Climate Change: Identifying Ohio Indicators for Sensitivity to Temperature and Hydrologic Change

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OCT 26, 2010

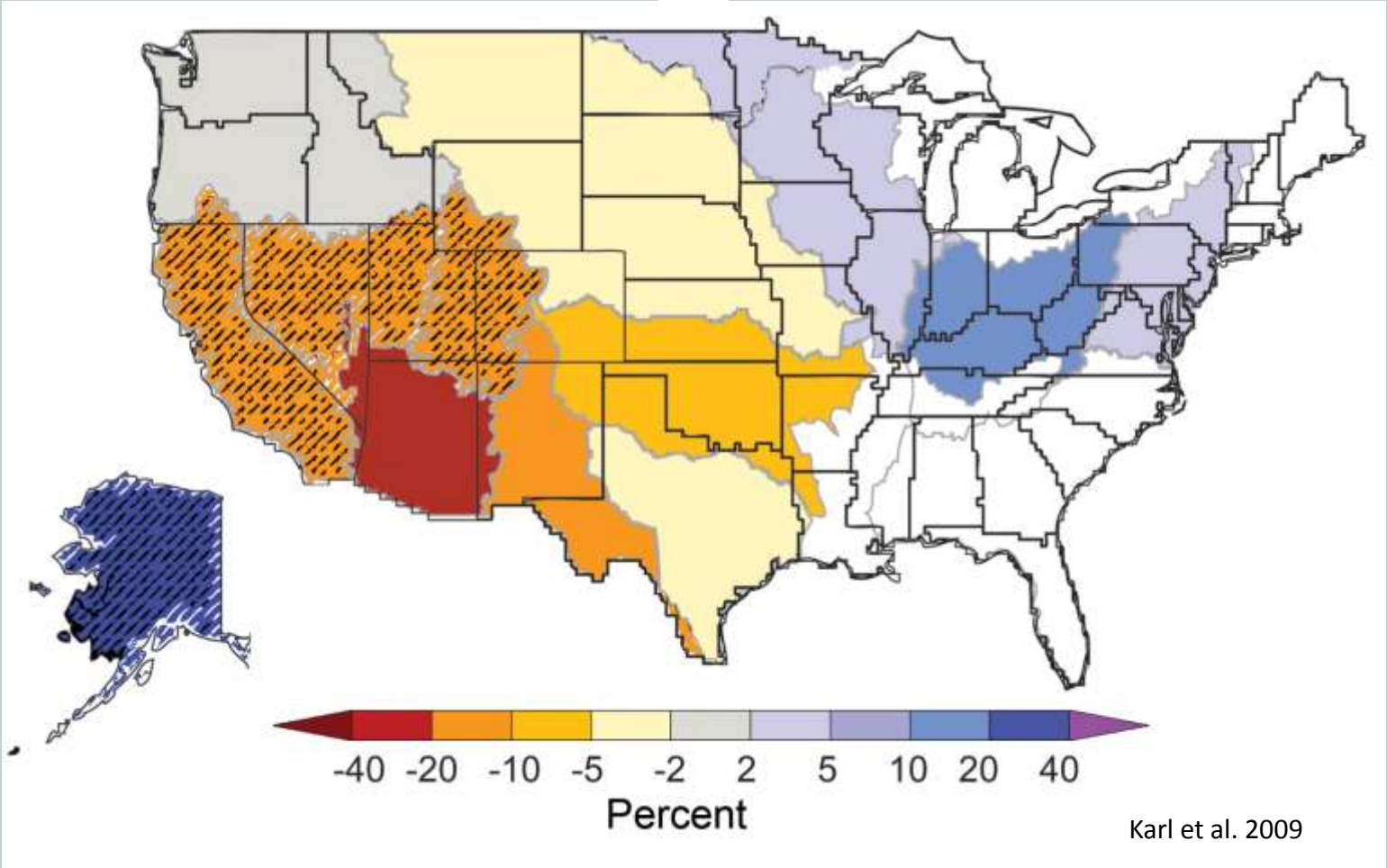
Evidence of Climate Change in the Great Lakes Region

- Temperatures are rising, especially in winter.
- Extreme rainfall events (24-hr and 7-day) are becoming more frequent.
- Winters have become shorter.
- Spring is coming earlier.
- Duration of ice cover is shorter, especially on smaller lakes.

Union of Concerned Scientists (UCS) and is based on *Confronting Climate Change in the Great Lakes Region: Impacts on our Communities and Ecosystems* (Kling et al., 2003).

Source: Edge of the Wilderness Scenic Byways

Projected Impacts on Runoff

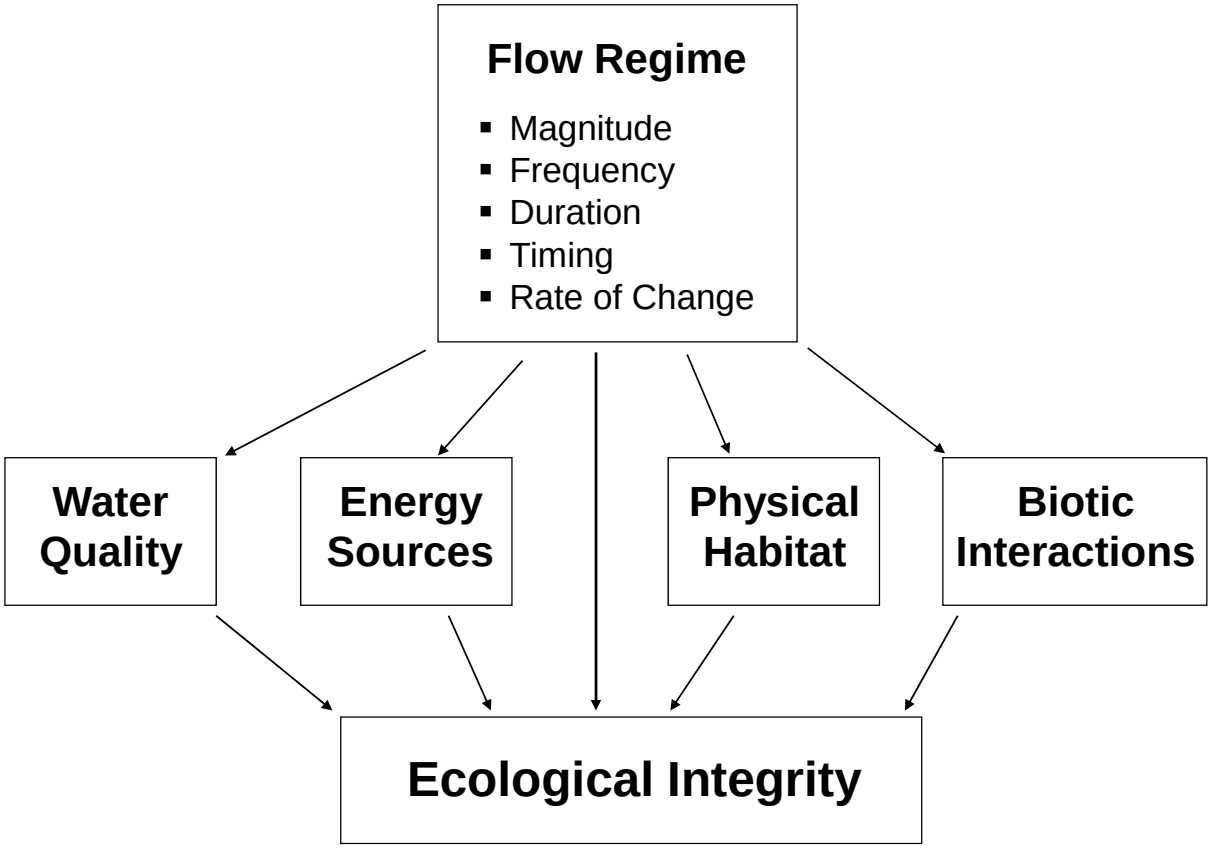


Karl et al. 2009

Approaches to Studied Effects of Climate Change

1. *Changes in species distribution and ranges*;
2. Changes in phenology (e.g., date of emergence for macroinvertebrates, spawning dates for fish); and
3. Changes in evolutionary effects due to altered selection regimes from temperature, flow

Changes to Flow Regime Due to Climate Change

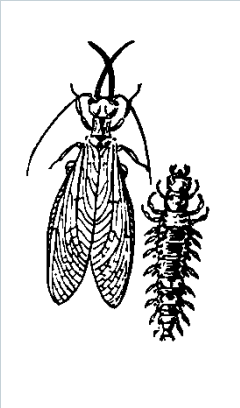


Identification of Taxa Potentially Sensitive to Climate Change

- Mined database for and fish and macroinvertebrate taxa that could serve as indicators of climate change
  - (sensitive to temperature or other measures such as hydrological stressors)
- Calculated weighted stressor values (WSVs) and "Taxa Indicator Values" (TIVs) for temperature and habitat measures that would be correlated with hydrological alterations.
- The WSVs were generated by relating historical taxa/species from sites in Ohio to chemical and habitat stressors and calculating weighted average values for each taxa/stressor combination where the weighting is the relative abundance of the taxa/species at a site.
  - Also calculated non-weighted "Average Stressor Values" or ASVs for taxa identified as present/absent

How to Measure Hydrological Changes

- Accurate flow data difficult to obtain for ungaged areas especially in small streams (potential high variability)
- Confounding effects of habitat on flow regime impacts to aquatic life usually ignored



Hydro-QHEI

- QHEI (and other habitat tools) have a number of metrics associated with stream flow characteristics, either by measuring current velocity attributes or stream depths
- Developed a subset of metrics into a “Hydro-QHEI” indicator that would best represent influence of flow in the QHEI

Scoring of Hydro-QHEI

Current Metric		Depth Metric	
QHEI Current Attribute	Score	QHEI Depth Attribute	Score
Very Fast Current	+5	Deep Pools (Cover Metric)	+4
Fast Current	+3	Pool Depths > 1m	+4
Moderate Current	+2	Pool Depths 0.7 – 1.0 m	+3
Slow Current	+1	Pool Depths 0.4 – 0.7 m	+2
Eddies	+2	Pool Depths 0.2 – 0.4 m	+1
Very Deep Riffles	+3	Pool Depths < 0.20	-1
Moderate Depth Riffles	+1	Deep Riffles	+3
Interstitial Flow	-1	Moderate Riffles	+2
Intermittent Flow	-3	Shallow Riffles	+1
		Riffles Absent or Non-functional	-1

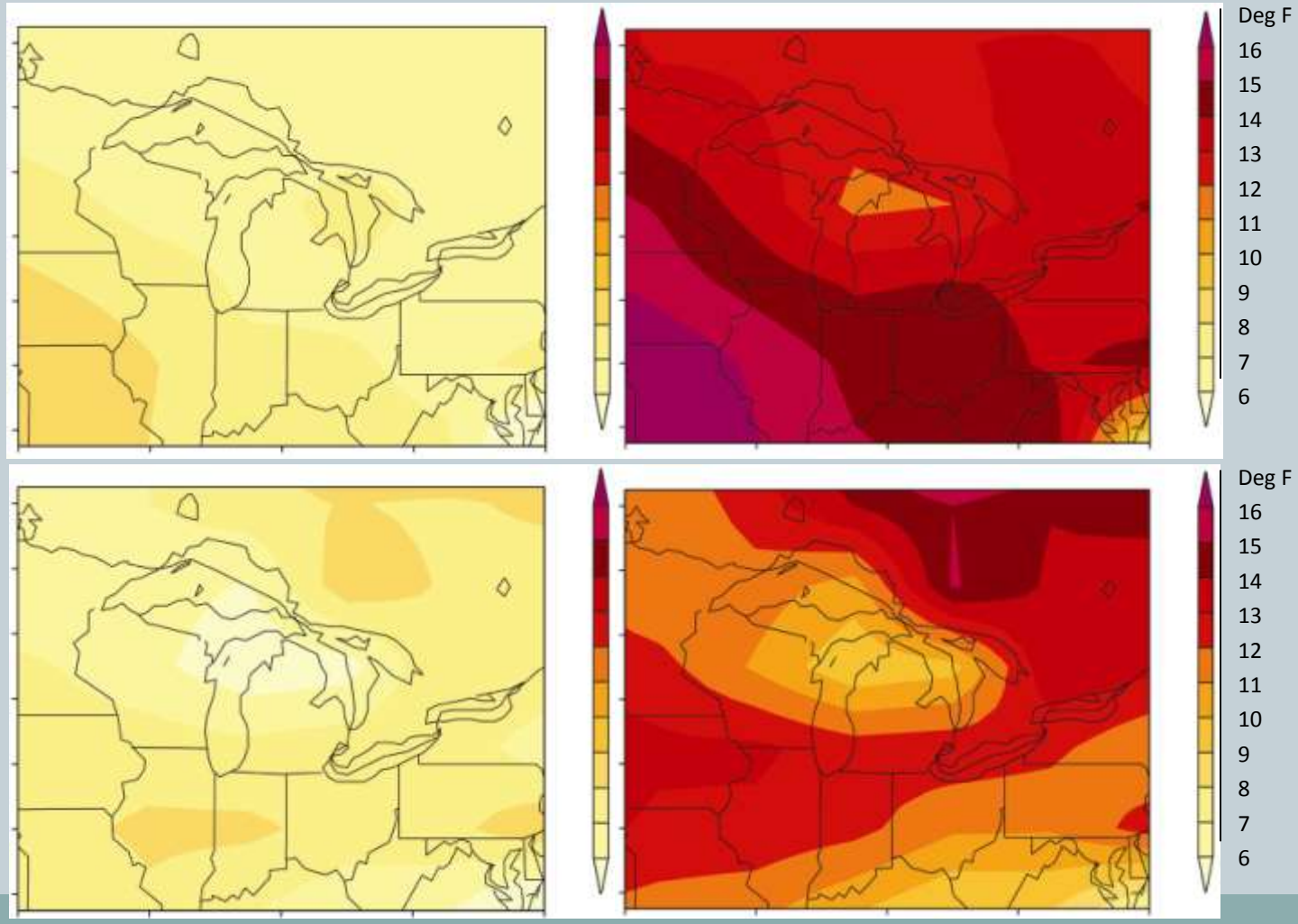
Linked Taxa/Species Occurrences to Hydro-QHEI and Field Temperature Data (STORET)

- Developed “Weighted Stressor Values” where biological and habitat data is linked for Temperature and Hydro-QHEI attributes
- For fish and macroinvertebrates developed list of candidate species and taxa sensitive (or tolerant) to these indicators

Projected Temperature Increase in the Great Lakes Region (by 2070-99)

Summer

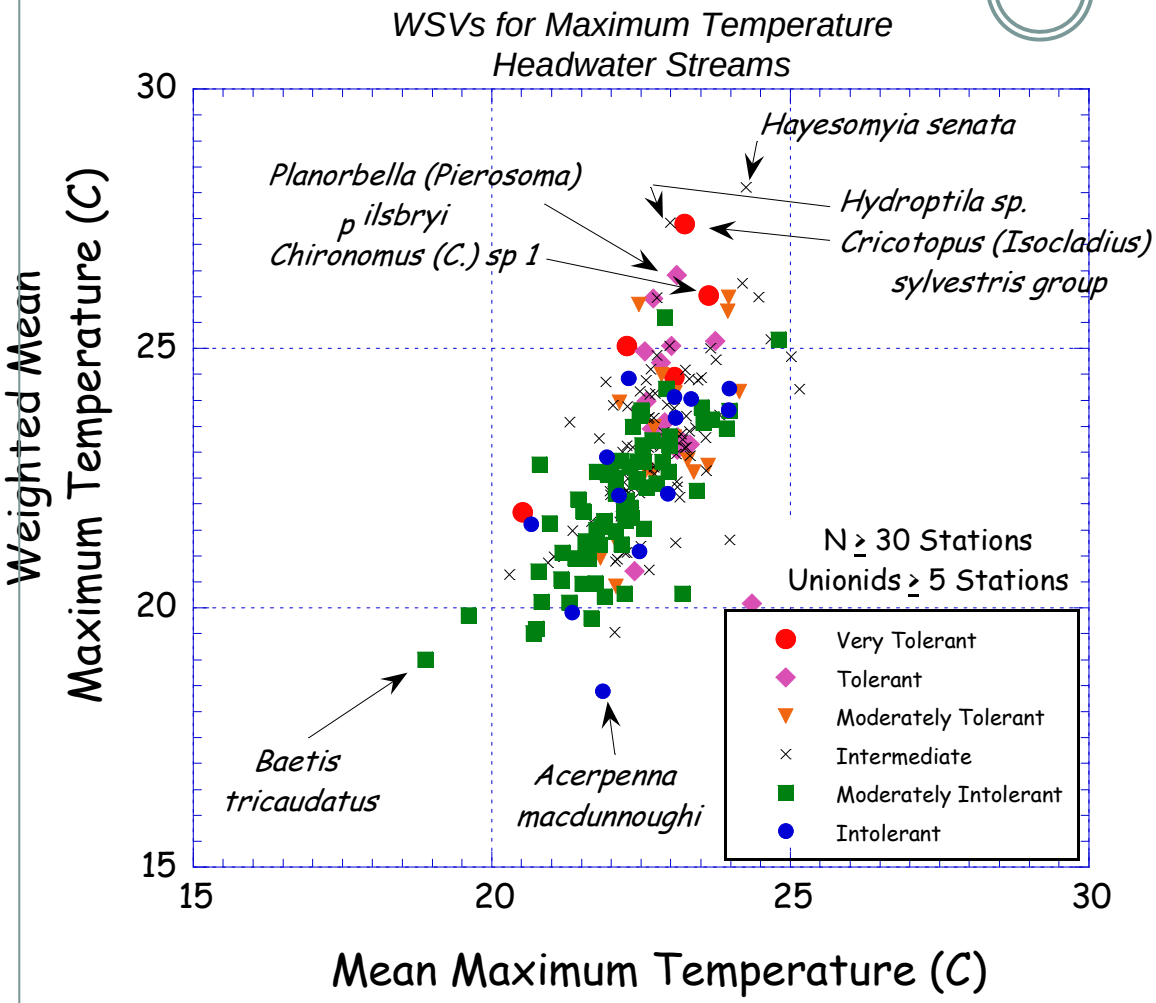
Winter

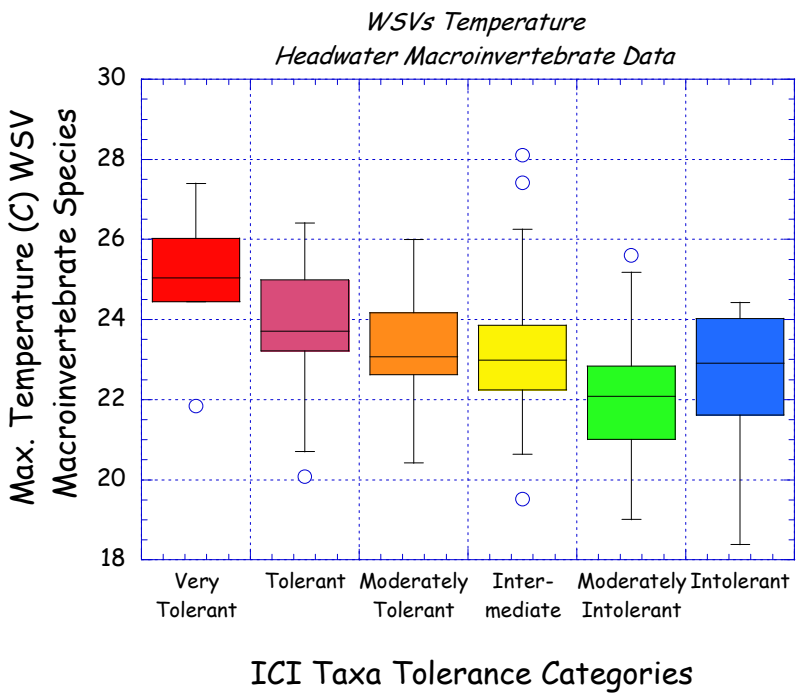


Lower emissions

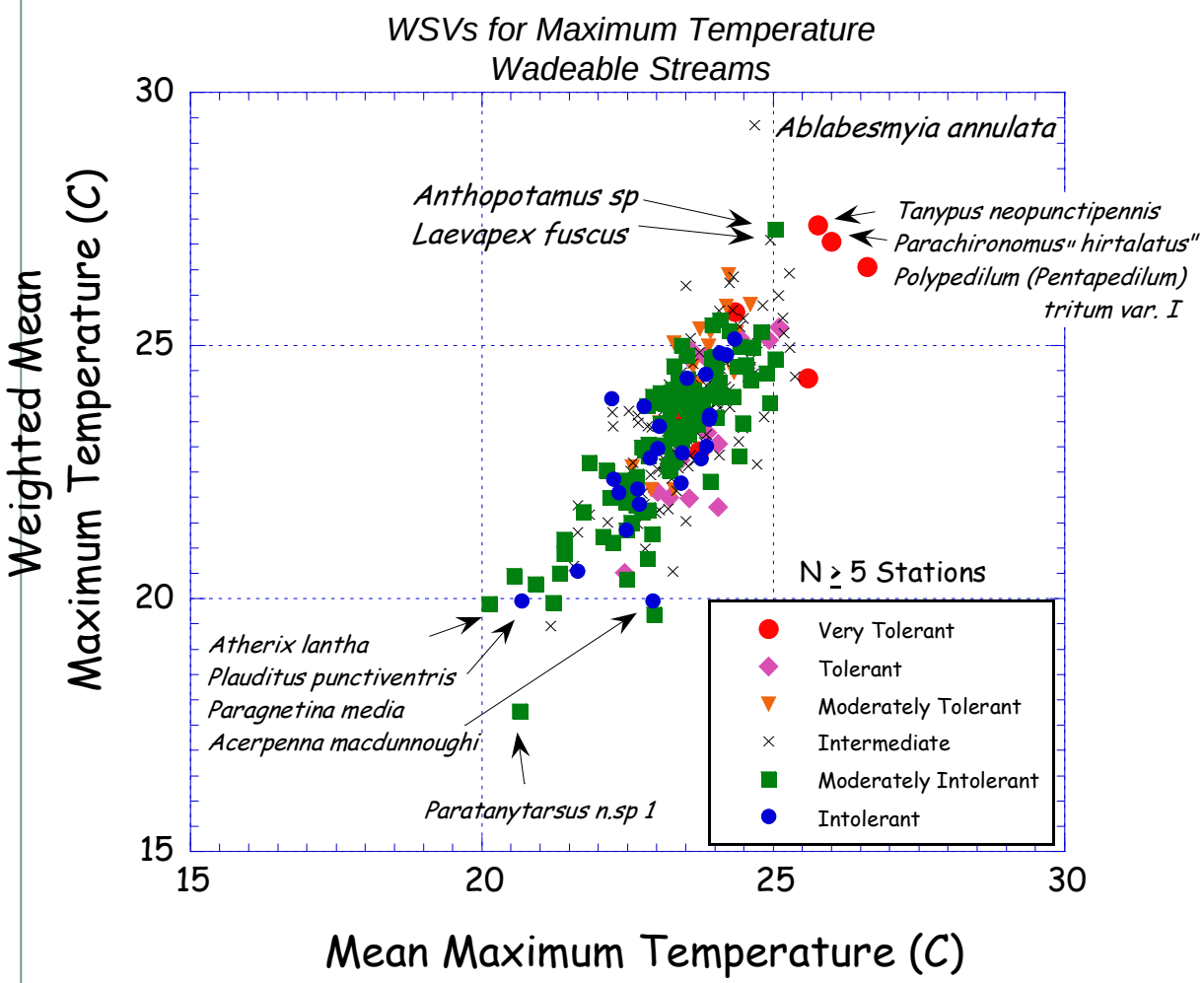
Higher emissions

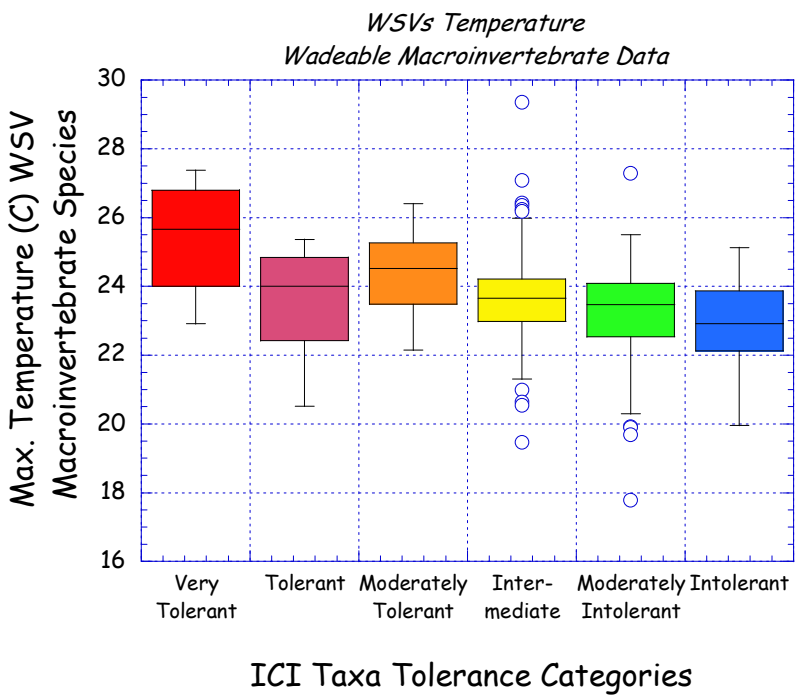
Macros & Temperature



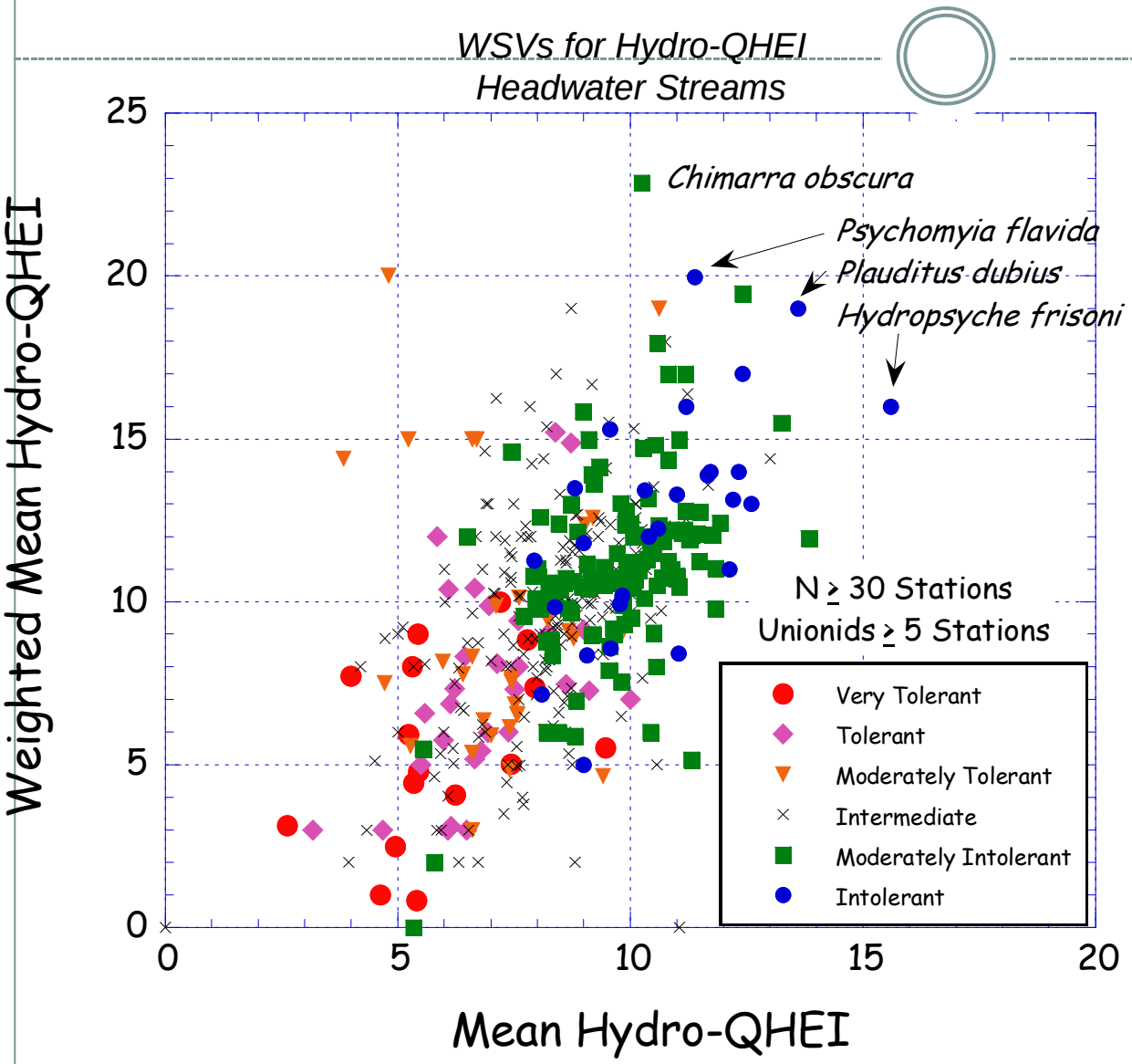


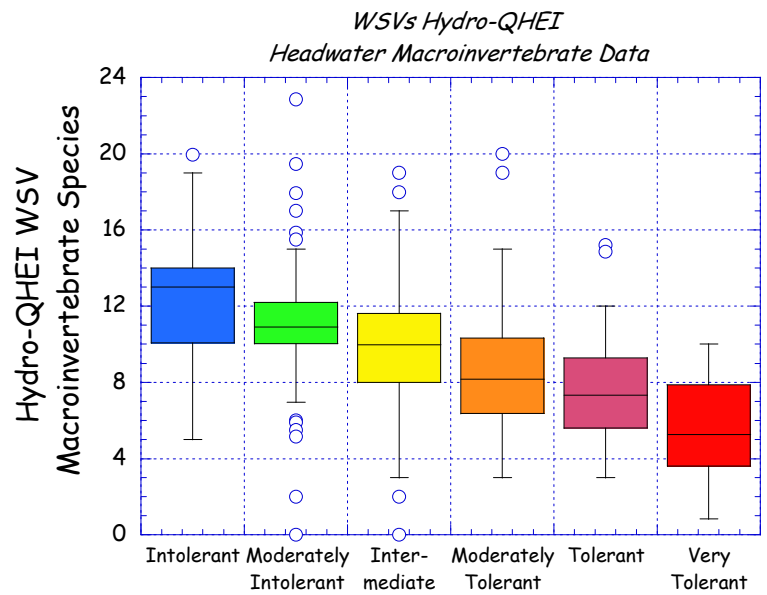
Wadeable Streams



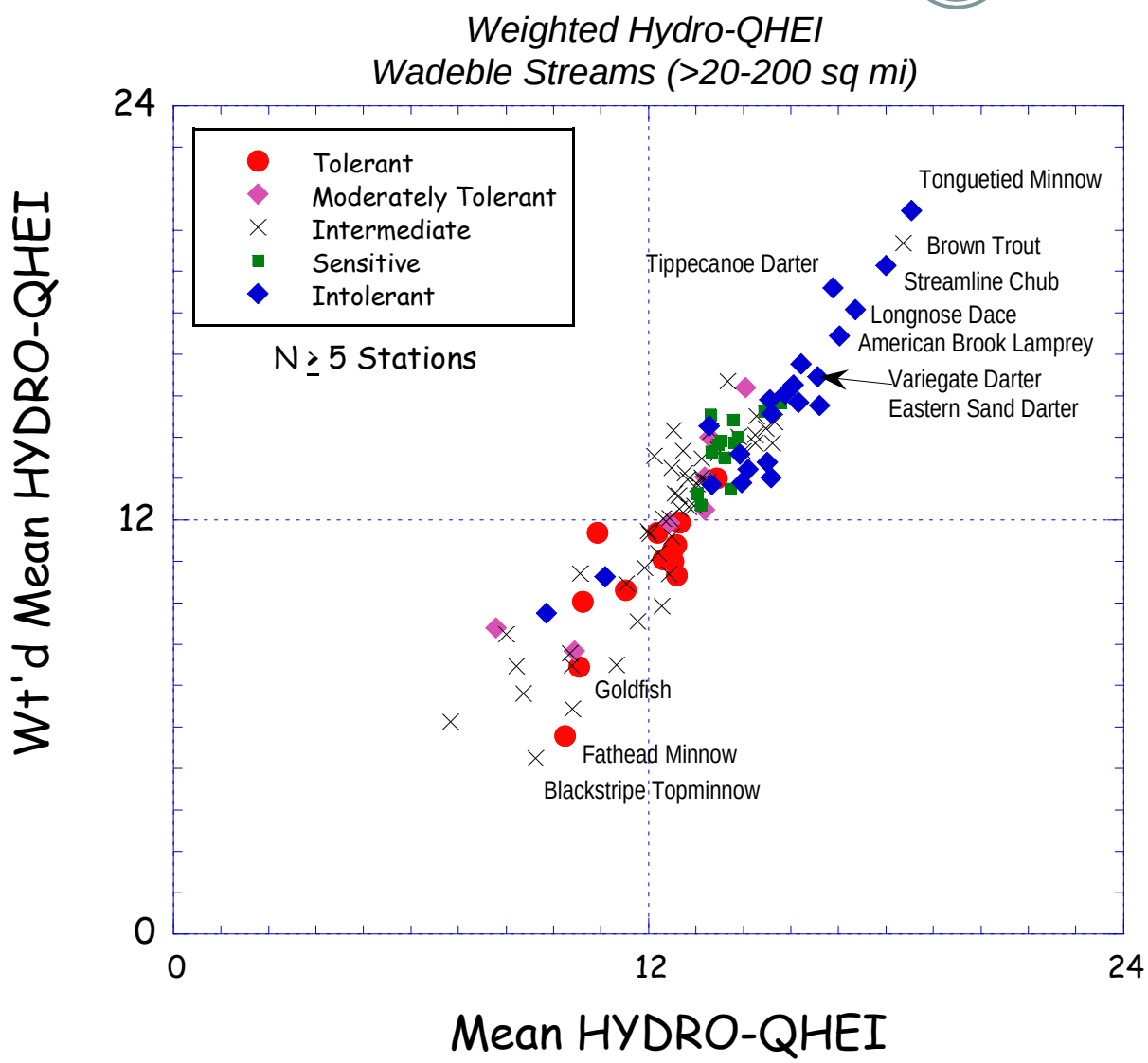


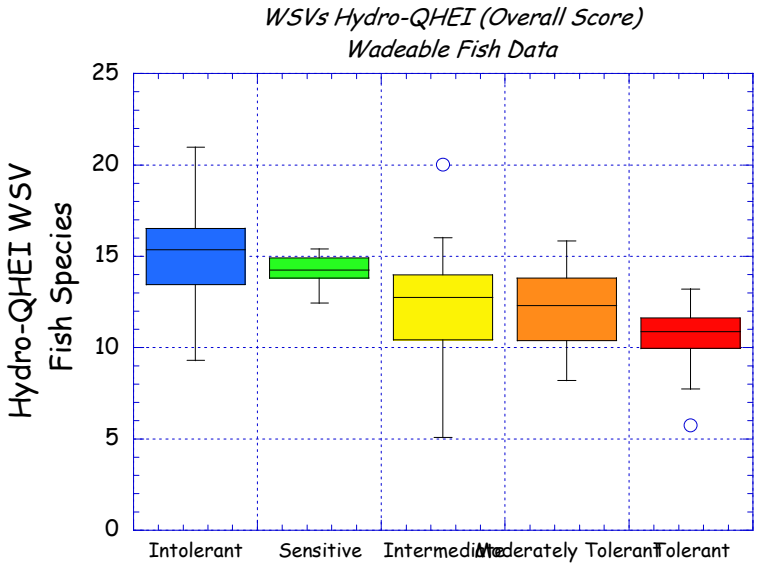
Macros in Headwaters: Hydro-QHEI





Fish in Wadeable Streams: HydroQHEI





Have There Been Any Changes in Occurrence by Stream Size? Only Sites Sampled During Each Period

		Sample Size		1st Percentile			5thPercentile			25th Percentile		
Species Code	Species Name	1978-1989	1998-2008	1978-1989	1998-2008	Trend	1978-1989	1998-2008	Trend	1978-1989	1998-2008	Trend
01-006	least brook lamprey [ ]	19	16	4.9	4.9	-	4.9	4.9	-	16.3	9.6	+
34-001	central mudminnow [T]	18	1	5.0	9.0	-	5.0	9.0	-	10.8	9.0	+
40-009	black redhorse [I]	211	153	10.1	28.2	-	35.6	69.8	-	105.3	140.8	-
40-010	golden redhorse [M]	507	353	7.8	8.0	-	27.6	24.5	+	111.3	122.0	-
40-015	northern hog sucker [M]	553	424	5.3	6.0	-	10.0	14.5	-	46.7	71.5	-
43-001	common carp [T]	562	287	11.5	8.4	+	28.4	19.3	+	207.0	130.0	+
43-004	hornyhead chub [I]	37	19	1.5	1.5	-	9.4	4.0	+	32.0	32.8	-
43-005	river chub [I]	90	73	6.7	41.0	-	33.0	47.9	-	80.0	105.0	-
43-007	bigeye chub [I]	16	20	15.0	16.9	-	15.6	16.9	-	34.0	56.7	-
43-012	longnose dace [R]	0	0	0.0	0.0	-	0.0	0.0	-	0.0	0.0	-
43-014	tonguetied minnow [S]	12	5	34.0	7.5	+	34.0	7.5	+	34.0	27.4	+
43-017	redside dace [I]	22	17	5.0	5.0	-	5.0	5.8	-	7.5	7.5	-
43-021	silver shiner [I]	191	148	10.7	13.9	-	32.0	16.5	+	74.0	45.0	+
43-022	rosyface shiner [I]	133	114	6.8	5.0	+	32.0	9.1	+	79.5	99.0	-
43-034	sand shiner [M]	111	262	5.9	7.5	-	16.9	16.7	+	51.4	77.0	-
43-042	fathead minnow [T]	53	51	0.8	0.8	-	2.8	2.5	+	16.0	7.4	+
43-043	bluntnose minnow [T]	646	449	1.5	1.5	-	7.4	6.8	+	37.0	29.0	+
47-004	yellow bullhead [T]	296	176	2.1	1.8	+	8.0	9.0	-	32.5	23.0	+
47-008	stonecat madtom [I]	115	68	20.5	10.9	+	33.0	69.0	-	101.0	105.0	-
47-012	brindled madtom [I]	42	24	19.7	19.7	-	19.7	29.7	-	32.0	89.0	-
54-002	blackstripe topminnow [	74	36	2.6	1.5	+	10.3	2.6	+	32.0	25.0	+
77-004	smallmouth bass [M]	520	428	11.4	8.7	+	24.5	23.9	+	104.0	125.5	-
77-008	green sunfish [T]	673	396	2.5	1.5	+	8.0	6.9	+	44.5	29.5	+
77-011	longear sunfish [M]	510	339	8.6	6.3	+	28.2	15.2	+	132.0	122.0	+
80-004	dusky darter [M]	12	27	16.1	4.9	+	21.4	14.4	+	120.5	157.0	-
80-011	logperch [M]	138	246	1.5	14.3	-	28.5	32.0	-	74.0	151.0	-
80-013	eastern sand darter [R]	2	3	286.0	174.0	+	286.0	174.0	+	286.0	202.0	+
80-015	greenside darter [M]	299	306	8.5	5.9	+	16.0	9.9	+	42.0	41.0	+
80-022	rainbow darter [M]	267	253	2.5	2.6	-	6.8	8.2	-	28.2	26.5	+
90-002	mottled sculpin [ ]	107	137	1.5	1.5	-	2.5	4.9	-	9.6	16.7	-
95-001	brook stickleback [ ]	17	10	7.4	7.4	-	8.6	7.4	+	21.0	8.0	+

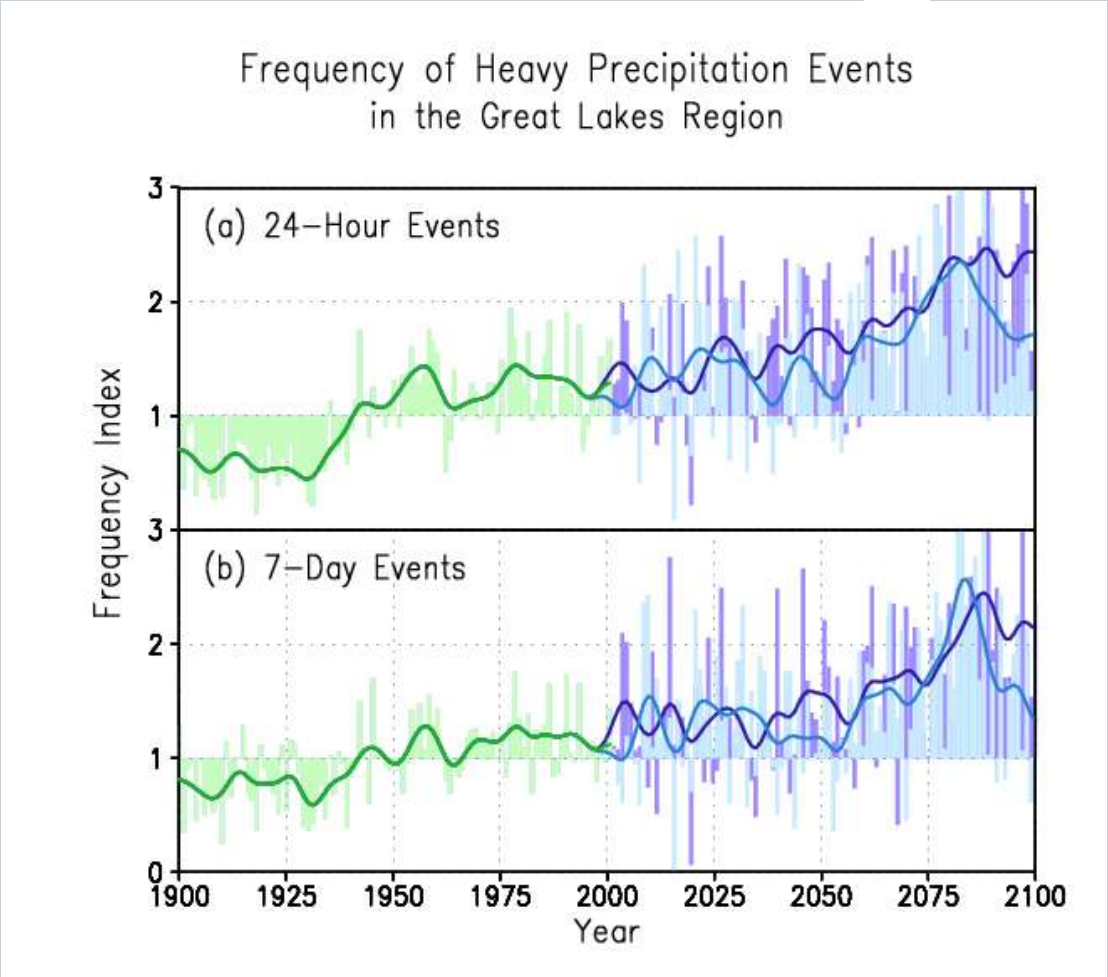
Initial Trend Assessment for Sensitive and Tolerant Taxa

- Compared probability of collection of sensitive species/taxa from 1980s to 2000s
- Treated each sample at a specific station as an independent data point
  - Identified all sites where a taxa was collected at least once on 1980s and/or 2000s and had one or more samples during each period
  - Was the probably of capturing a taxa the same, higher or lower between sampling periods

Species/Taxa Trends, Continued

- Compared each sample at a site to all samples in later (or earlier) period to determine
  - Count of sites where there was no change in occurrence
    - Taxa present in both samples
    - Taxa absent in both samples
  - Count of sites where taxa was present in the 1980s, but not in a sample in 2000s ("Disappeared")
  - Count of sites where taxa was absent in the 1980s, but collected in a sample in the 2000s ("Appeared")

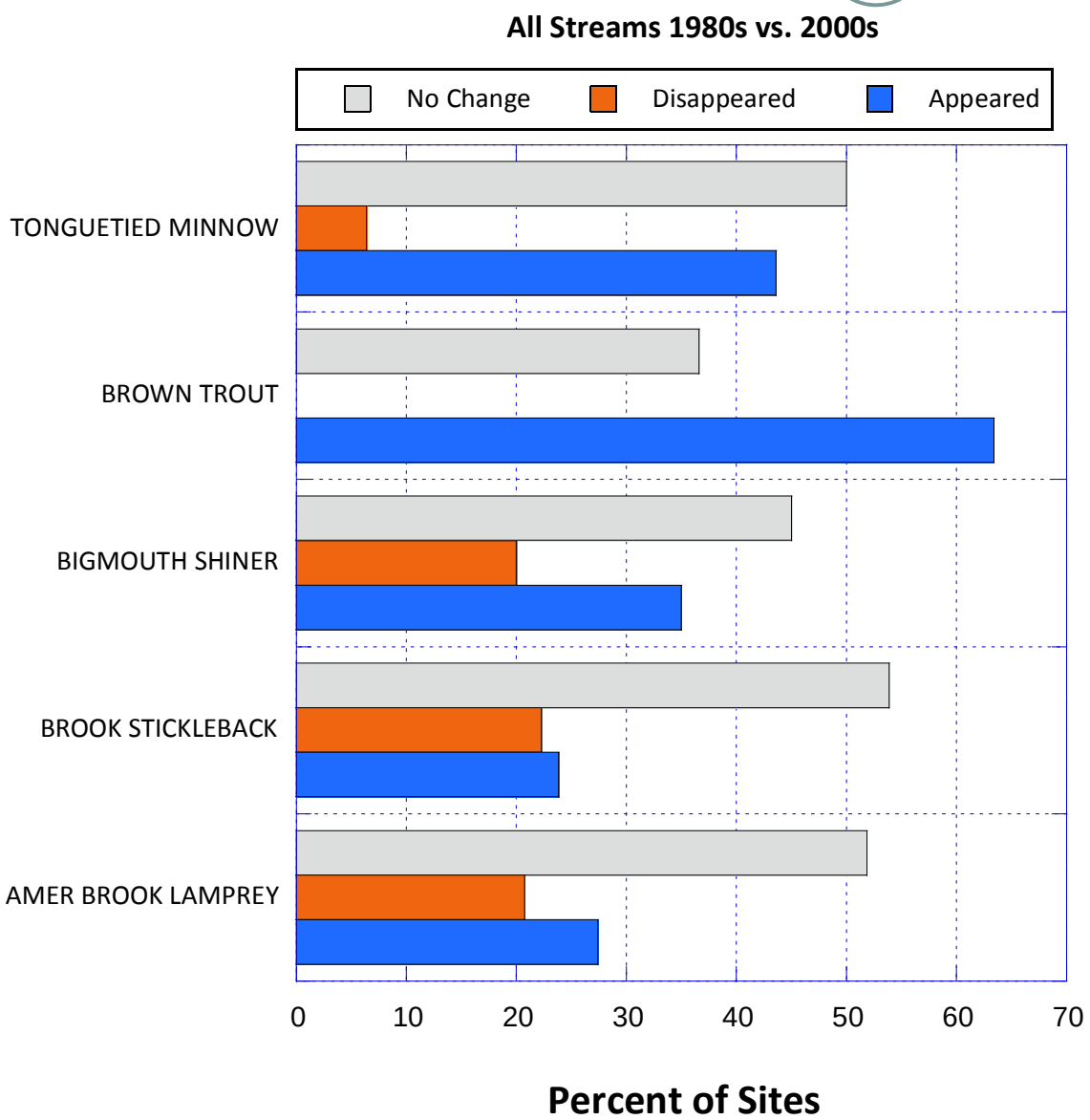
Projected Precipitation Changes in the Great Lakes Region (by 2070-99)



- Doubling of heavy precipitation events
- Seasonal shifts in precipitation --
  * <u>More</u> rain in winter and spring (planting season)
  * <u>Less</u> rain during the summer and fall growing seasons

Wuebbles, D.J. and K. Hayhoe. 2004. Climate Change Projections for the United States Midwest. Mitigation and Adaptation Strategies for Global Change 9(4): 335-363.

Preliminary Results: Anv Pattern to Occurrence?



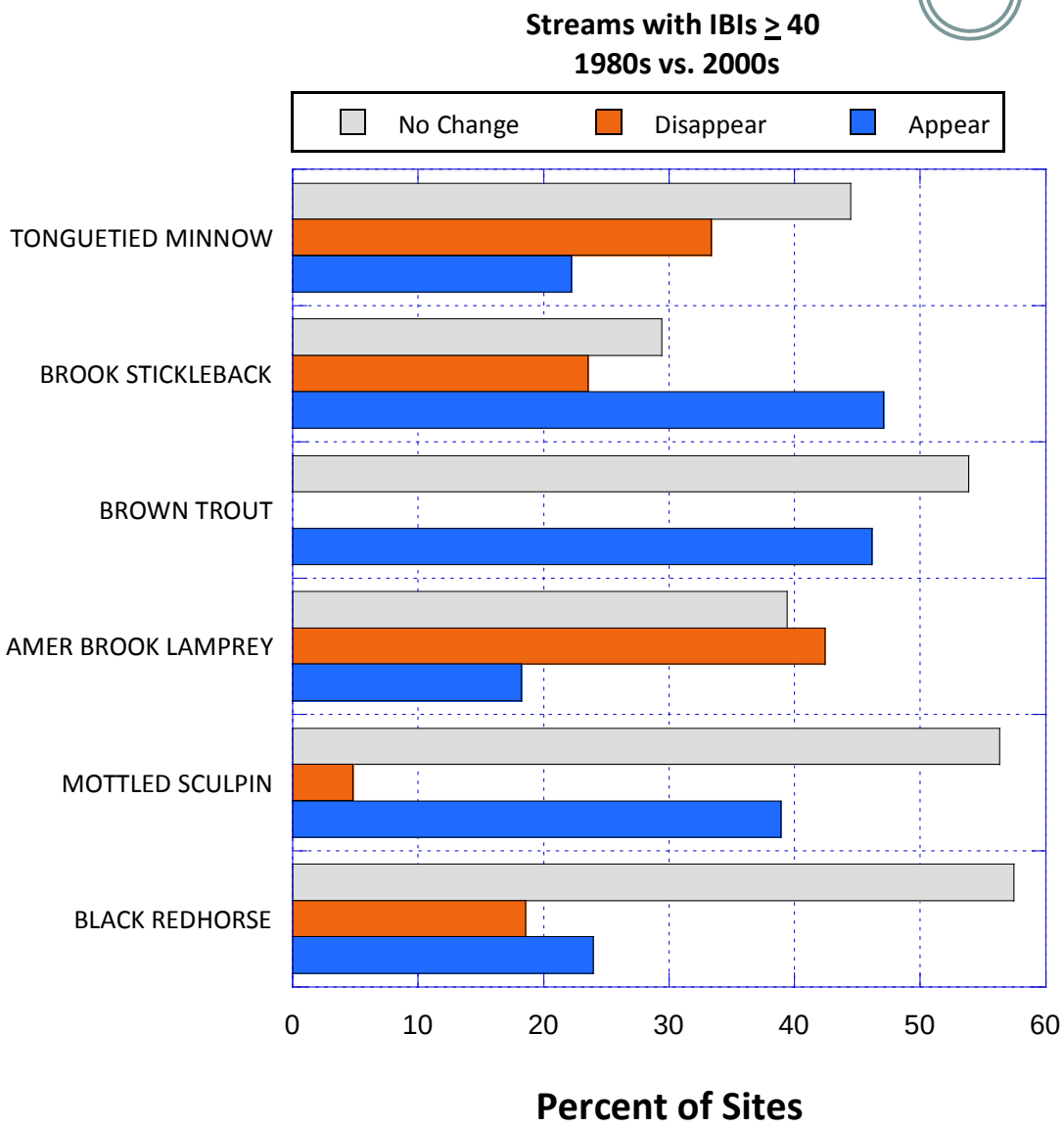
Responding to Point Source Reductions

Stocked Species

Local Distribution; Responding to Point Source Reductions

No Pattern

Preliminary Results: IBIs ≥ 40



No Clear Pattern

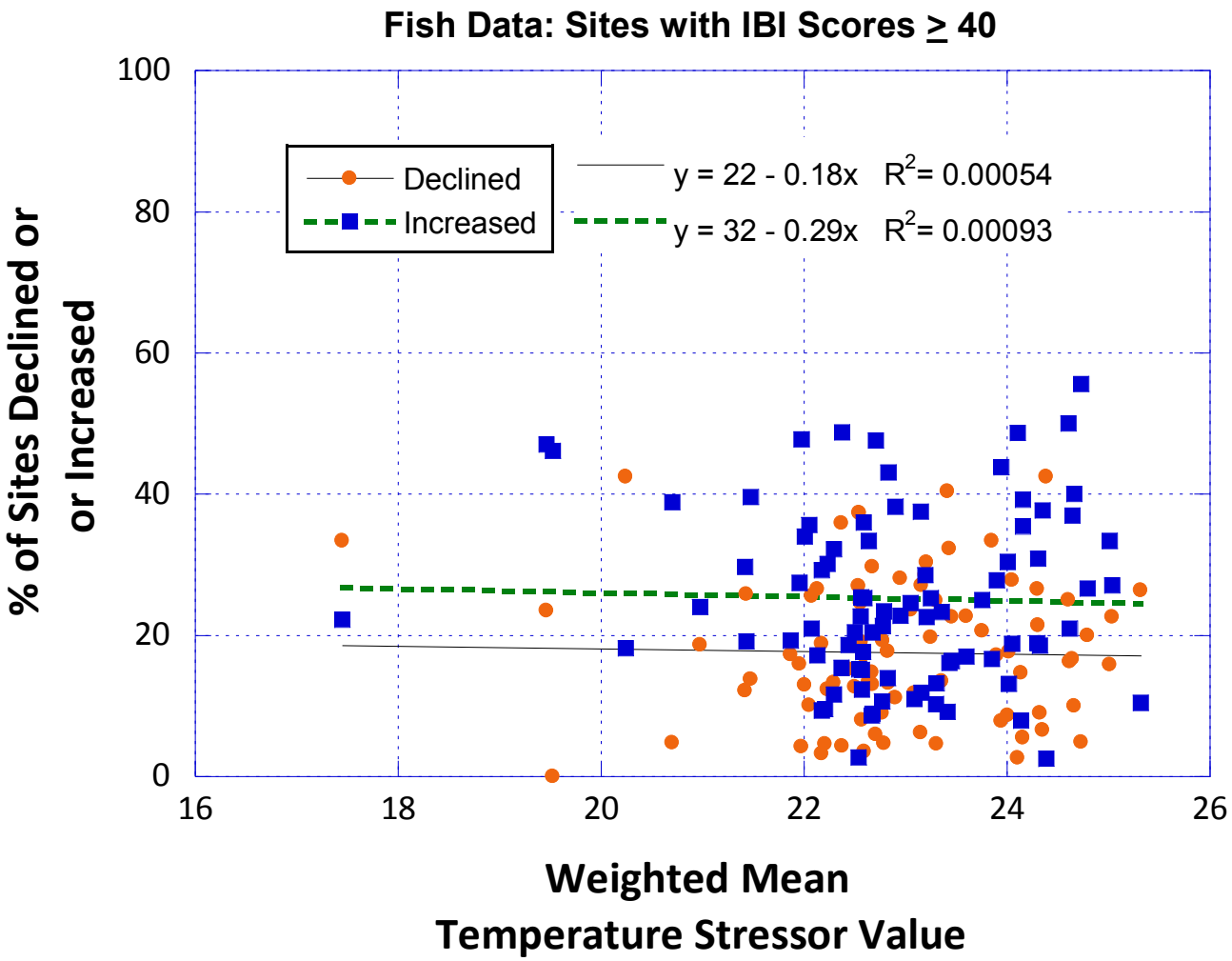
Stocked Species

Some Decline

Increase

No Clear Pattern

Scatter Plot: Temperature WSV vs. Declines or Increases in Collections at Sites



All Sites: Trend by Fish Species

Taxa	Taxaname	Toler-ance	Mean Max Temp C	No. Sites	Trend from 1980s to 2000s No Change % (#)	Decreaxe % (#)	Increase % (#)	Trend	Cause:
43014	TONGUETIED MINNOW	S	17.45	79	50.0 (47)	6.4 (6)	43.6 (41)		
95001	BROOK STICKLEBACK		19.46	205	53.9	22.3 (43)	23.8 (46)		
25001	BROWN TROUT		19.52	93	36.6 (41)	0.0 (0)	63.4 (71)		
01007	AMER BROOK LAMPREY	R	20.24	113	51.9 (70)	20.7 (28)	27.4 (37)		
90002	MOTTLED SCULPIN		20.70	790	54.5	5.0 (46)	40.4		
43033	BIGMOUTH SHINER		20.83	27	45.0 (9)	20.0 (4)	35.0 (7)		
40009	BLACK REDHORSE	I	20.97	1105	52.5	18.1	29.4		
43011	WESTERN BLACKNOSE DACE	T	21.42	1216	60.7	13.1	26.2		
80025	LEAST DARTER		21.42	13	36.4 (4)	0.0 (0)	63.6 (7)		
40008	SILVER REDHORSE	M	21.43	875	46.3	15.7	38.0		
43016	SOUTH. REDBELLY DACE		21.47	317	45.8	23.3 (81)	30.8		
25002	RAINBOW TROUT		21.60	111	41.7 (55)	31.8 (42)	26.5 (35)		
43017	REDSIDE DACE	I	21.87	175	55.6 (90)	17.3 (28)	27.2 (44)		
43005	RIVER CHUB	I	21.96	550	47.2	13.3	39.5		
80016	BANDED DARTER	I	21.97	1201	39.0	4.9 (91)	56.1		
43042	FATHEAD MINNOW	T	22.01	757	51.8	24.8	23.4		
43022	ROSYFACE SHINER	I	22.05	907	47.0	8.4 (114)	44.7		
63001	TROUT-PERCH		22.08	250	50.8	23.8 (73)	25.4 (78)		

Trend at Sites with IBIs ≥ 40 (Warmwater or Better)

Taxa	Taxaname	Toler-ance	Mean Max Temp C	No. Sites	Trend from 1980s to 2000s No Change % (#)	Decreaxe % (#)	Increase % (#)	Trend
95001	BROOK STICKLEBACK		19.46	21	29.4 (5)	23.5 (4)	47.1 (8)	
25001	BROWN TROUT		19.52	11	53.8 (7)	0.0 (0)	46.2 (6)	
01007	AMER BROOK LAMPREY	R	20.24	34	39.4 (13)	42.4 (14)	18.2 (6)	
90002	MOTTLED SCULPIN		20.70	375	56.3 (223)	4.8 (19)	38.9 (154)	
40009	BLACK REDHORSE	I	20.97	592	57.4 (405)	18.6 (131)	24.0 (169)	
43011	WESTERN BLACKNOSE DACE	T	21.42	502	58.2 (302)	12.1 (63)	29.7 (154)	
40008	SILVER REDHORSE	M	21.43	375	55.0 (258)	25.8 (121)	19.2 (90)	
43016	SOUTH. REDBELLY DACE		21.47	161	46.7 (85)	13.7 (25)	39.6 (72)	
43017	REDSIDE DACE	I	21.87	67	63.5 (33)	17.3 (9)	19.2 (10)	
43005	RIVER CHUB	I	21.96	248	56.7 (153)	15.9 (43)	27.4 (74)	
80016	BANDED DARTER	I	21.97	655	48.0 (386)	4.2 (34)	47.8 (384)	
43042	FATHEAD MINNOW	T	22.01	181	53.0 (106)	13.0 (26)	34.0 (68)	
43022	ROSYFACE SHINER	I	22.05	524	54.3 (372)	10.1 (69)	35.6 (244)	
63001	TROUT-PERCH		22.08	138	53.5 (92)	25.6 (44)	20.9 (36)	
37001	GRASS PICKEREL	P	22.13	283	56.2 (199)	26.6 (94)	17.2 (61)	
80022	RAINBOW DARTER	M	22.18	862	67.6 (650)	3.2 (31)	29.2 (281)	
40016	WHITE SUCKER	T	22.18	825	71.8 (610)	18.8 (160)	9.4 (80)	
40015	NORTHERN HOG SUCKER	M	22.21	933	85.8 (887)	4.6 (48)	9.6 (99)	
43004	HORNYHEAD CHUB	I	22.23	88	57.5 (84)	12.3 (18)	30.1 (44)	
43021	SILVER SHINER	I	22.29	596	56.0 (421)	11.8 (89)	32.2 (242)	
43013	CREEK CHUB	T	22.29	752	75.1 (576)	13.3 (102)	11.6 (89)	
37003	NORTHERN PIKE		22.37	33	48.7 (19)	35.9 (14)	15.4 (6)	
43007	BIGEYE CHUB	I	22.38	151	46.9 (76)	4.3 (7)	48.8 (79)	

All Sites: Trend by Macro Species

Taxa	Taxaname	Toler-ance	Mean Max Temp C	No. Sites	Trend from 1980s to 2000s: No Change % (#)	Decreaxe % (#)	Increase % (#)		Cause:
11115	Baetis tricaudatus	MI	18.89	41	0.0 (0)	4.5 (1)	95.5 (21)		*Improved Taxonomy*
53300	Glossosoma sp	MI	19.31	28	52.9 (9)	23.5 (4)	23.5 (4)		
80750	Eukiefferiella devonica g	MI	19.66	26	33.3 (6)	16.7 (3)	50.0 (9)		
34700	Agnetina capitata complex	MI	19.88	88	43.5 (27)	22.6 (14)	33.9 (21)		
11155	Plauditus punctiventris	MI	20.12	25	0.0 (0)	0.0 (0)	100.0		*Improved Taxonomy*
52450	Ceratopsyche sparna	MI	20.52	102	42.3 (30)	14.1 (10)	43.7 (31)		
13010	Leucrocuta hebe	MI	20.63	45	18.5 (5)	81.5 (22)	0.0 (0)		*Changing Taxonomy*
82220	Tvetenia discoloripes gro	MI	20.66	135	28.9 (26)	27.8 (25)	43.3 (39)		
94201	Lymnaeidae	MI	20.68	22	47.4 (9)	31.6 (6)	21.1 (4)		
50906	Psychomyia flavida	MI	20.68	69	38.8 (19)	6.1 (3)	55.1 (27)		
52440	Ceratopsyche slossonae	MI	20.70	85	40.8 (20)	30.6 (15)	28.6 (14)		
59310	Mystacides sepulchralis	MI	20.75	31	28.6 (6)	9.5 (2)	61.9 (13)		
84440	Polypedilum (Uresipedilum	MI	20.78	58	17.6 (6)	11.8 (4)	70.6 (24)		
07820	Cambarus (Cambarus) sp A	MI	20.81	28	27.8 (5)	33.3 (6)	38.9 (7)		
67300	Hydrochus sp	MI	20.82	22	61.1 (11)	27.8 (5)	11.1 (2)		
15000	Paraleptophlebia sp	MI	20.83	44	19.2 (5)	76.9 (20)	3.8 (1)		
80204	Brillia flavifrons group	MI	20.95	26	35.3 (6)	29.4 (5)	35.3 (6)		
70600	Antocha sp	MI	20.97	115	23.6 (17)	11.1 (8)	65.3 (47)		
85400	Micropsectra sp	MI	21.04	38	23.8 (5)	38.1 (8)	38.1 (8)		
13500	Stenonema sp	MI	21.08	21	33.3 (5)	53.3 (8)	13.3 (2)		

Recommendations

- Incorporate flow data into analyses of data changes in species distributions
- Broaden indicators to include some the ecological “traits” that have been studied elsewhere
- Focus work on very small streams where effects might be more readily observed
- Identify some headwater watersheds that can be sampled more frequently (e.g., yearly) with biological, flow and more robust temperature sampling

Discussion

- Other Indicators
- Other methodologies
- Headwater stream indicators

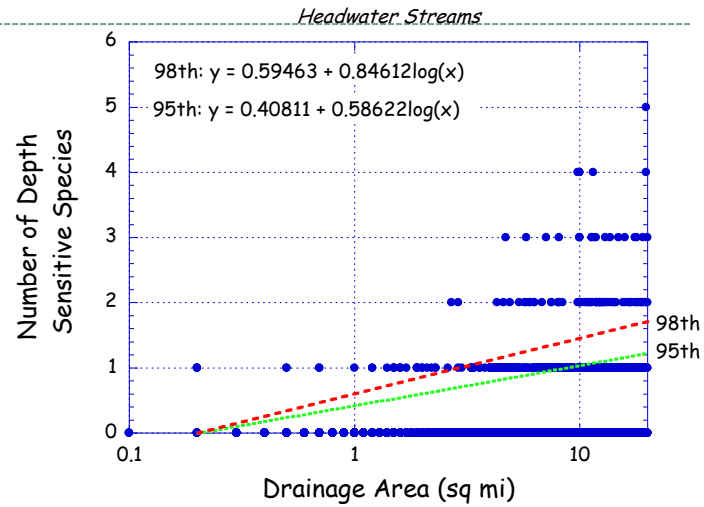
Other Work: Develop Flow IBI/ICI

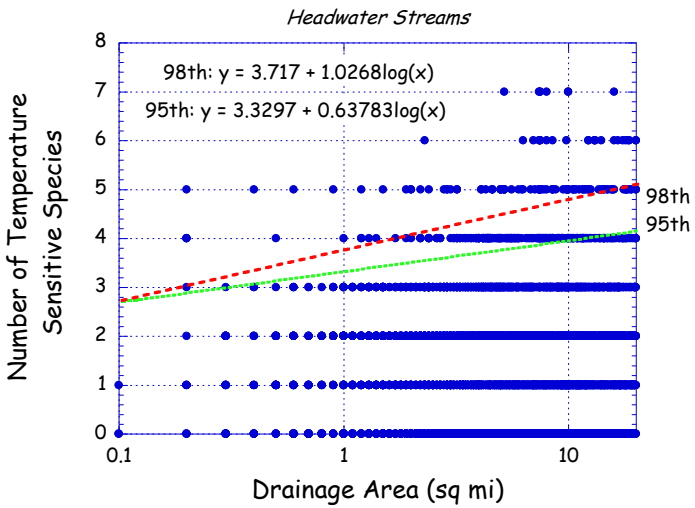
Table 1. Weighted stressor values (WSVs) for Hydro-QHEI current metric, Hydro-QHEI depth metric, overall Hydro-QHEI and for maximum Jul-Aug temperature for fish species in headwater streams. Species represent those ranked most sensitive by the weighted metrics scores with cut-offs given for each metric.

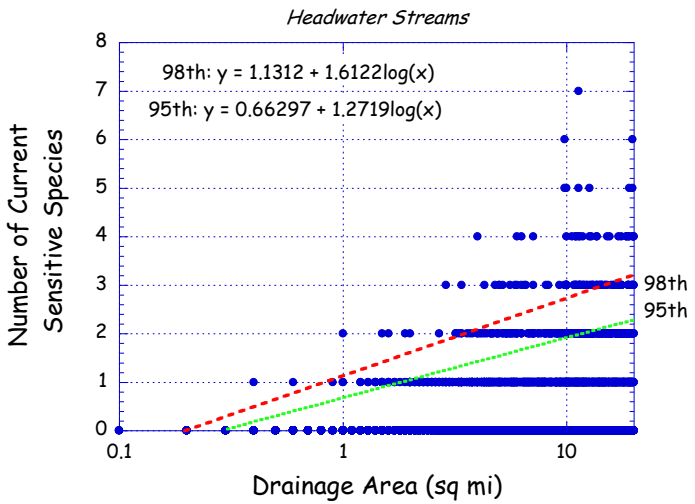
Species	Current > 5	Species	Depth > 7.8	Species	Hydro-QHEI > 12.8	Species	Max. Temp(C) < 22 C
tonguetied minnow	9.3	tonguetied minnow	11.7	tonguetied minnow	21.1	bigmouth shiner	19.0
longnose dace	6.9	bigeye chub	9.1	longnose dace	15.3	brook stickleback	19.4
river chub	6.4	rosyside dace	8.9	bigeye chub	14.0	brown trout	19.9
mimic shiner	5.8	longnose dace	8.4	mimic shiner	13.8	American brook lamprey	20.2
banded darter	5.8	emerald shiner	8.2	rosyface shiner	13.5	longnose dace	20.6
rosyface shiner	5.5	black redhorse	8.0	river chub	13.4	mottled sculpin	20.7
stonecat madtom	5.4	mimic shiner	8.0	banded darter	13.1	northern brook lamprey	20.8
variegate darter	5.3	rosyface shiner	7.9	silver shiner	13.0	least darter	21.4
northern hog sucker	5.2	brown trout	7.8	brindled madtom	12.8	south. redbelly dace	21.5
brindled madtom	5.1	brindled madtom	7.8	black redhorse	12.8	western blacknose dace[1]	21.6
						bigeye chub	21.7
						black redhorse	21.9
						rainbow trout	21.9
						river chub	22.0
						central mudminnow[1]	22.0
						grass pickerel[1]	22.0

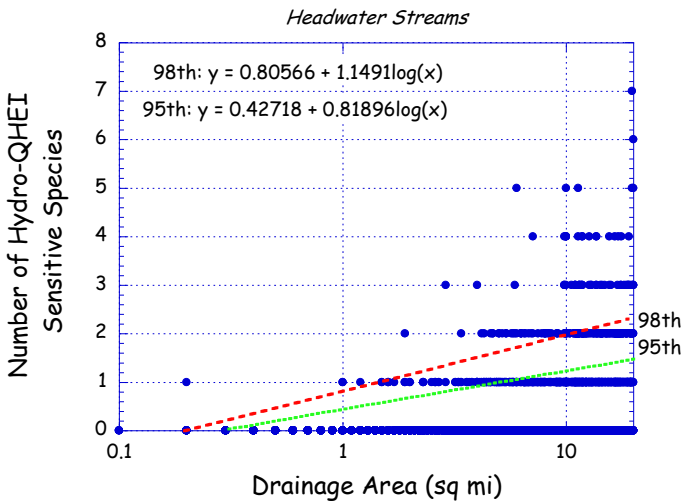
[1]These species are tolerant or partially tolerant and were excluded from the proportional metric

Calibration Plots – Fish Headwater

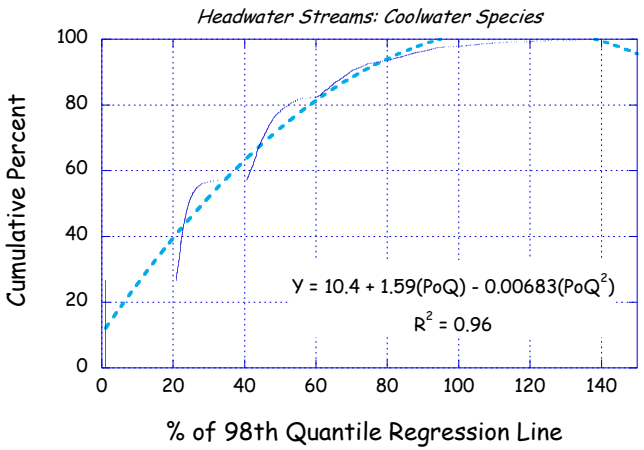


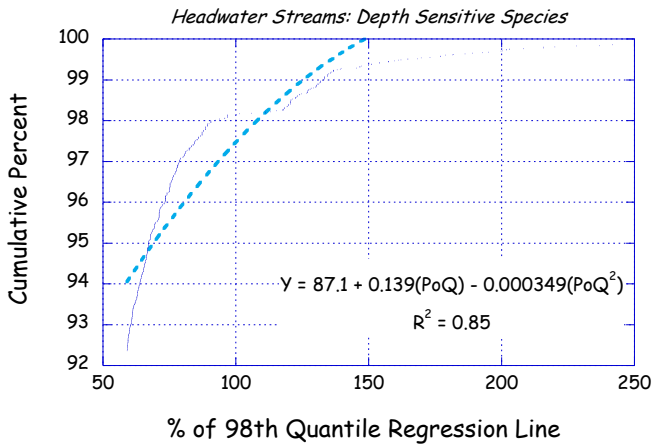


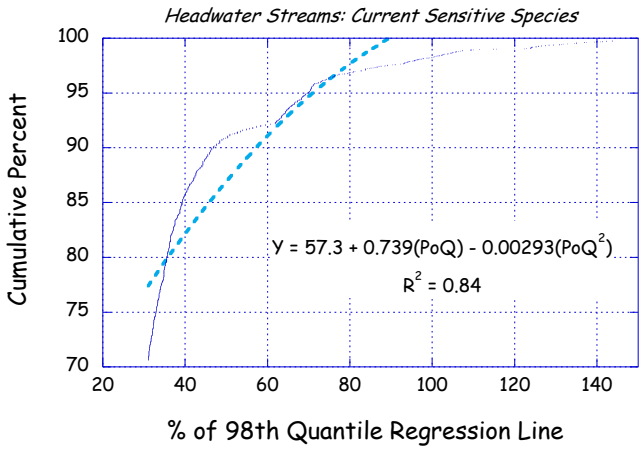


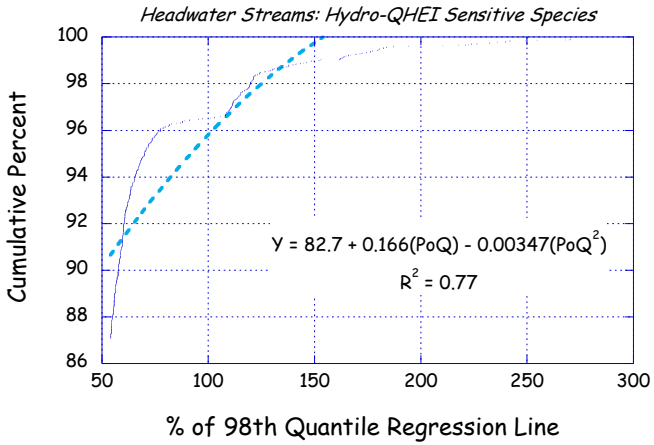


Scoring Curves – Fish Headwaters









Calibrated Using Continuous Methods

Table XX. Maximum species richness line equations generated by 95th and 98th quantile regression lines generated using USGS Blossom Statistical Software (version W2001.08d)	
Headwater Streams - Fish	
Depth metric	95th: Depth sens. species = 0.40811 + 0.58622log(drainage area, sq mi)
	98th : Depth sens. species = 0.59463 + 0.84612log(drainage area, sq mi)
Current metric	95th: Current sens. species = 0.66297 + 1.2719log(drainage area, sq mi)
	98th : Current sens. species = 1.1312 + 1.6122log(drainage area, sq mi)
Coolwater metric	95th: Coolwater species = 3.3297 + 0.63783log(drainage area, sq mi)
	98th : Coolwater species = 3.717 + 1.0268log(drainage area, sq mi)
Hydro-QHEI metric	95th: HQHEI sens. sp. = 0.42718 + 1.1491 log(drainage area, sq mi)
	98th : HQHEI sens. sp. = 0.80566 + 0.80566log(drainage area, sq mi)
Headwater Streams - Macroinvertebrates	
Depth metric	95th: Depth sens. taxa = 1.24 + 0.8008log(drainage area, sq mi)
	98th : Depth sens. taxa = 1.7454 + 1.0639log(drainage area, sq mi)
Current metric	95th: Current sens. taxa = 2.9058 + 0.90378log(drainage area, sq mi)
	98th : Current sens. taxa = 3.9009 + 0.90057log(drainage area, sq mi)
Coolwater metric	95th: Coolwater taxa = 3.6315 – 0.52675log(drainage area, sq mi)
	98th : Coolwater taxa = 5.9251 – 1.0755log(drainage area, sq mi)
Hydro-QHEI metric	95th: HQHEI sens. taxa = 1.9186 + 0.91636 log(drainage area, sq mi)
	98th : HQHEI sens. taxa = 2.6026 + 1.1547 log(drainage area, sq mi)
Wadeable Streams - Fish	
Depth metric	95th: Depth sens. sp = -0.39326 + 1.5858log(drainage area, sq mi)
	98th : Depth sens. sp = -0.23966 + 1.7601log(drainage area, sq mi)
Current metric	95th: Current sens. sp = 2.9058 + 0.90378log(drainage area, sq mi)
	98th : Current sens. sp = 3.9009 + 0.90057log(drainage area, sq mi)
Coolwater metric	95th: Coolwater sp = 2.0
	98th : Coolwater sp = 3.0
Hydro-QHEI metric	95th: HQHEI sens. sp = -0.43746 + 1.6136 log(drainage area, sq mi)
	98th : HQHEI sens. sp = -0.23966 + 1.7601 log(drainage area, sq mi)