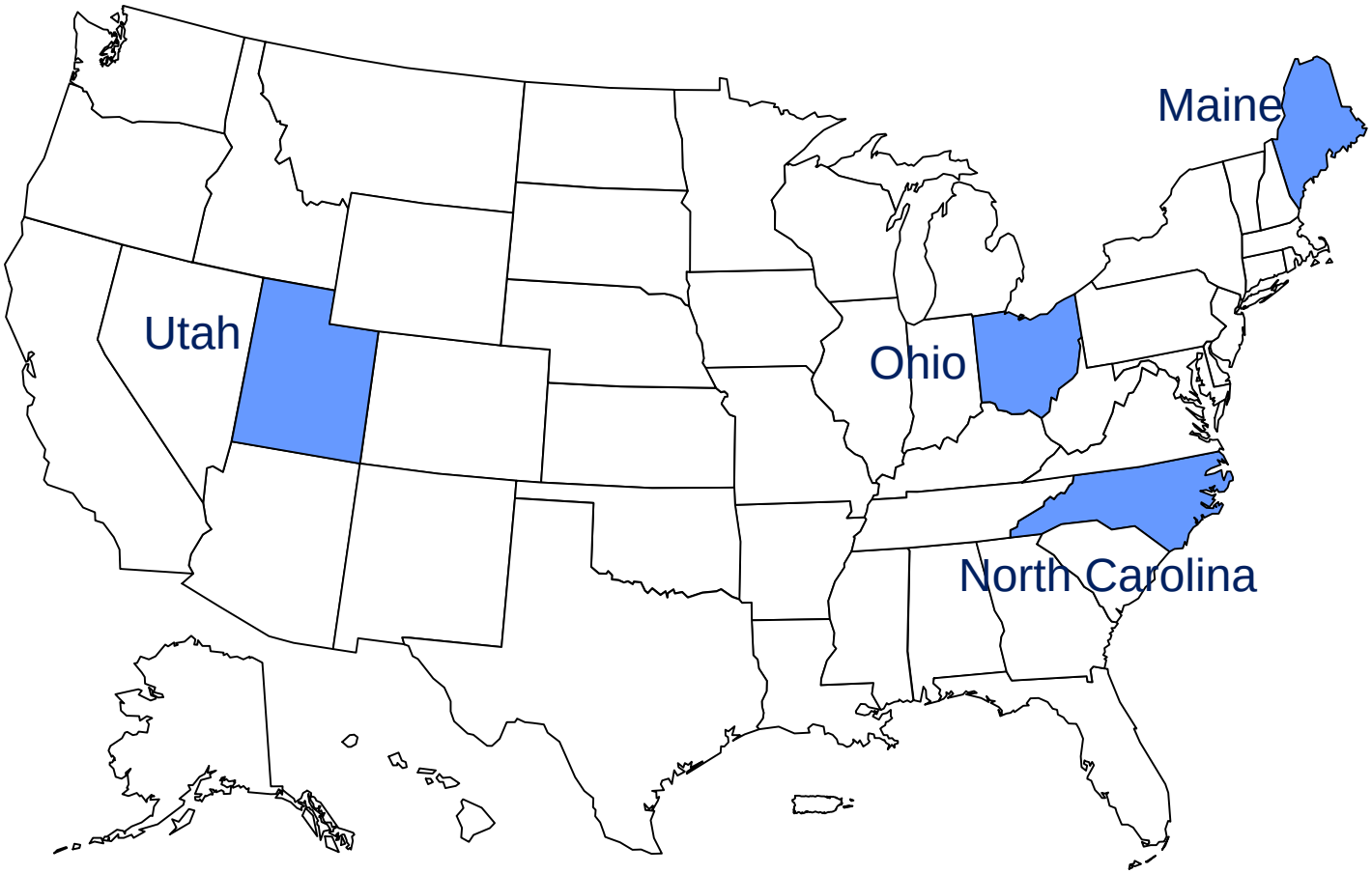
Indicators – Results from Other Regions



Selection of Sites and Samples

- Evaluated data from reference sites with longest-term data
- Reference or best available conditions
  - This is defined in different ways (biology, land use land cover)
- For our study – did our best to limit potential confounding factors

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Questions

- Which indicators/metrics appear to be most responsive/most likely to detect climate change effects?
- How did responses differ among regions?
- What can be done to track whether trends in commonly-used metrics might be driven by climatic changes?

Biological Indicators

Surrogates -gauge condition of aquatic systems

- Assess condition (e.g., early warning of degradation, trends)
- Diagnose cause
- Link appropriately to expected stressors

Existing metrics are naïve with regard to the additional effects of progressive changes in temperature and hydrologic regimes

Correlation analyses: metrics vs. YEAR - Utah

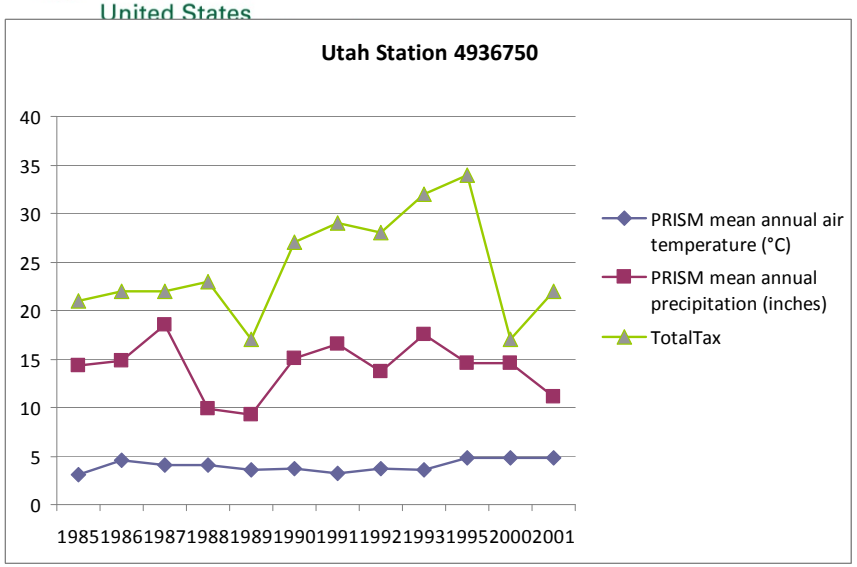
Biological Metric vs. YEAR	Utah							
	4927250		4951200		4936750		5940440	
	r	p	r	p	r	p	r	p
Cold water taxa richness		**0.00**		**0.02**	-0.38	0.23	-0.64	0.07
Cold water taxa relative abundance		**0.00**		**0.02**	-0.15	0.64	-0.12	0.76
Warm water taxa richness	-0.21	0.42		**0.00**	0.38	0.22	0.00	---
Warm water taxa relative abundance	-0.21	0.42	0.41	0.15	0.42	0.17	--	---
Total taxa richness	-0.29	0.26	-0.28	0.34	0.08	0.81	-0.54	0.14
EPT taxa richness		**0.01**	-0.49	0.08	-0.21	0.52	-0.65	0.06
EPT relative abundance	0.06	0.81	0.06	0.85	-0.26	0.42	0.44	0.23
Ephemeroptera taxa richness		**0.02**		**0.02**	-0.04	0.89	-0.57	0.11
Plecoptera taxa richness		**0.00**	-0.53	0.05	-0.29	0.36		**0.03**
Shannon Wiener diversity index	0.13	0.62	-0.43	0.12	-0.08	0.81	-0.25	0.52
OCH taxa richness		**0.01**	0.46	0.10		**0.00**	0.28	0.47
OCH taxa relative abundance		**0.00**	0.40	0.15	0.32	0.31	-0.59	0.10
HBI	-0.19	0.47	0.28	0.34	0.32	0.31	-0.46	0.21

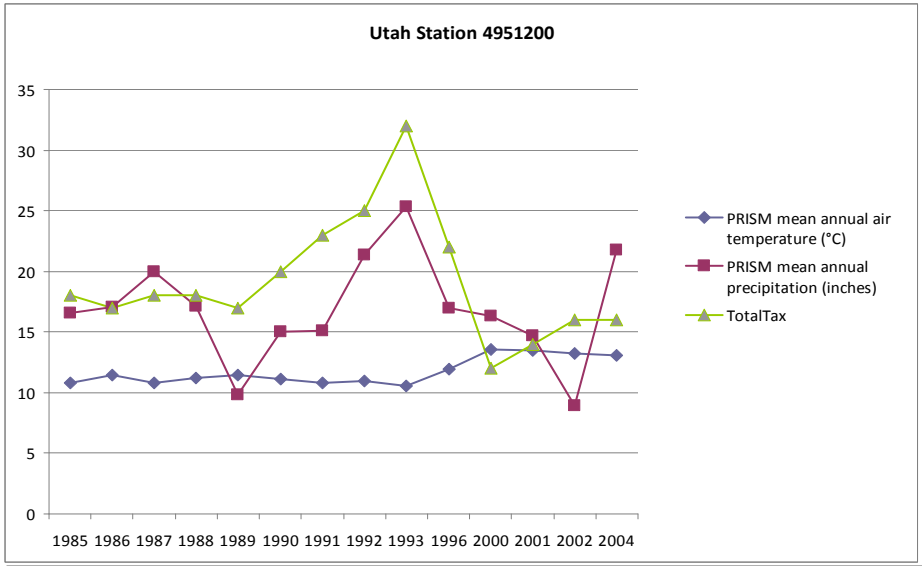
Correlation analyses: metrics vs. PRISM mean annual air temperature - Utah

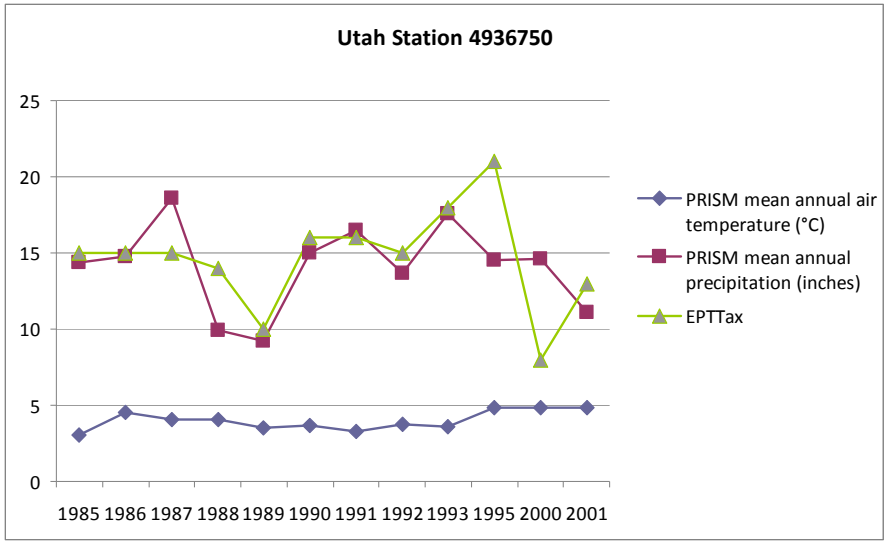
Biological Metric vs. TEMP	Utah							
	4927250		4951200		4936750		5940440	
	r	p	r	p	r	p	r	p
Cold water taxa richness	**-0.63**	**0.01**	**-0.73**	**0.00**	-0.08	0.82	-0.14	0.73
Cold water taxa relative abundance	-0.30	0.24	**-0.56**	**0.04**	-0.20	0.53	-0.29	0.46
Warm water taxa richness	-0.44	0.08	**0.76**	**0.00**	-0.03	0.93	--	---
Warm water taxa relative abundance	-0.35	0.17	**0.62**	**0.02**	0.01	0.98	--	---
Total taxa richness	-0.48	0.05	**-0.68**	**0.01**	-0.08	0.81	-0.20	0.60
EPT taxa richness	**-0.57**	**0.02**	**-0.79**	**0.00**	-0.09	0.77	-0.43	0.25
EPT relative abundance	0.03	0.91	0.29	0.32	0.04	0.90	0.07	0.86
Ephemeroptera taxa richness	**-0.59**	**0.01**	**-0.81**	**0.00**	-0.26	0.41	-0.22	0.56
Plecoptera taxa richness	-0.45	0.07	**-0.65**	**0.01**	0.17	0.61	**-0.72**	**0.03**
Shannon Wiener diversity index	-0.13	0.62	**-0.67**	**0.01**	-0.12	0.71	-0.29	0.46
OCH taxa richness	0.11	0.68	0.12	0.68	0.27	0.40	0.59	0.09
OCH taxa relative abundance	0.44	0.07	0.27	0.36	-0.11	0.74	-0.01	0.98
HBI	-0.32	0.21	0.04	0.89	0.09	0.77	0.09	0.82

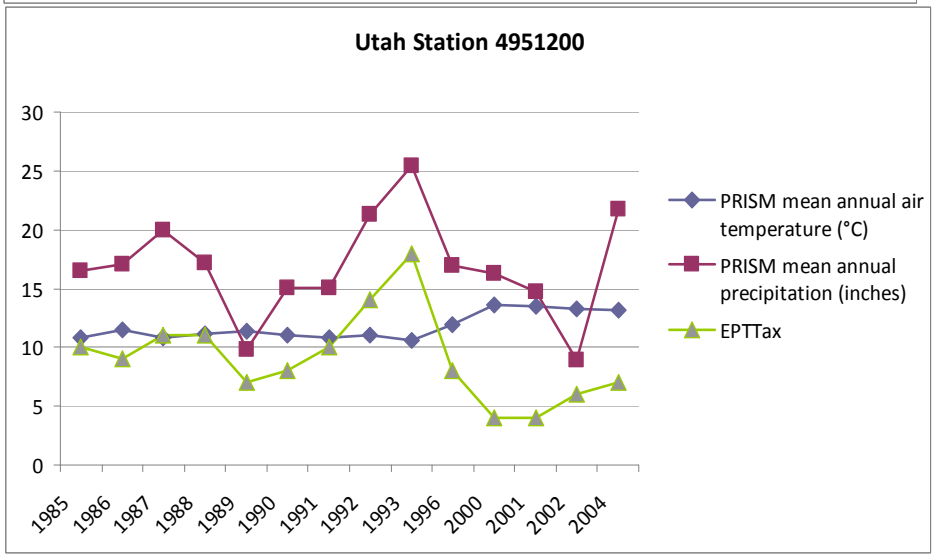
Fewer significant relationships with precipitation in Utah

Trends of metrics with precipitation - Utah









Correlation analyses: metrics vs. YEAR - Maine

Biological Metric vs. YEAR	Maine					
	56817		57011		57065	
	r	p	r	p	r	p
Cold water taxa richness	**0.49**	**0.02**	-0.17	0.60	0.54	0.13
Cold water taxa relative abundance	**0.48**	**0.03**	0.29	0.36	0.45	0.23
Warm water taxa richness	**0.75**	**0.00**	-0.51	0.09	0.58	0.10
Warm water taxa relative abundance	**0.51**	**0.02**	-0.48	0.11	-0.36	0.34
Total taxa richness	**0.76**	**0.00**	**0.81**	**0.00**	0.56	0.11
EPT taxa richness	**0.72**	**0.00**	-0.47	0.12	0.51	0.16
EPT relative abundance	-0.09	0.68	**-0.66**	**0.02**	-0.36	0.34
Ephemeroptera taxa richness	**0.58**	**0.01**	**0.63**	**0.03**	0.37	0.33
Plecoptera taxa richness	-0.16	0.47	0.05	0.88	0.44	0.23
Shannon Wiener diversity index	**0.64**	**0.00**	0.12	0.72	0.43	0.25
OCH taxa richness	**0.45**	**0.04**	0.43	0.16	0.28	0.47
OCH taxa relative abundance	0.31	0.16	-0.52	0.09	0.37	0.33
HBI	-0.11	0.64	**0.75**	**0.01**	0.18	0.65

Few significant relationships with temperature or precipitation in Maine

Correlation analyses: metrics vs. YEAR – North Carolina

Significant correlations are highlighted in yellow.

There aren't very many!

More with precipitation

				NC			
	Blue Ridge	**NC0109 (BR)**	**NC0207 (BR)**	**NC0209 (BR)**	**Piedmont**	**NC0075 (P)**	**NC0248 (P)**
	Year	Year	Year	Year	Year	Year	Year
Temp_CoreColdPct	-0.41	0.57	0.33	0.29	-0.01	-0.02	-0.14
	N=9	N=11	N=9	N=7	N=14	N=7	N=7
	p=.278	p=.067	p=.391	p=.522	p=.970	p=.969	p=.760
Temp_CoreWarmPct	0.25	-0.04	0.09	-0.33	-0.04	-0.73	-0.55
	N=9	N=11	N=9	N=7	N=14	N=7	N=7
	p=.525	p=.904	p=.824	p=.469	p=.895	p=.060	p=.202
Temp_CoreCold_Tax	-0.08	0.55	0.38	0.82	0.04	-0.39	0.28
	N=9	N=11	N=9	N=7	N=14	N=7	N=7
	p=.848	p=.080	p=.316	p=.024	p=.885	p=.393	p=.542
Temp_CoreWarm_Tax	0.09	-0.58	-0.04	-0.53	0.06	0.60	0.14
	N=9	N=11	N=9	N=7	N=14	N=7	N=7
	p=.814	p=.059	p=.914	p=.219	p=.840	p=.157	p=.772

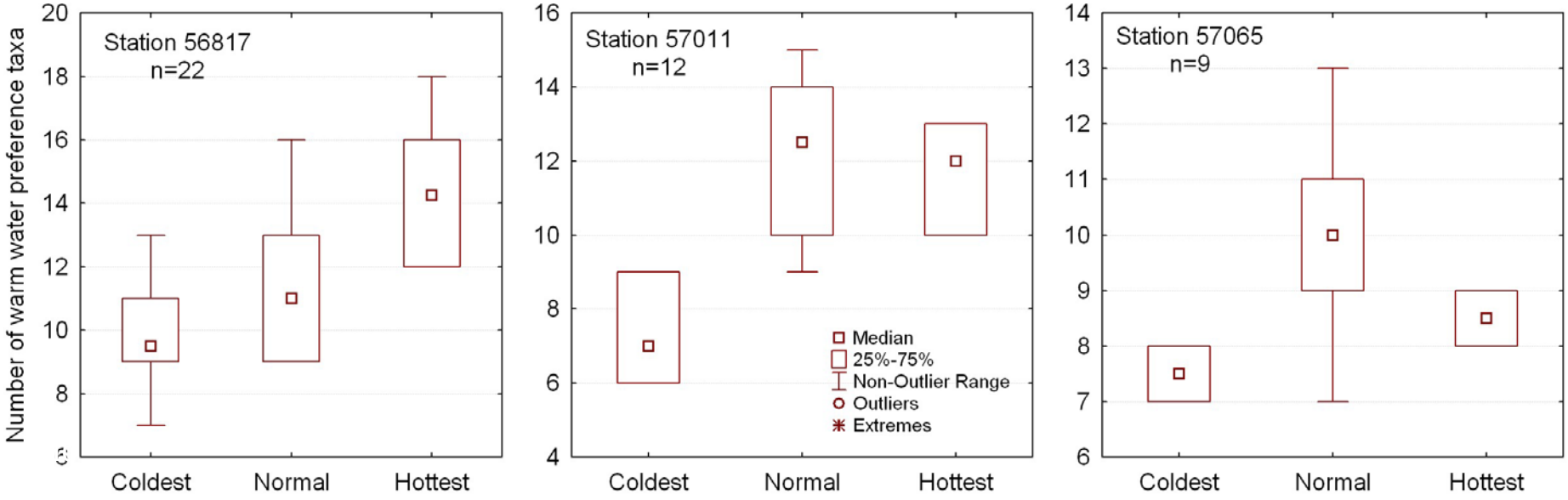
	Blue Ridge	**NC0109 (BR)**	**NC0207 (BR)**	**NC0209 (BR)**	**Piedmont**	**NC0075 (P)**	**NC0248 (P)**
	tmean14	tmean14	tmean14	tmean14	tmean14	tmean14	tmean14
Temp_CoreColdPct	-0.05	-0.32	0.17	0.07	-0.09	-0.10	-0.10
	N=9	N=11	N=9	N=7	N=14	N=7	N=7
	p=.903	p=.344	p=.665	p=.883	p=.760	p=.838	p=.837
Temp_CoreWarmPct	0.56	0.00	0.26	-0.45	-0.18	-0.16	-0.54
	N=9	N=11	N=9	N=7	N=14	N=7	N=7
	p=.118	p=.998	p=.491	p=.310	p=.548	p=.738	p=.215
Temp_CoreCold_Tax	-0.26	-0.38	0.43	0.00	-0.06	-0.09	-0.20
	N=9	N=11	N=9	N=7	N=14	N=7	N=7
	p=.507	p=.246	p=.245	p=.993	p=.849	p=.841	p=.667
Temp_CoreWarm_Tax	0.54	-0.18	0.27	-0.48	-0.40	0.56	-0.47
	N=9	N=11	N=9	N=7	N=14	N=7	N=7
	p=.131	p=.592	p=.478	p=.276	p=.157	p=.194	p=.291

	Blue Ridge	**NC0109 (BR)**	**NC0207 (BR)**	**NC0209 (BR)**	**Piedmont**	**NC0075 (P)**	**NC0248 (P)**
	ppt14	ppt14	ppt14	ppt14	ppt14	ppt14	ppt14
Temp_CoreColdPct	0.26	0.63	0.71	0.54	0.39	0.64	-0.29
	N=9	N=11	N=9	N=7	N=14	N=7	N=7
	p=.495	p=.038	p=.032	p=.209	p=.164	p=.119	p=.527
Temp_CoreWarmPct	-0.26	-0.57	-0.32	-0.58	-0.03	0.10	0.25
	N=9	N=11	N=9	N=7	N=14	N=7	N=7
	p=.494	p=.065	p=.402	p=.168	p=.930	p=.824	p=.581
Temp_CoreCold_Tax	0.09	0.85	0.39	0.31	0.47	0.34	0.00
	N=9	N=11	N=9	N=7	N=14	N=7	N=7
	p=.826	p=.001	p=.305	p=.498	p=.088	p=.457	p=.992
Temp_CoreWarm_Tax	-0.38	-0.65	-0.29	-0.56	-0.21	0.20	-0.43
	N=9	N=11	N=9	N=7	N=14	N=7	N=7
	p=.316	p=.029	p=.445	p=.189	p=.479	p=.663	p=.333

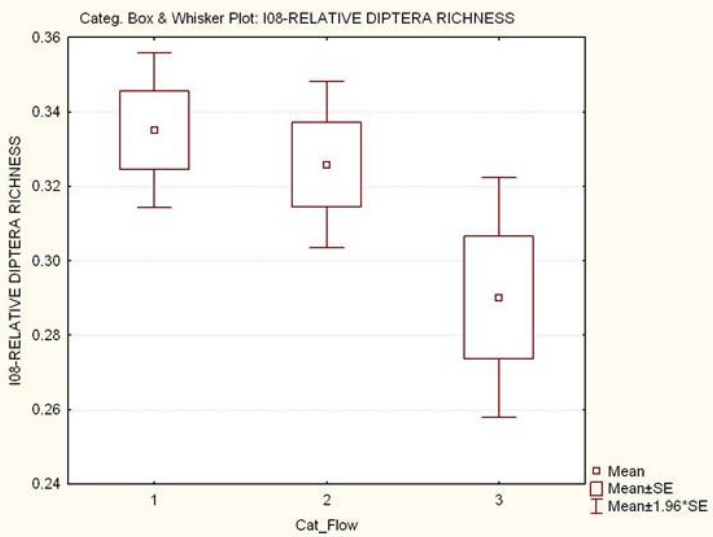
ANOVA Results - Maine

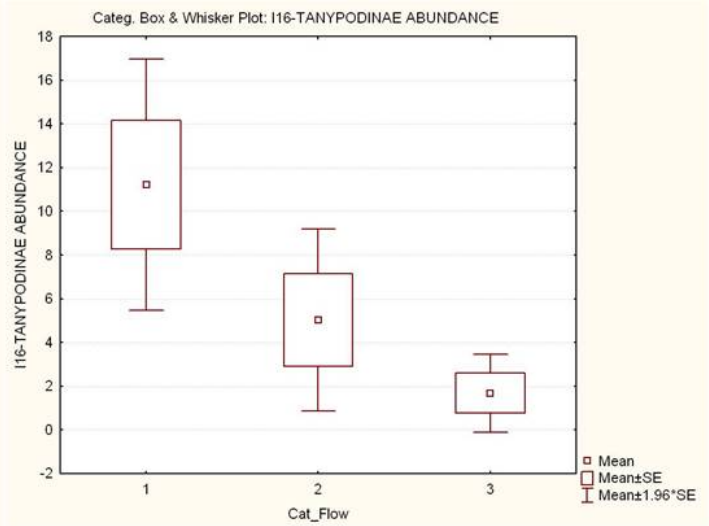
- All 3 sites, mean # warm water preference taxa **lowest** in the coldest year samples

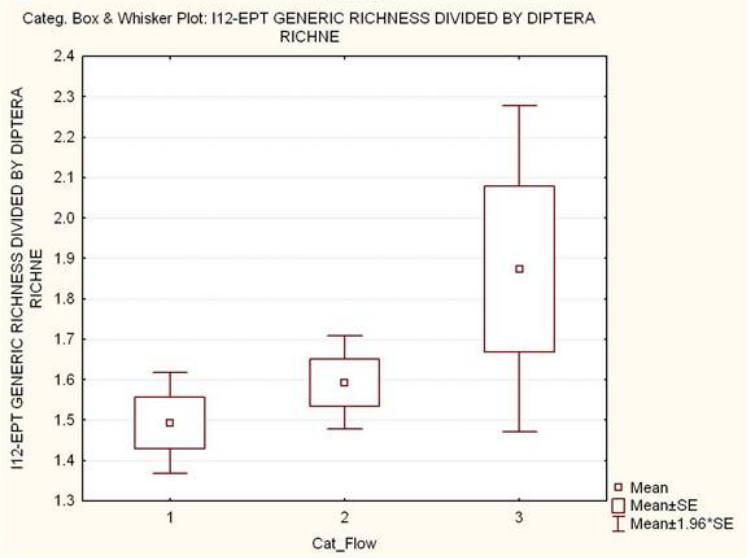
- Trends with cold water preference trait groups were **variable and not interpretable** with regard to climate change

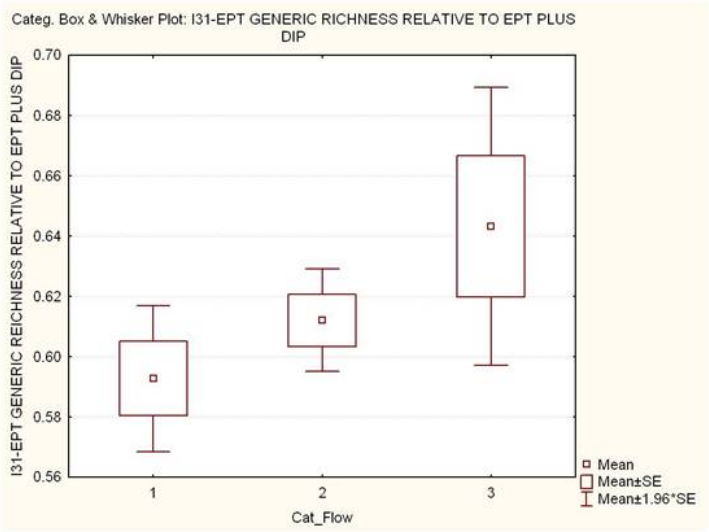


Maine Site 56187 - significant relationships between model input metrics and dry (1)/normal (2)/high flow (3) years





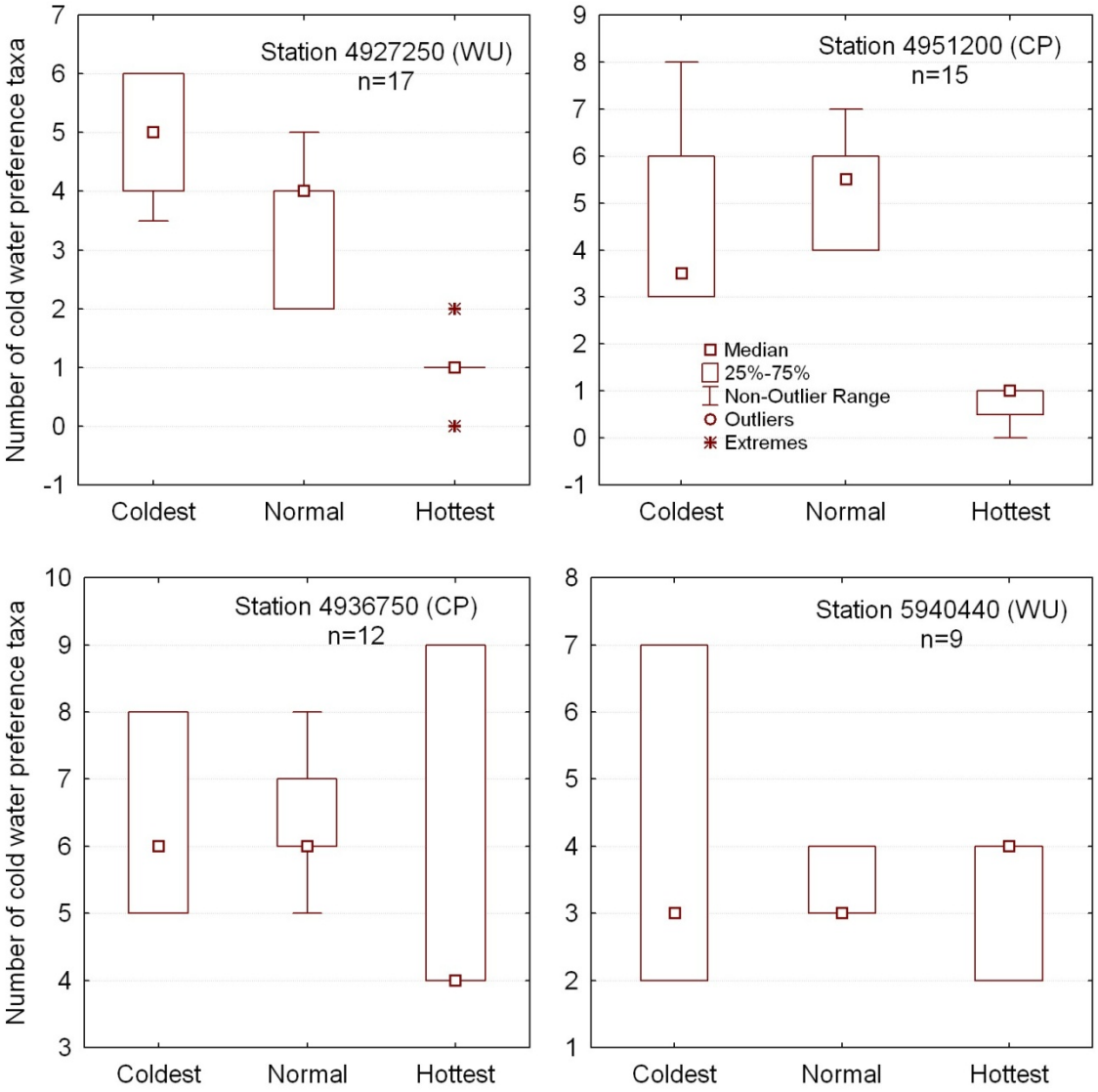


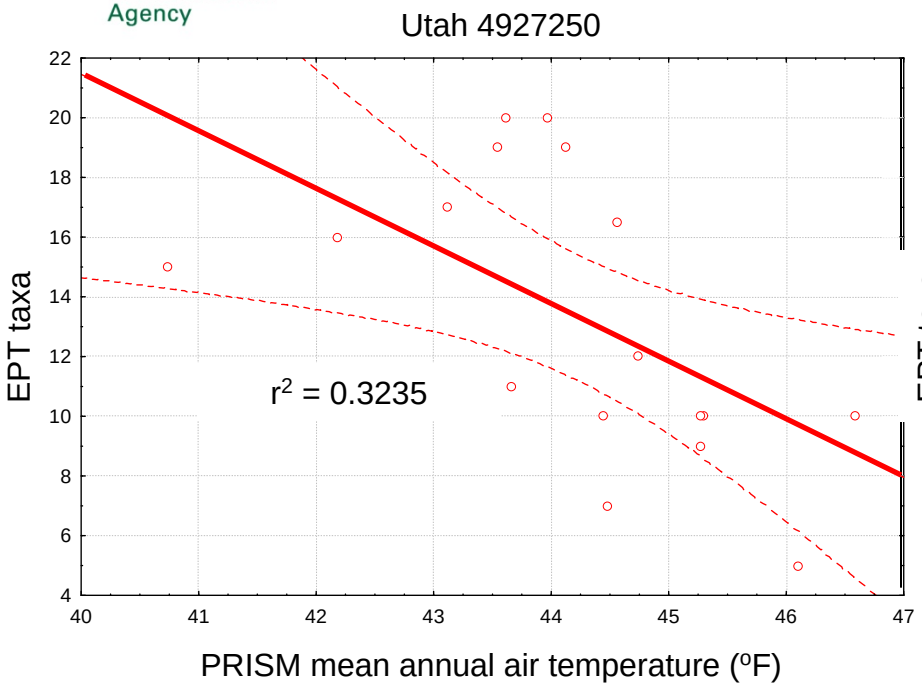


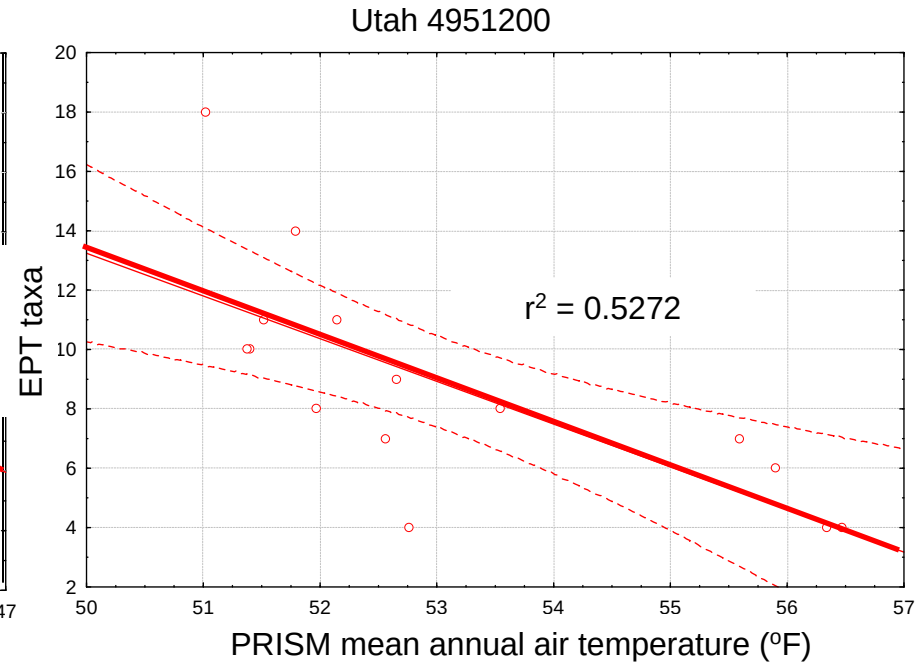
Results from Utah

At 2 sites, cold water preference trait groups in hottest year samples were **strongly differentiated** from the normal and cold year samples

No detectable trends with the warm water preference trait groups







~2 EPT taxa lost per ºF

~1.4 EPT taxa lost per ºF

By 2050, potential loss of 40% of community EPT taxa

Since this is a reference station → assume climate change cause

At other stations → how do we separate causes?

Link between cold & warm water taxa and EPT taxa – RICHNESS

Site	# Samples	Cold		Warm	
		r	p	r	p
UT 4927250	17	**0.88**	**0.00**	**0.65**	**0.01**
UT 4951200	14	**0.72**	**0.00**	-0.47	0.09
UT 4936750	12	**0.79**	**0.00**	-0.19	0.55
UT 5940440	9	**0.87**	**0.00**	NA	NA

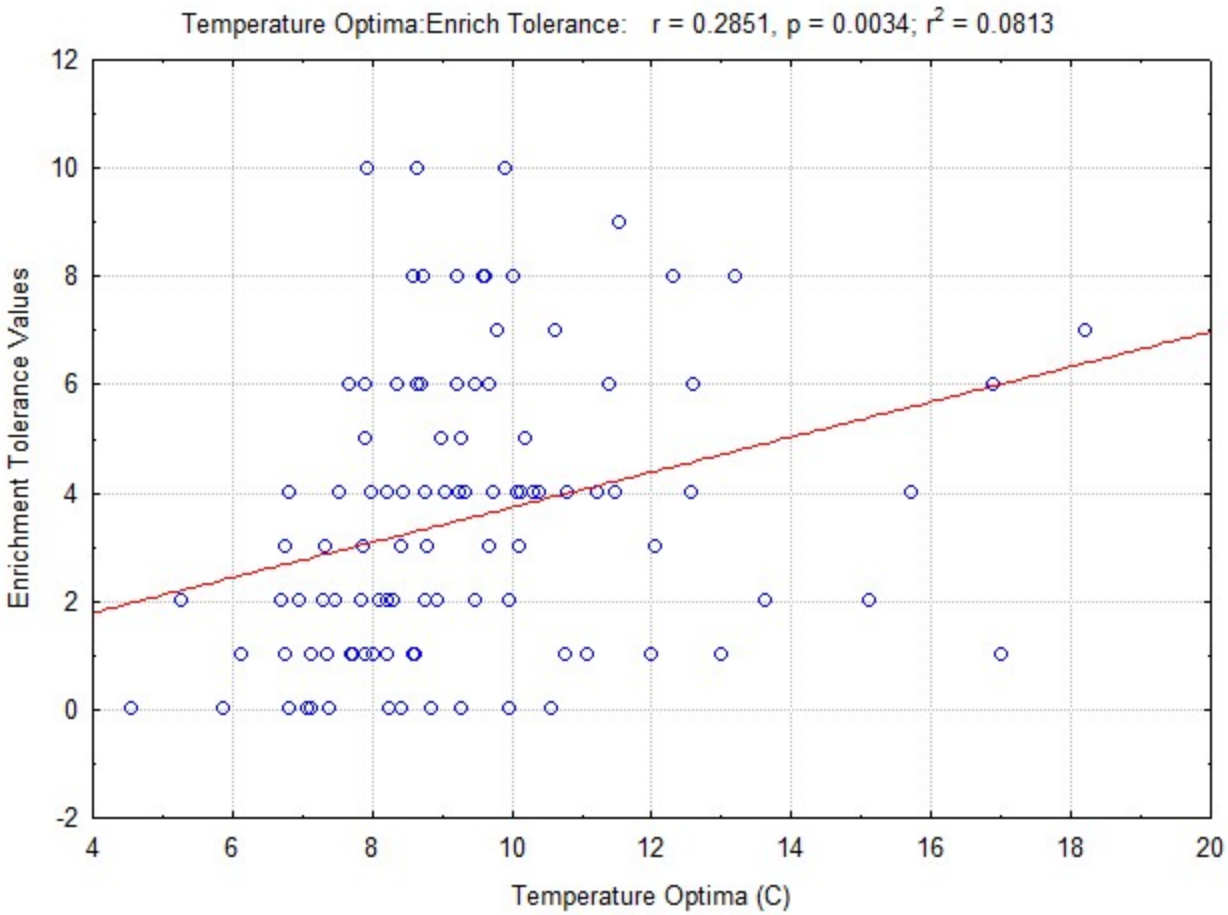
- Less of a relationship with % individuals

Link between warm water taxa and EPT taxa – RICHNESS

Site	# Samples	Cold		Warm	
		r	p	r	p
ME 56817	22	**0.60**	**0.00**	**0.86**	**0.00**
ME 57011	12	0.13	0.68	**0.86**	**0.00**
ME 57065	9	0.63	0.07	**0.77**	**0.02**

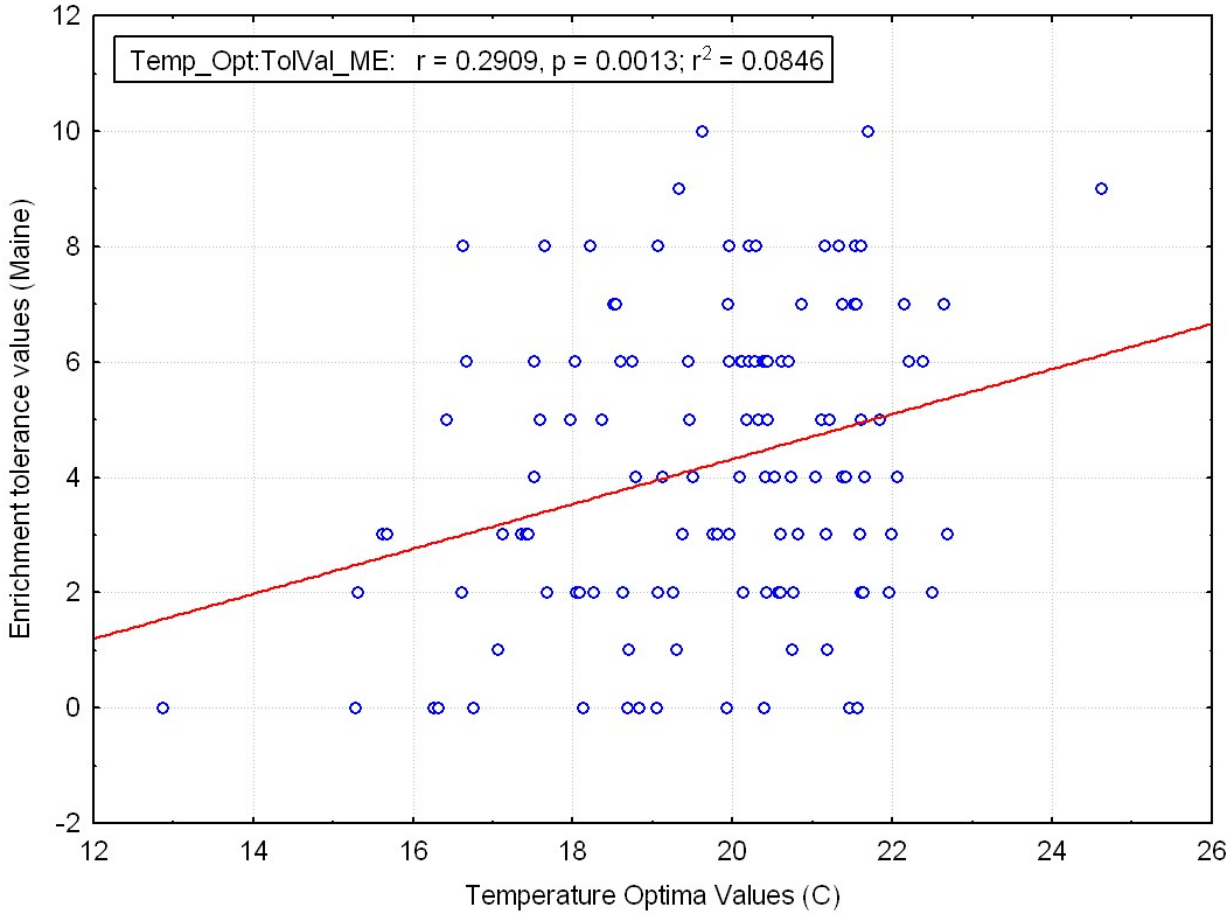
- Maine warm water taxa significantly correlated with # EPT taxa at all 3 sites
- Less of a relationship with % individuals

Link between Utah cold water taxa and enrichment tolerance values



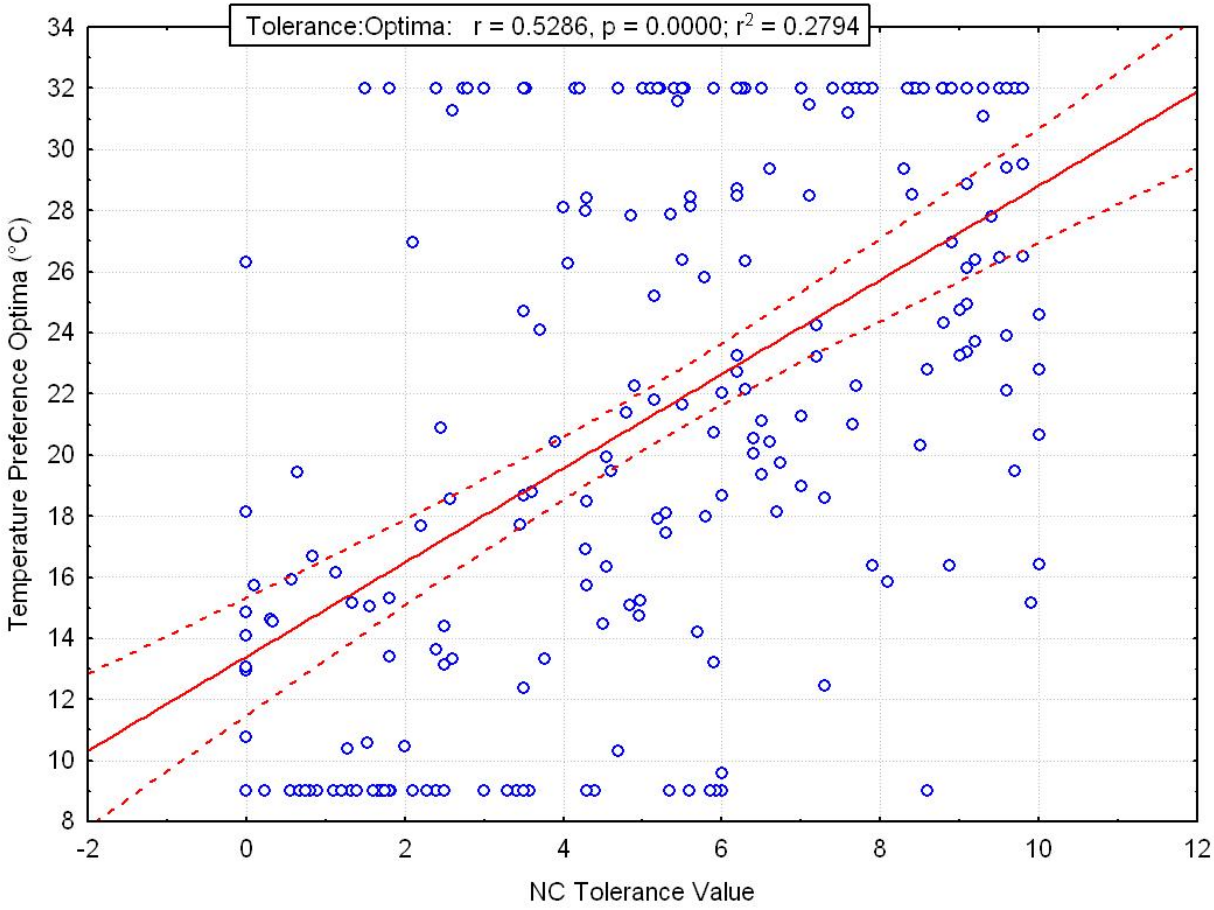
- Temperature optima values from the Utah dataset were significantly correlated with Utah enrichment tolerance values (NM enrichment tolerance values were applied to UT taxa for this analysis)

Link between Maine cold water taxa and enrichment tolerance values



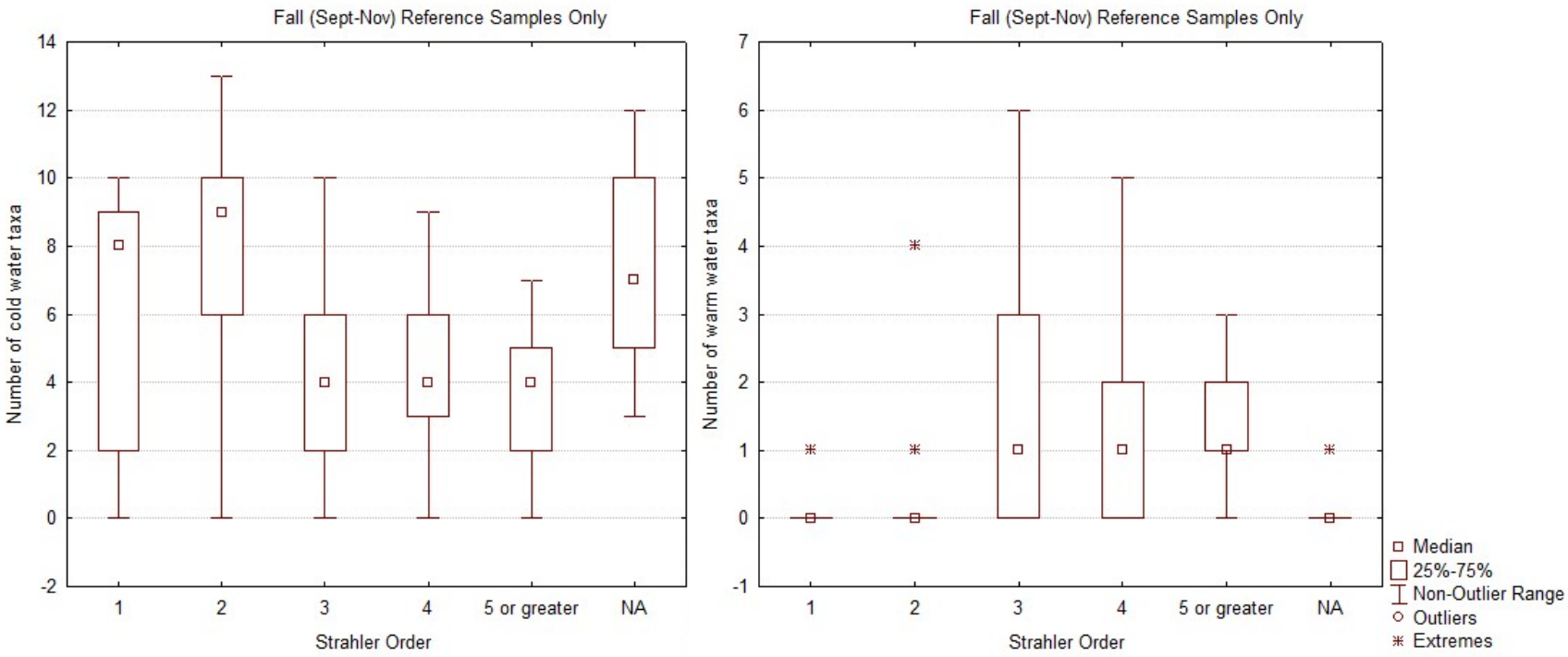
- Temperature optima values from the Maine dataset were significantly correlated with Maine (enrichment) tolerance values.

Link between North Carolina cold water taxa and enrichment tolerance values



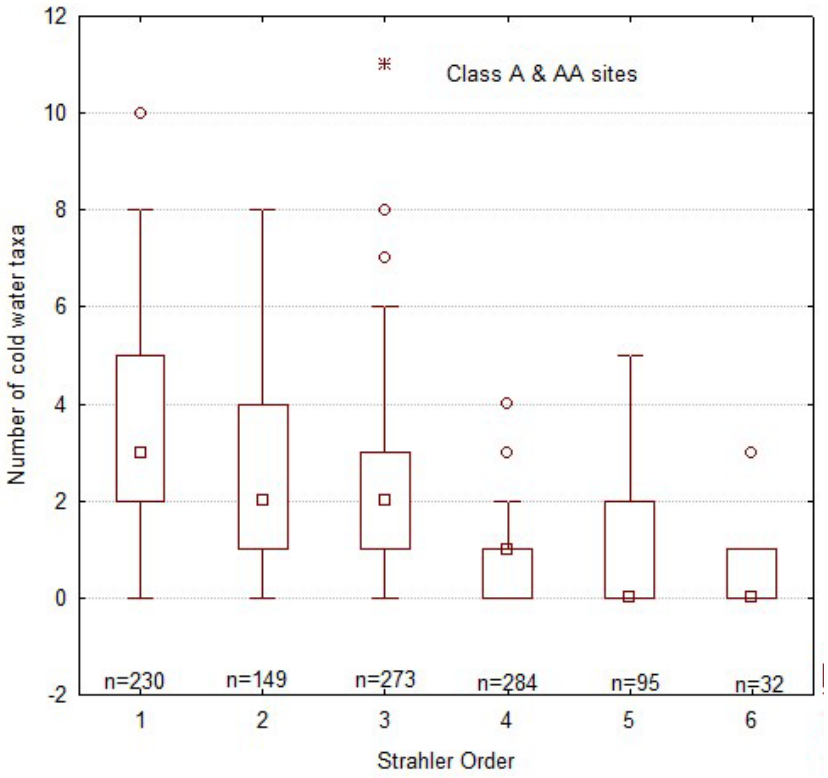
- Temperature optima values from the North Carolina dataset were significantly correlated with NC(enrichment) tolerance values.

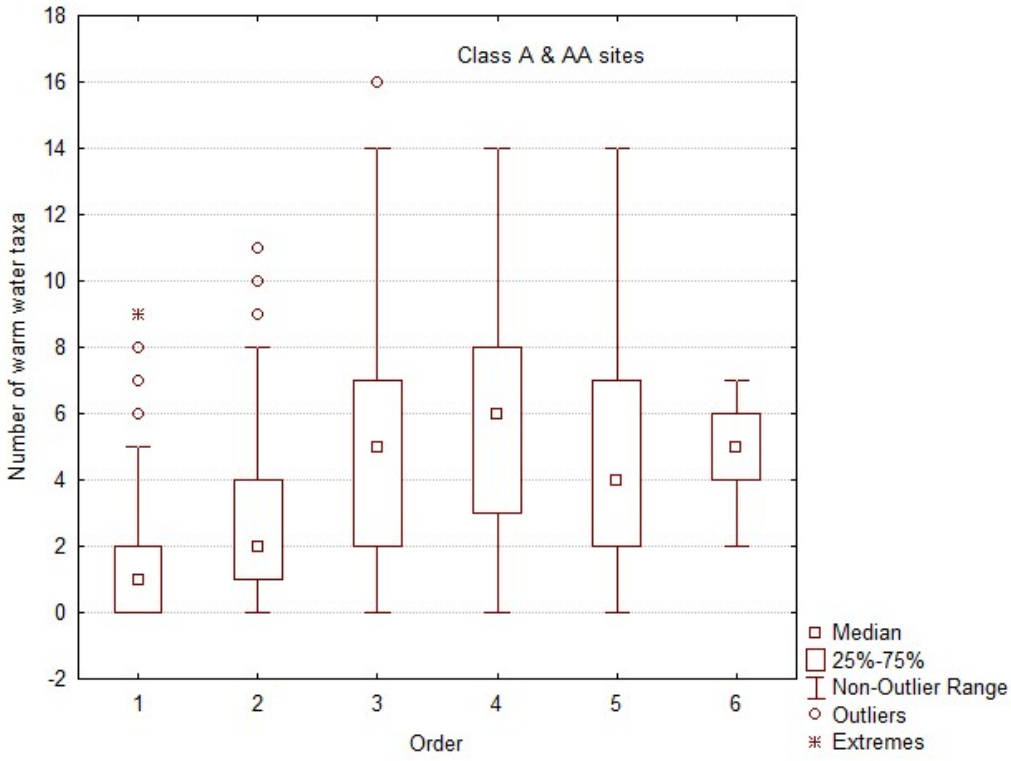
Distribution of number of cold and warm water taxa across Strahler Orders in Utah – fall reference samples



Based on data from 67 reference sites (multiple samples were taken from some sites). Samples sizes are as follows: 1st order = 11; 2nd order = 29; 3rd order = 22; 4th order = 41; 5th order or greater = 21; NA = 5.

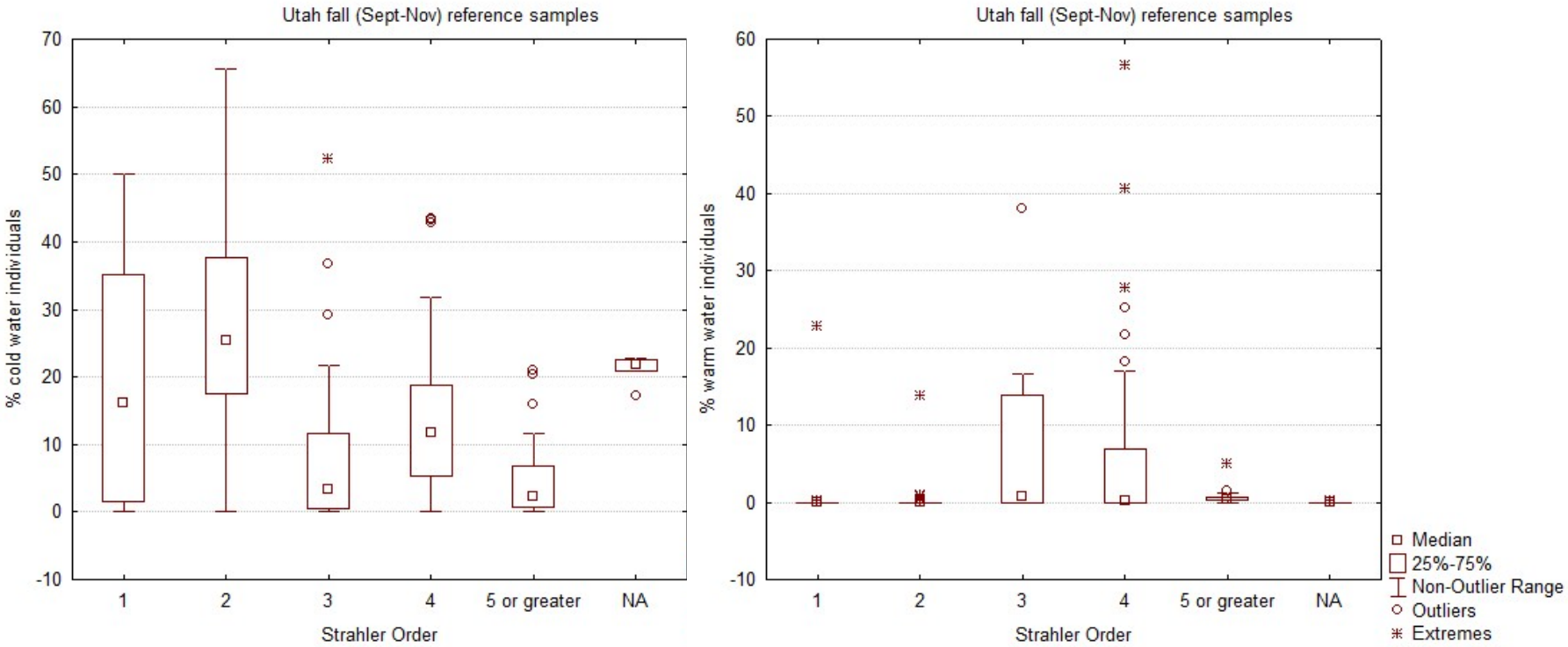
Distribution of cold and warm water taxa – Class AA & A sites (all reps)





- Higher median # cold water taxa at 1-3 order streams vs. 4-6 order
- Higher median # warm water taxa at 3-6 order streams vs. 1-2 order
- Similar patterns at all sites (vs. just Class AA & A), but more ‘noise’

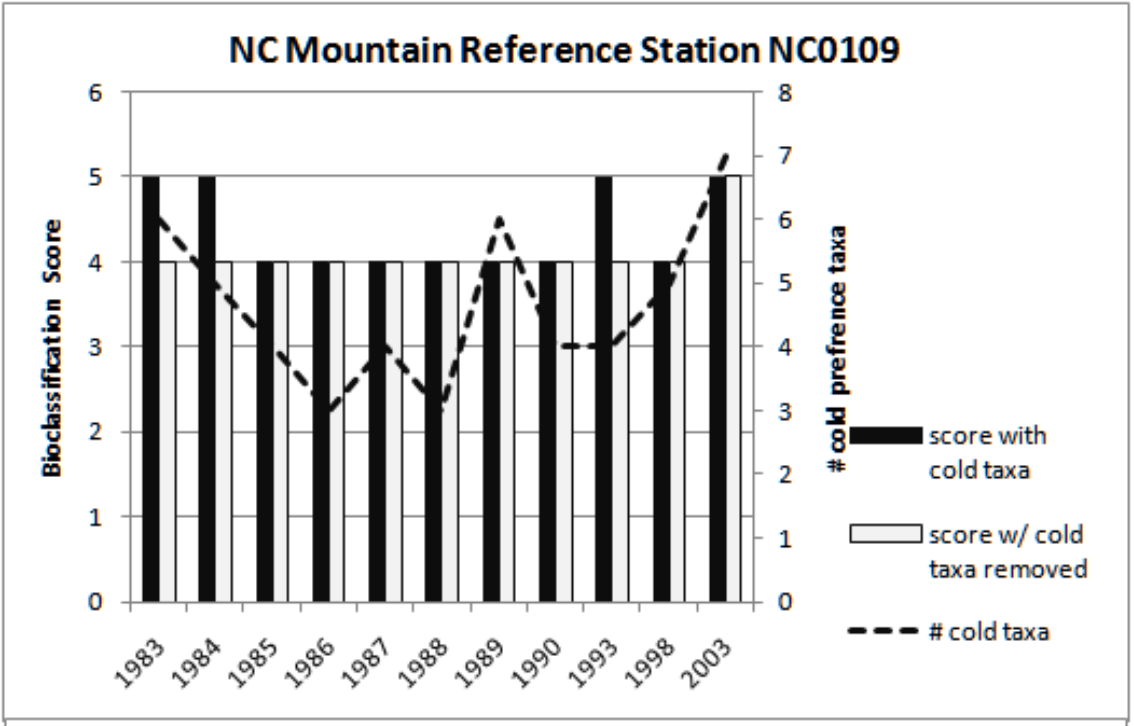
Distribution of % cold and warm water individuals across Strahler Orders in Utah - fall reference samples

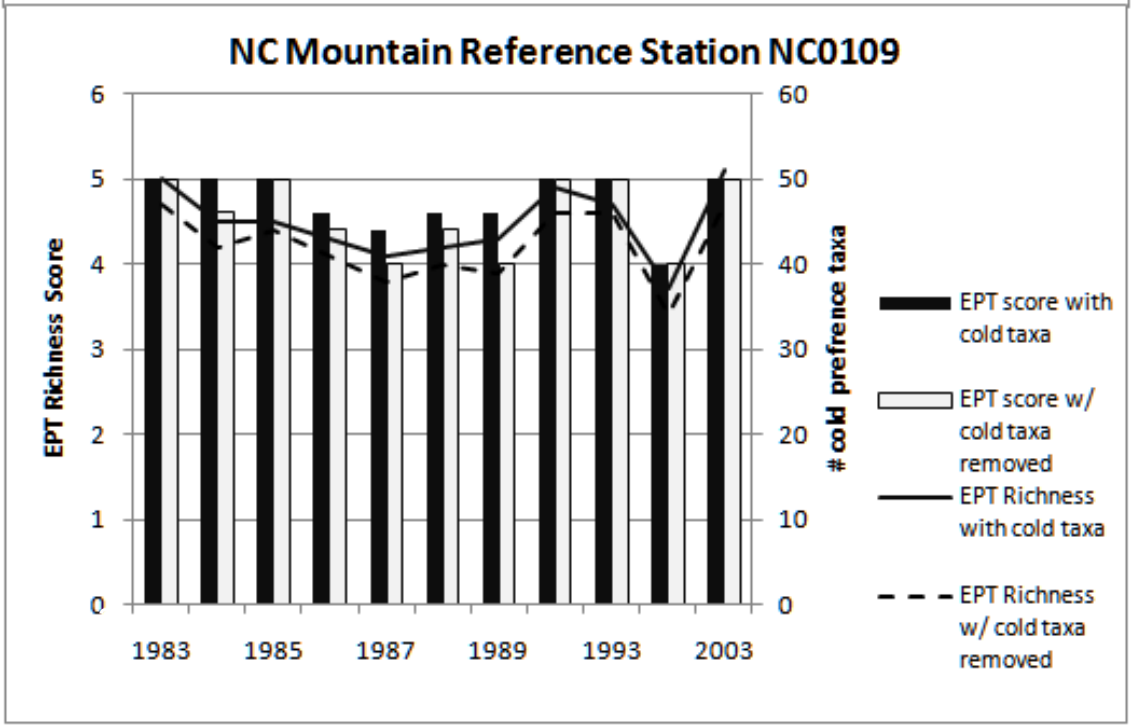


Based on data from 67 reference sites (multiple samples were taken from some sites). Samples sizes are as follows: 1st order = 11; 2nd order = 29; 3rd order = 22; 4th order = 41; 5th order or greater = 21; NA = 5.

Summary

- We did find a links between cold and warm water trait groups and several commonly-used metrics (i.e. EPT, HBI)
- Because of this, it is likely that CC will have some impact on bioassessments; however this will depend on many factors (i.e. how abundant are these cold and warm water taxa? How commonly do they occur at sites?)



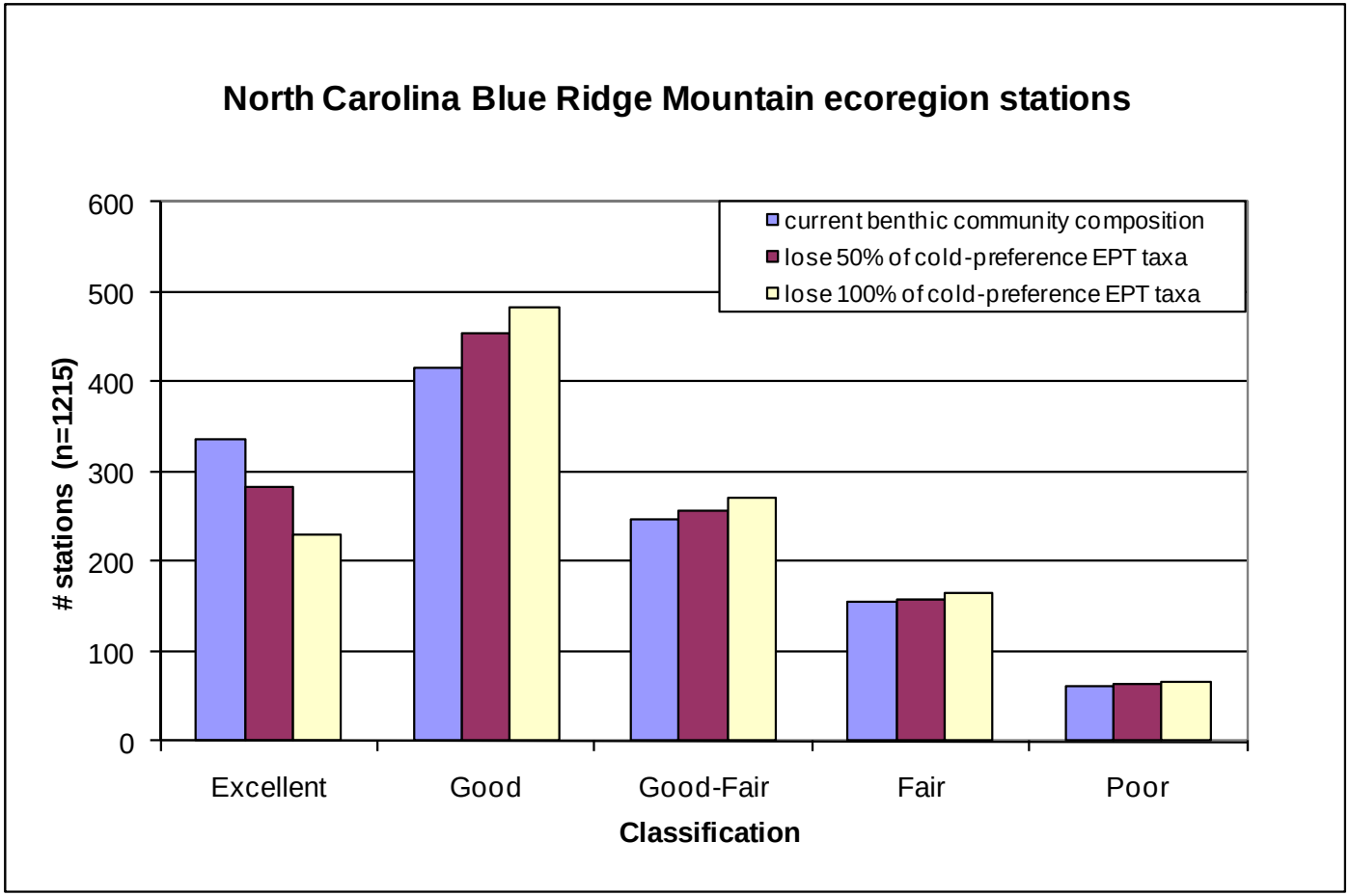


Implication

Changes in EPT metric (many years) or station rating (some years) scores

Reference station drift

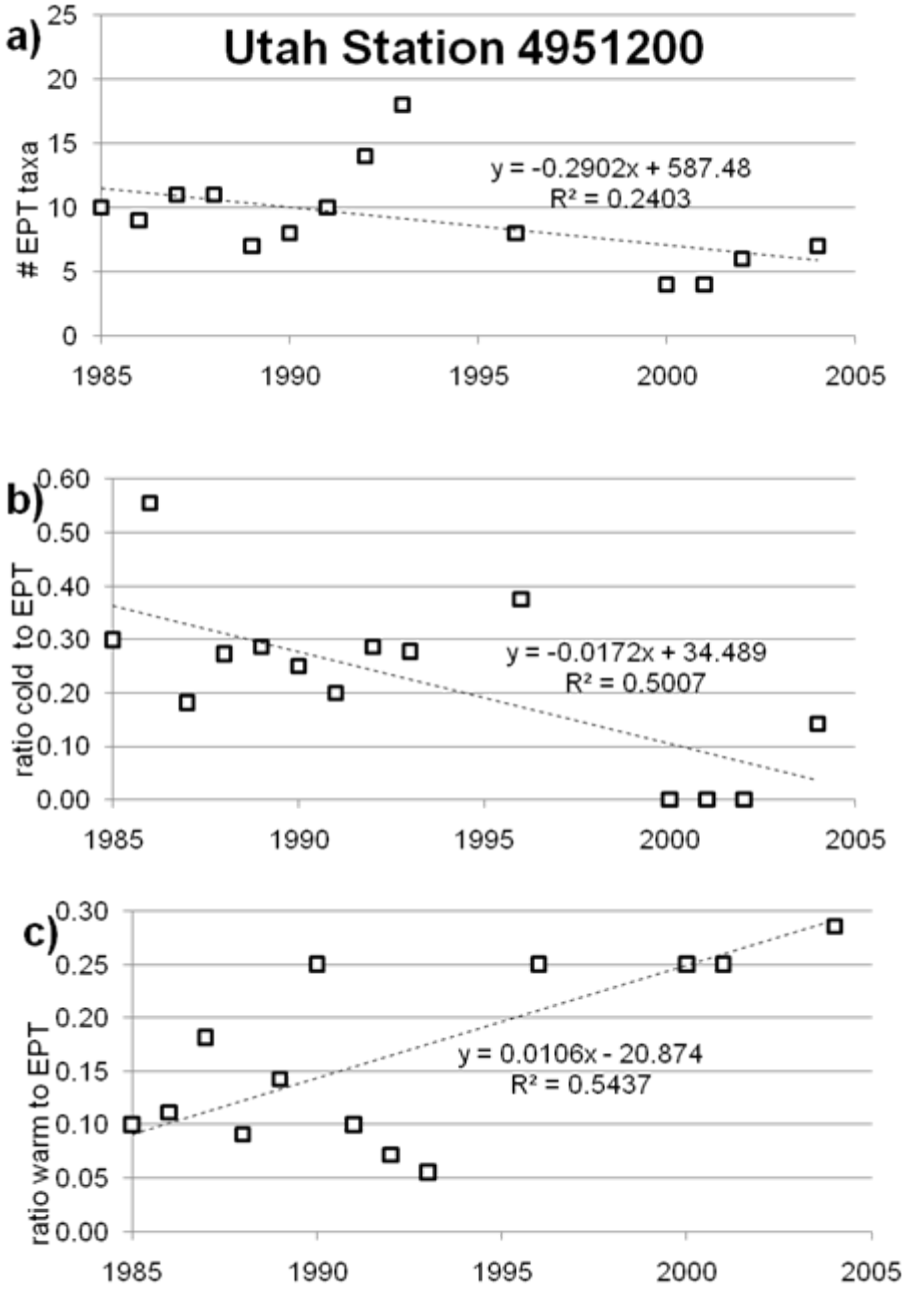
1215 Blue Ridge Mountain ecoregion biomonitoring stations
26 cold-preference taxa of 1142 total taxa
14 cold-preference EPT taxa of 443 EPT taxa



Reference-based comparisons→lowering of standards

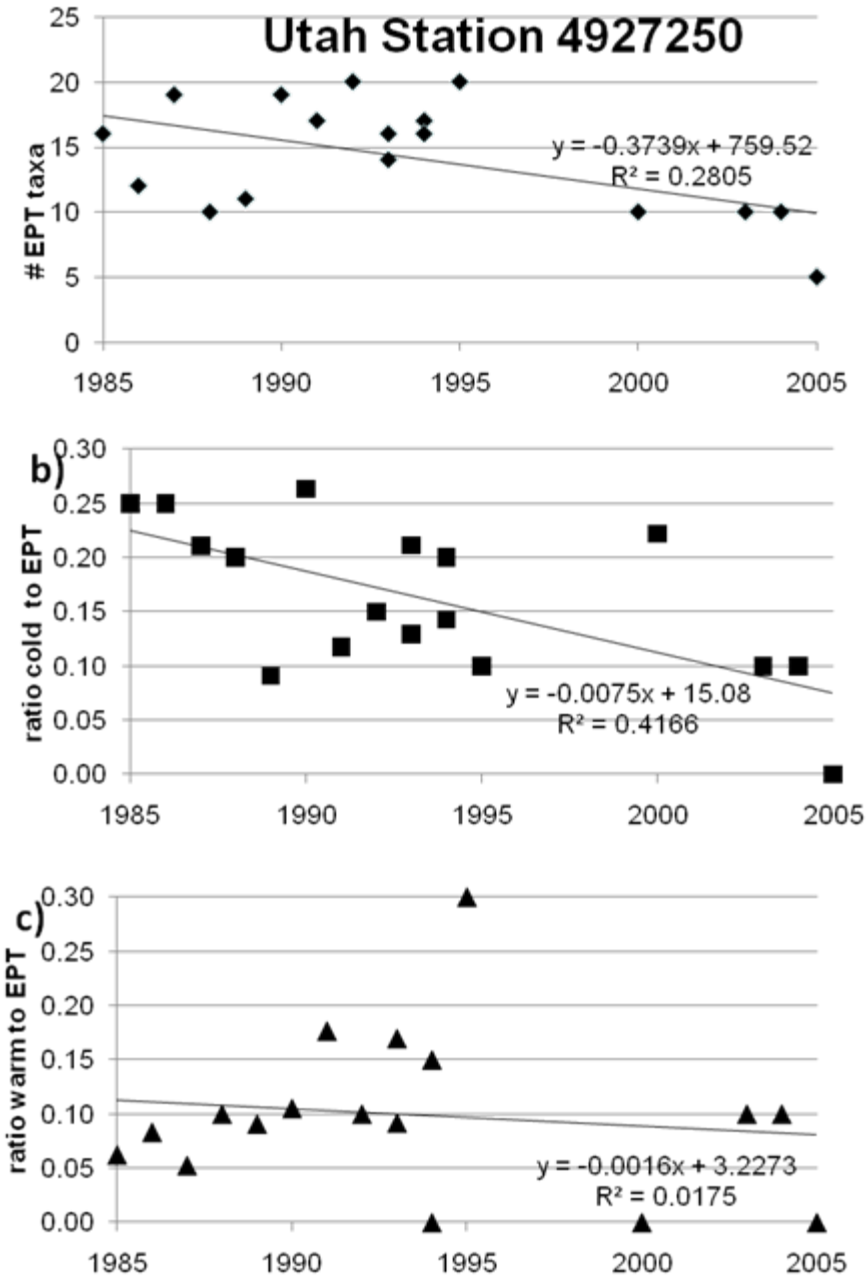
United States Environmental Protection Agency

Tracking cold-to-total and warm-to-total EPT richness metrics separately successfully accounted for the trends in total EPT richness over time



United States Environmental Protection Agency

Tracking cold-to-total and warm-to-total EPT richness metrics separately successfully accounted for the trends in total EPT richness over time



Application of Modified Metrics

Calculation of traditional metrics (e.g., EPT richness) along with modified cold and warm preference metrics

Metric ratios → proportional changes in cold and warm preference taxa → proportion of climate change contribution

United States Environmental Protection Agency

Questions?
Comments?