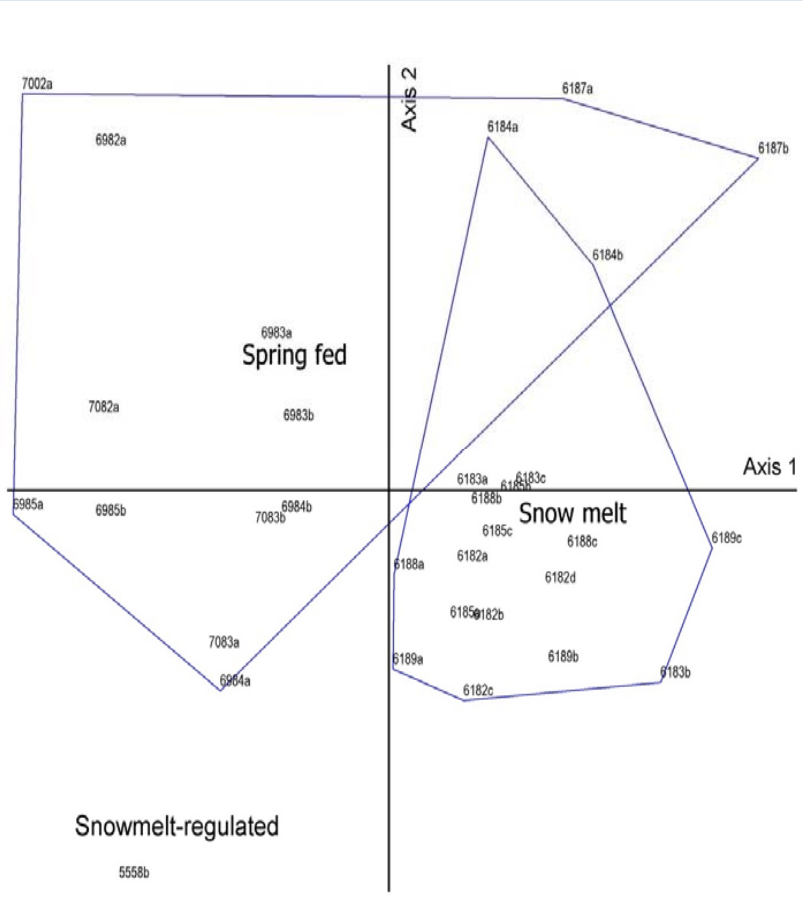
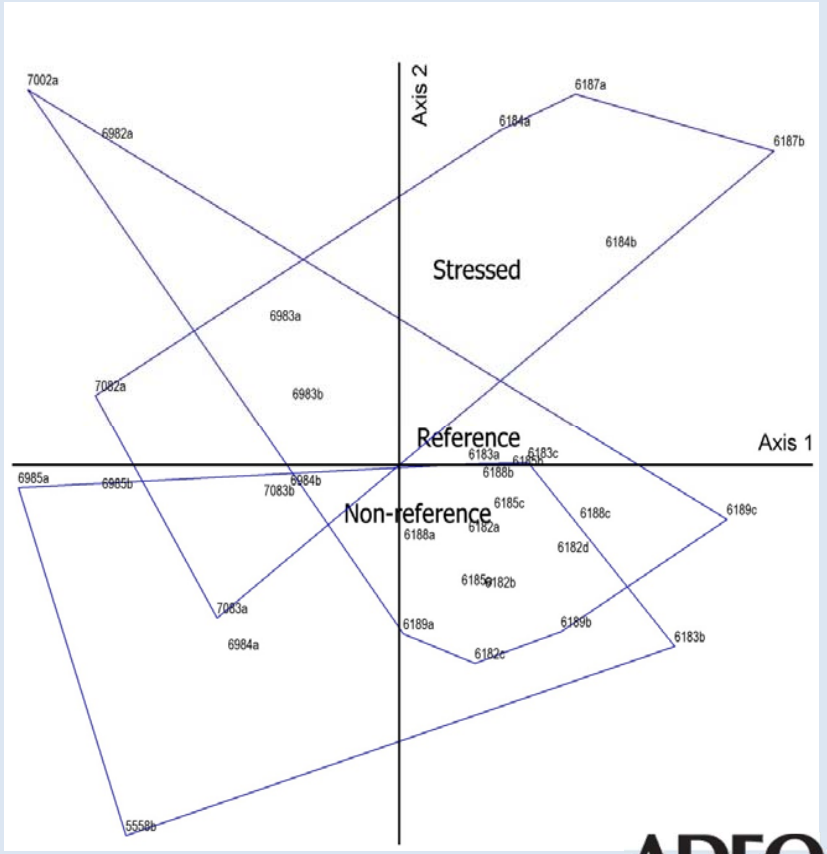
Source



Condition



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BMAs vs. Environmental Variables (MRPP)

	A	p-value
North vs. South	0.06	< 0.01
Warm vs. Cold	0.06	< 0.01
Water source	0.06	< 0.01
Condition	0.02	0.02

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IBI Justification

- All three multivariate methods showed that assemblages differed depending on:
  - Location
  - Water type
  - Temperature
  - **Condition** (Sedimentation stress)
- These differences, particularly reference vs. stressed, provided confirmation that a useful IBI could be developed

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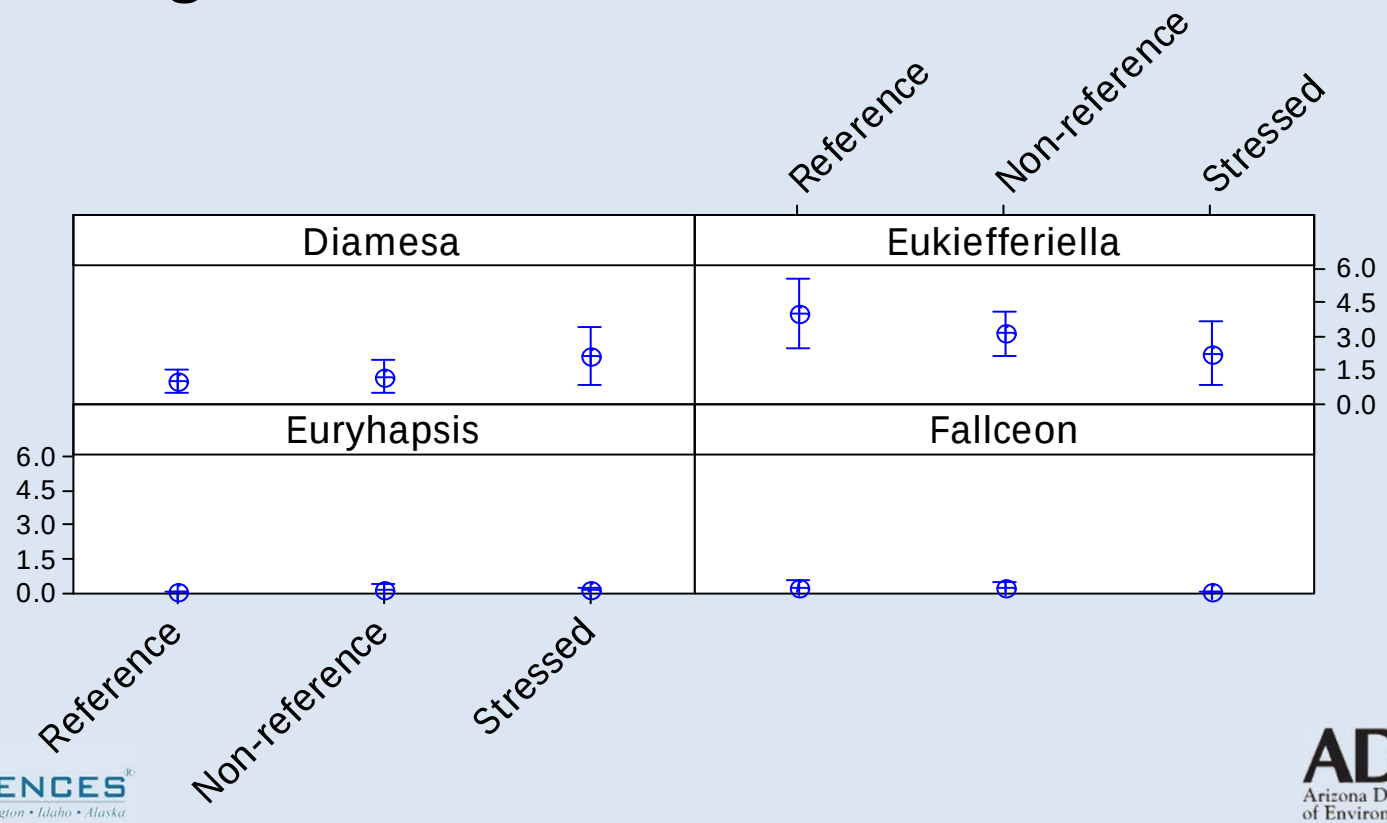
Development of Index

- Abundances (Log_{10} + 1) of 150 taxa compared between reference, non-reference, and stressed (mean and 90% CIs)
- Taxa categorized as either Decreasers or Increasers



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Development of Index Continued

- 69 taxa categorized as:
  - Decreasers
  - Increasers
- Abundances converted to presence/absence
- Each taxon = 1 point; invasive taxa = 2 points

$$\text{MIBI score} = \sum \text{Decreasers} - \sum(\text{Increasers} + \textbf{Invasives})$$

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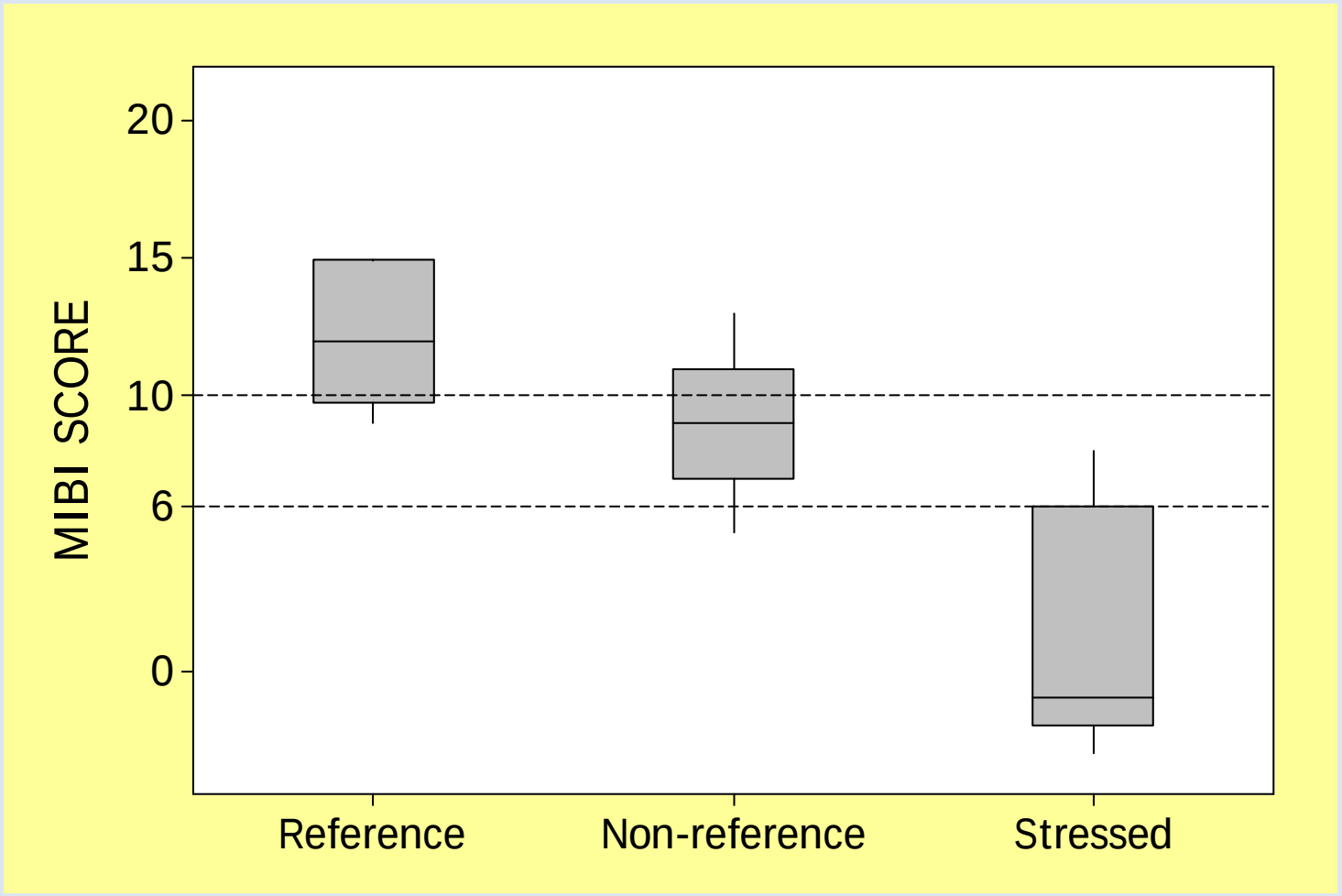
“The Dream Come True Graph”



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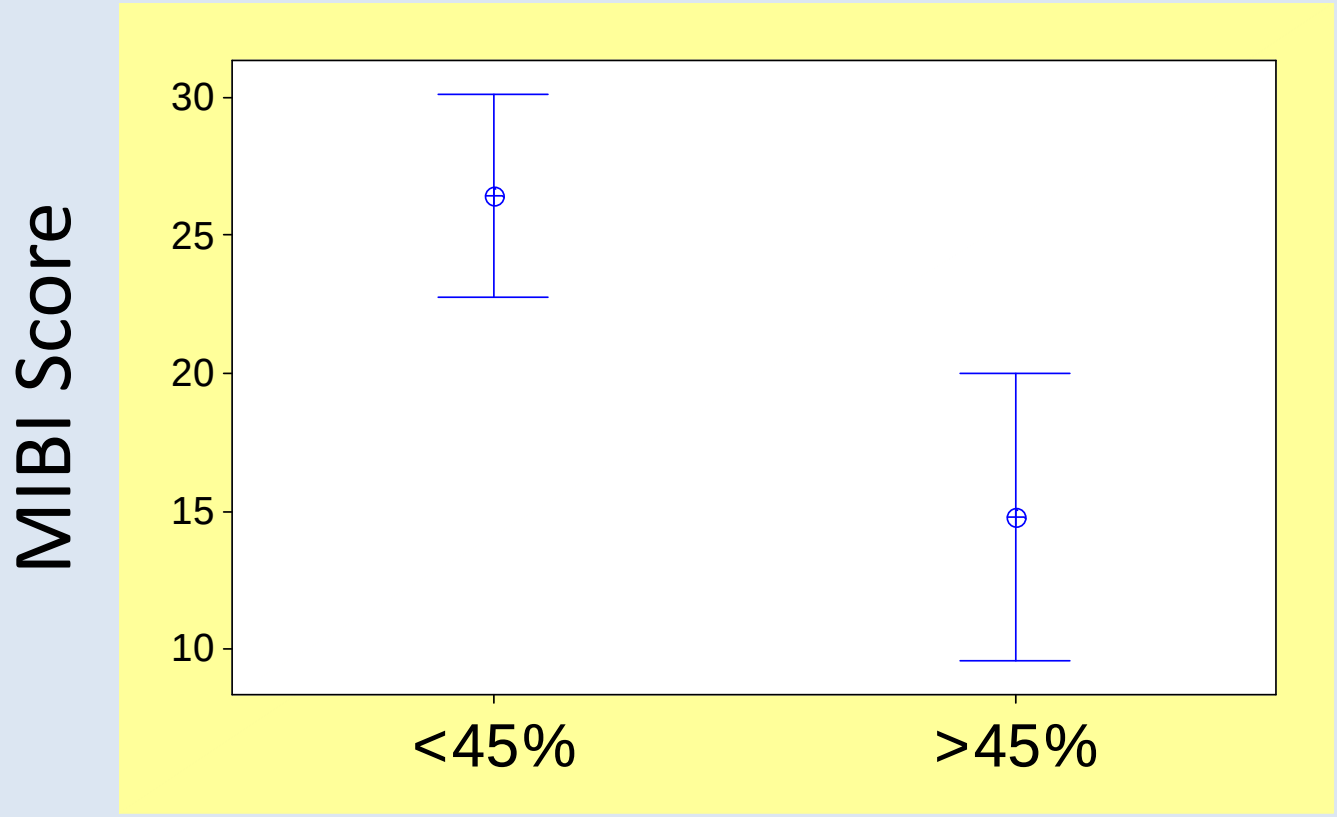
MIBI vs. % Fines



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Example:

Family	Genus/species	Decreasers	Increasers
Belostomatidae	*Abedus*	1	
Chironomidae	*Alotanypus*	1	
Chironomidae	*Apedilum*		1
Coenagrionidae	*Argia*	1	
Ceratopogonidae	*Atrichopogon*	1	
Baetidae	*Baetis magnus*	1	
Ceratopogonidae	*Bezzia/Palpomyia*	1	
Chironomidae	*Boreoheptagyia*		1
Caenidae	*Caenis bajaensis*	1	
Tipulidae	*Cryptolabis*	1	
Ceratopogonidae	*Dasyhelea*	1	
Chironomidae	*Diamesa*		1
Hydrophilidae	*Enochrus*		1
Chironomidae	*Eukiefferiella2*	1	
Baetidae	*Fallceon*	1	
Helicopsychidae	*Helicopsyche*	1	
Hydrophilidae	*Helochares*		1
Empididae	*Hemerodromia*	1	
Cambaridae	*Orconectes*		2

∑ Decreasers = 13

∑ Increasers = 7

Score = 6

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Conclusions

- MIBI is simple to calculate & has good discriminatory ability
- This index based on AZ/NM Mountain Ecoregion and sediment stress **only**
- This project was pilot test; need to expand research to:
  - Develop/test index for different ecoregions and stressors
  - Collect more samples!
  - Document #days/year with flow to calibrate length of intermittency

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Conclusions

- FFGs, taxa richness, invasive taxa, and, rare and uncommon taxa **implicit** in this MIBI
- Limited knowledge of FFGs response to stress in perennial and intermittent streams
- AZ ecoregions and intermittent streams are highly variable
  - Separate indices will need to be developed by ecoregion
  - Do not recommend a statewide MIBI

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