Stream Nutrient Criteria for the Protection of Aquatic Life

Technical Advisory Committee

May 24, 2011

Meeting Objectives

- Review previous TAC meetings & work progress
- Review/discuss nutrient criteria benchmarks
- Discuss remaining issues and work needs

TAC Mission and Objectives

Assist IDNR in developing nutrient criteria for the protection of stream aquatic life designated uses

- Advise on scientific aspects of stream nutrients & nutrient effects
- Develop criteria recommendations
- Identify/describe future technical work needs

(TAC mission & process.doc – 3/22/10)

TAC Meeting - April 7, 2010

- TAC mission, objectives, process
- Background information
  - The nutrient “problem”
  - Water quality standards
  - Inventory of data & literature resources
- Planned work

TAC Meeting – September 29, 2010

- Recap previous TAC meeting
- On-line discussion forum: http://groups.google.com/group/iowa-stream-nutrient-tac/
- Data analysis approach and methods
- Preliminary results & discussion
- Next steps

TAC Internet Resources

- DNR nutrient web site:

  http://www.iowadnr.gov/water/standards/nutrients.html

  - Meeting agendas, notes, handouts
- TAC On-line forum: http://groups.google.com/group/iowa-stream-nutrient-tac/

  - Discussion topics and supplemental documents

Work Progress

- Literature review
- Stream monitoring
- Data analysis
- Documentation

Nutrient – Aquatic Life Response Data Analysis

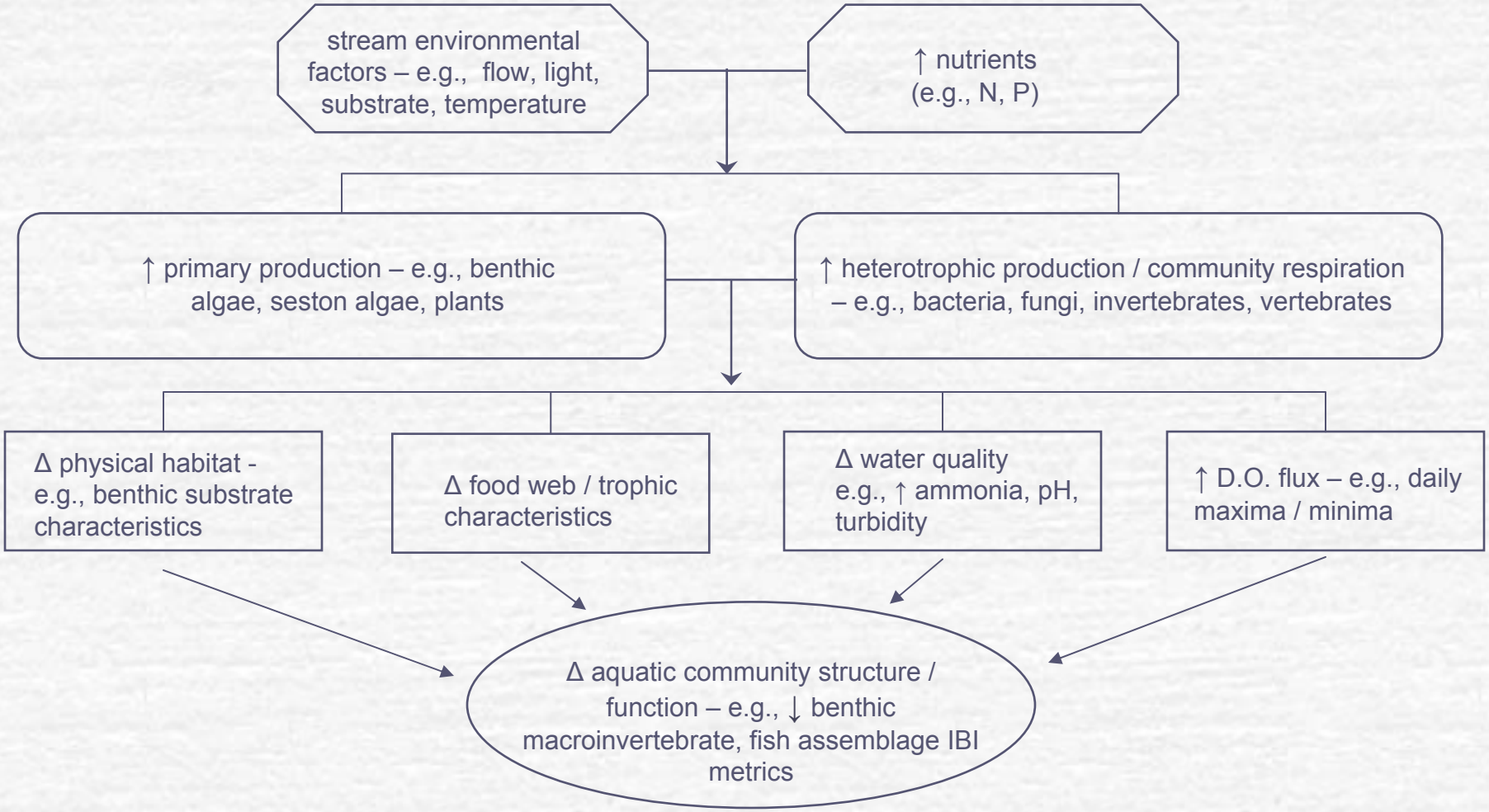
- Context
- Analysis methods
- Results – nutrient criteria benchmarks
- Discussion

IA Water Quality Standards

- Class B (aquatic life) - basis for sub-classifications:
  - Thermal characteristics
    - cold water, warm water
  - Stream size and flow
  - Ability to support game fish

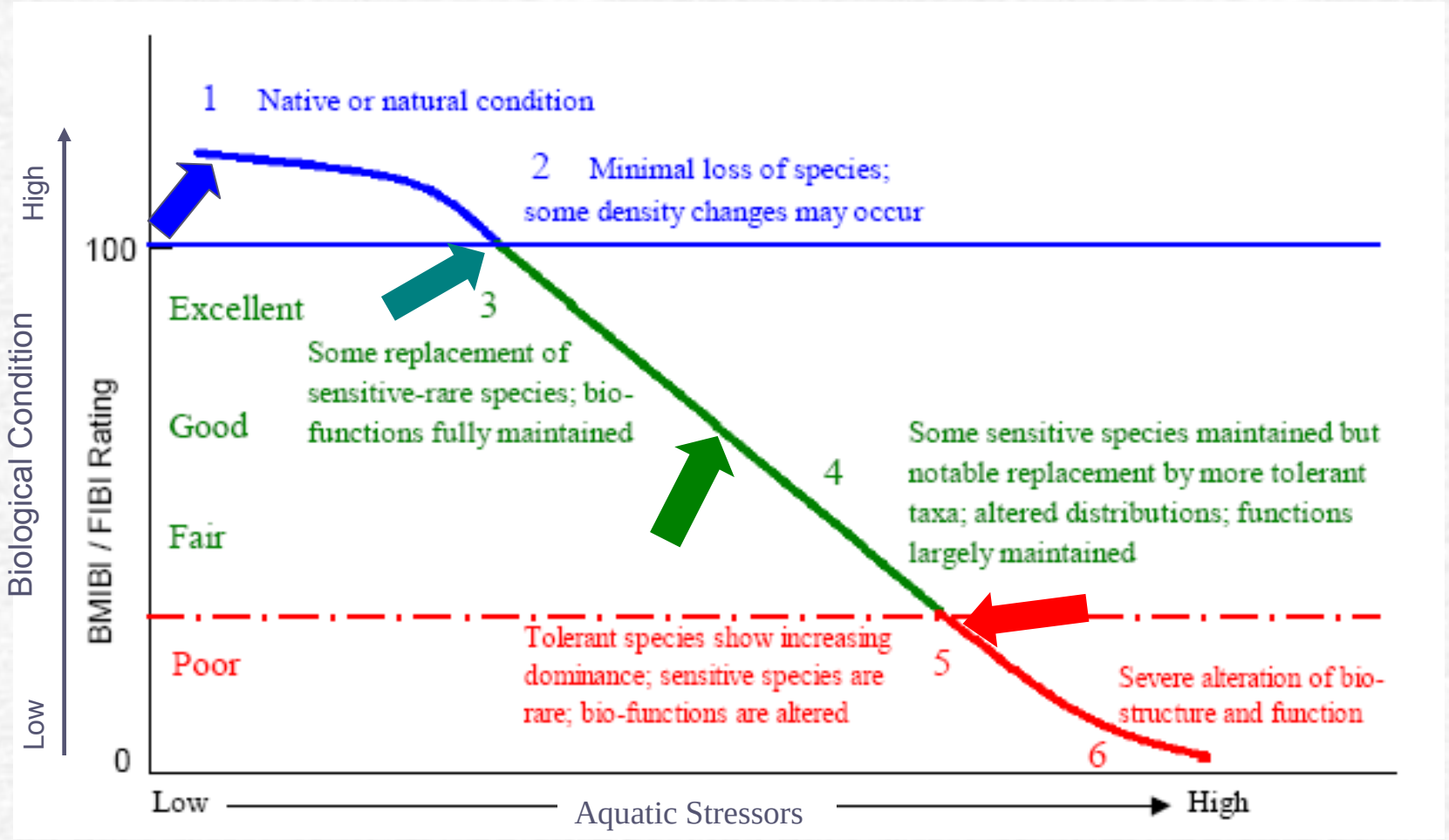
B(CW-1), B(CW-2),
B(WW-1), B(WW-2), B(WW-3)

Simplified Conceptual Model: Stream Nutrient Enrichment



Conceptual Stream Biological Condition Gradient (BCG)

(after Davies 2003)



Data

Regional Environmental Monitoring and Assessment Program (REMAP) – Iowa Probabilistic (Random) Stream Survey (2002-2006).

- 228 stream sites sampled statewide; Strahler stream order 2nd – 7th ; drainage area: 1.4 - 14,443 sq.mi.
- 2 - 3 samples/site analyzed for nutrients/chlorophyll collected during baseflow, summer/early fall biological index period
- D.O. / temperature continuous monitoring deployment (typically ~ 6 days)
- 204 valid BMIBI samples; typically 1 sample/site; 10% site repeats

Wadeable stream reference site network (1994-2008)

- 96 sites statewide; 209 valid BMIBI samples:
- Strahler stream order 2nd – 5th ; drainage area: 2.6 - 903 sq.mi.

Data metrics (and abbreviations) of the Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) and Fish Index of Biotic Integrity (FIBI)

BMIBI Metrics	FIBI Metrics
MH*-taxa richness (MHTTX)	# native fish species (NTVSP)
SH*-taxa richness (SHTTX)	# sucker species (SCKRSP)
MH-EPT richness (MHEPT)	# sensitive species (SNSTVSP)
SH-EPT richness (SHEPTX)	# benthic invertivore species (BINVSP)
MH-sensitive taxa (MHSEN)	% 3-dominant fish species (PTOP3)
SH-% 3-dominant taxa (SH3DOM)	% benthic invertivores (PBNV)
SH-Mod. Hilsenhoff Biotic index (SHMHBI)	% omnivores (POMV)
SH-% EPT (SHEPT)	% top carnivores (PTOPC)
SH-% Chironomidae (SHCHR)	% simple lithophil spawners (PLTH)
SH-% Ephemeroptera (SHEPH)	fish assmblg. tolerance index (TOLINDX)
SH-% Scrapers (SHSCR)	adjusted catch per unit effort (ACPUE)
SH-% Dom. functional feeding grp, (SHDFFG)	% fish with DELTs (PDELT)

Stressor-Response Data Analysis Variables

Nutrient	Nutrient Response
Nitrogen – Nitrate + Nitrite as N	Un-ionized Ammonia
Nitrogen – Total Ammonia as N	Chlorophyll A – Benthic
Nitrogen – Total (Calculated) as N	Chlorophyll A – Seston
Nitrogen – Total Kjeldahl as N	Dissolved Oxygen – diurnal flux
Phosphorus – Dissolved Orthophosphate as P	Dissolved Oxygen – diurnal minima
Phosphorus – Total as P	pH
Total Nitrogen (Calculated) : Total Phosphorus Ratio	TSS / Turbidity

Nutrient – Biological Response Data Analysis

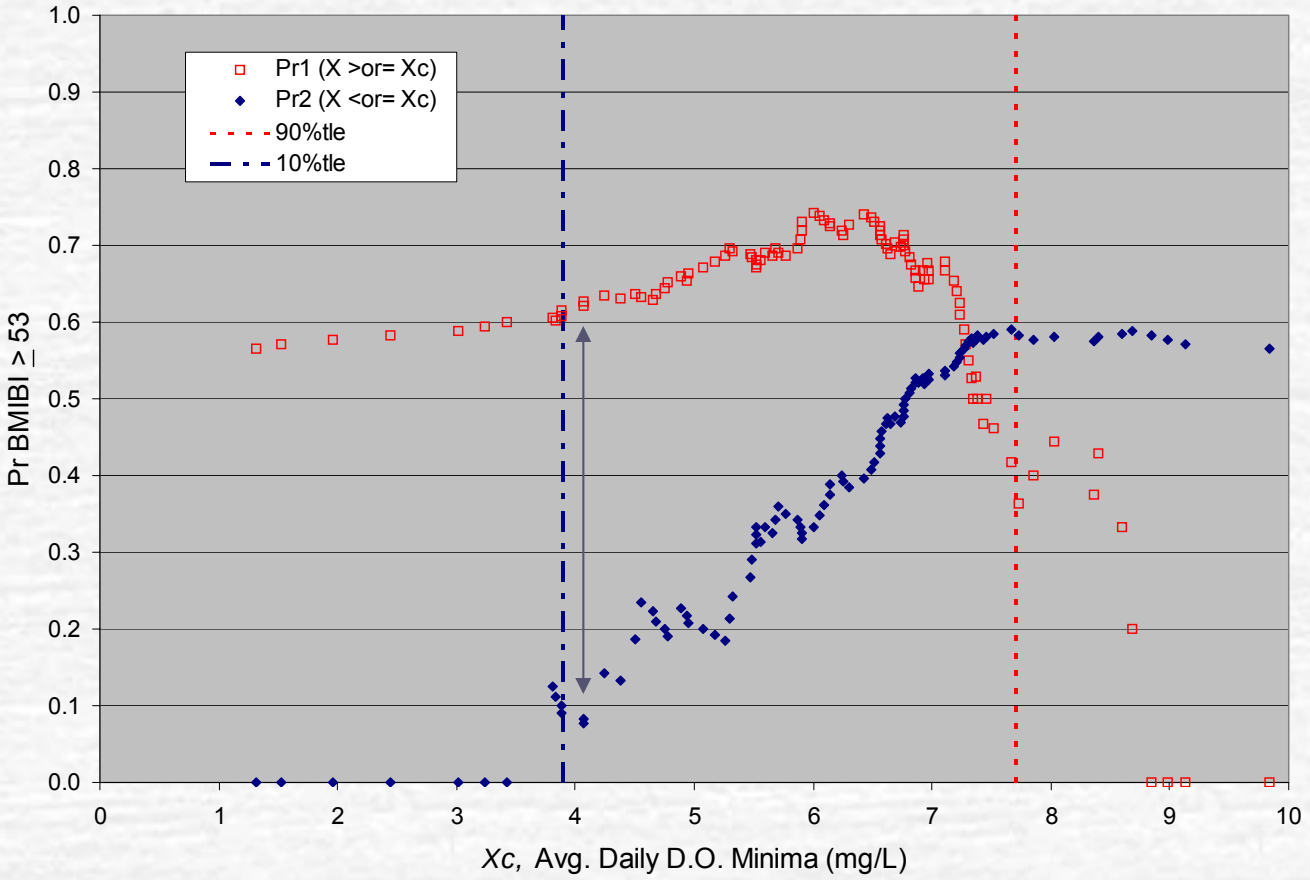
- Methods
  - Bivariate plots
  - Correlation / simple linear regression
  - Conditional probability
  - Regression tree
  - Quantile regression

Breakpoint methods

Methods: Conditional Probability (CP)

Breakpoint Analysis Steps:

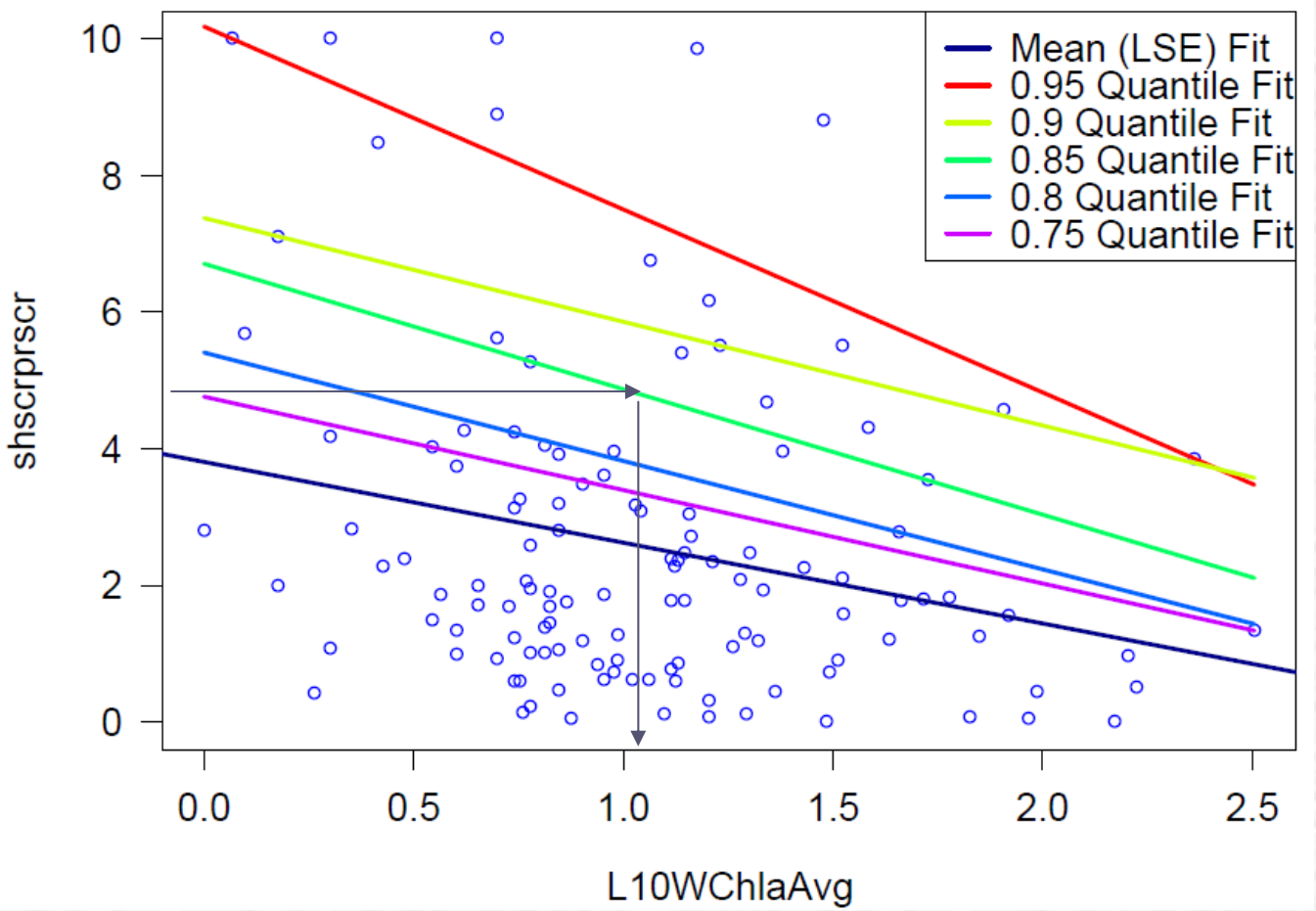
- Select stressor variable (x), response variable (y)
- Specify response variable cutoff value (e.g., Reference 25th pctle.)
- Generate plot and examine pattern
- Calculate forward & backward proportions attaining response cutoff
- Identify stressor 'breakpoint' level at which maximum difference in proportional attainment occurs
- Perform Chi-square binomial distribution test for significance of change



Methods: Quantile Regression (QR)

Breakpoint Analysis Steps:

- Select stressor variable (x), response variable (y)
- Choose regression quantiles (P95, P90, P85, P80, P75)
- Perform regression and examine regression slope coefficients for significance ($p<0.05$)
- Average P75-P95 regression intercept and slope coefficient values
- Specify response variable (y) benchmark level (Reference P75) and solve for stressor variable (x) using average intercept and slope coefficient.



Methods: Regression Tree (RT)

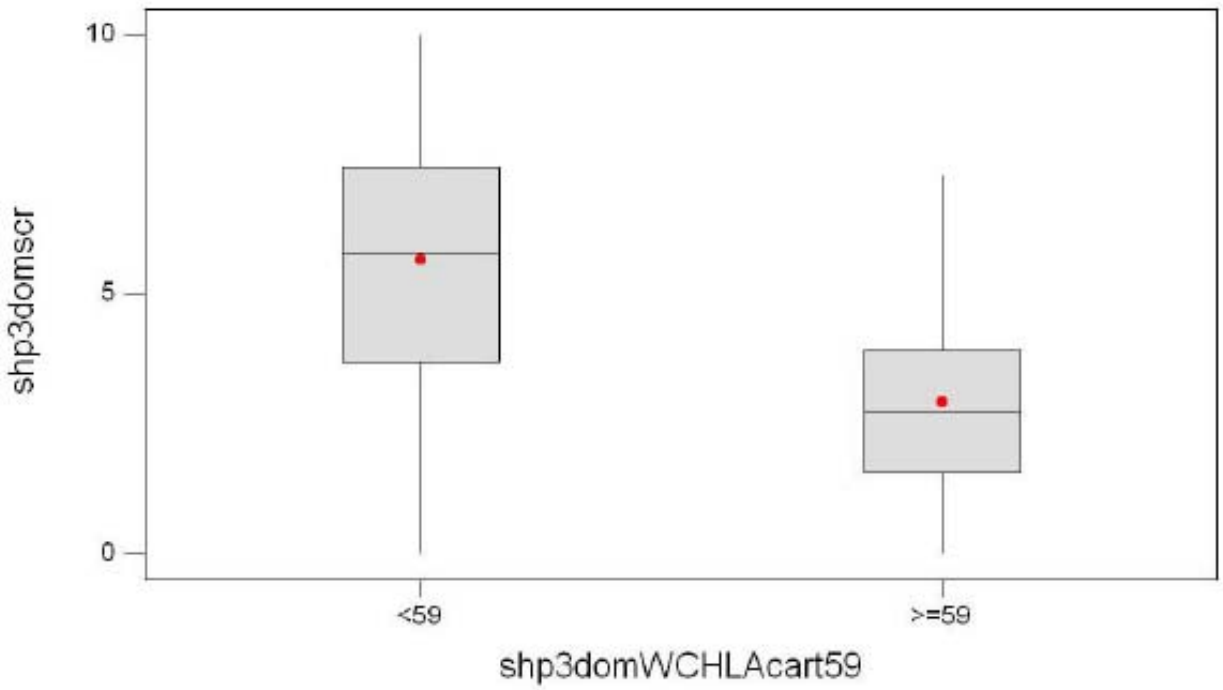


Figure 15. Boxplot distributions of shp3domscr representing WCHLA < CART breakpoint (59 ug/L) and WCHLA ≥ CART breakpoint.

Wadeable B(WW1), B(WW2)
Nutrient Stressor–Biological Response Data Analysis
Draft Benchmarks
Seston Chlorophyll A – Benthic Macroinvertebrate IBI

	Seston Chlorophyll A (ug/L)		
Biological Metric / Index	CP*	QR	RT
MH**-taxa richness (MHTTX)	-	-	(25.5)***
SH**-taxa richness (SHTTX)	-	15.1	3.6
MH-EPT richness (MHEPT)	-	-	10.6
SH-EPT richness (SHEPTX)	5.0	-	10.6
MH-sensitive taxa (MHSEN)	19.9	-	-
SH-% 3-dominant taxa (SH3DOM)	46.0	13.8	45.8
SH-Mod. Hilsenhoff Biotic index (SHMHBI)	-	-	5.2
SH-% EPT (SHEPT)	-	-	-
SH-% Chironomidae (SHCHR)	-	-	-
SH-% Ephemeroptera (SHEPH)	-	-	-
SH-% Scrapers (SHSCR)	-	15.9	5.2
SH-% Dom. functional feeding grp, (SHDFFG)	33.5	-	33.4
Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI)	5.0	-	5.2
Range	5.0 - 46.0	13.8 - 15.9	3.6 - 45.8
Mean	21.9	14.9	14.9
Median	19.9	15.1	7.9
* Analysis Method: CP, Conditional Probability; QR, Quantile Regression; RT, Regression Tree			
** MH, Multi-habitat sample; SH, Standard-Habitat sample			
*** ( ) indicates direction of biological response opposite of expected			

Wadeable B(WW1), B(WW2)
Nutrient Stressor–Biological Response Data Analysis
Draft Benchmarks
Seston Chlorophyll A – Fish IBI

	Seston Chlorophyll A (ug/L)		
Biological Metric / Index	CP*	QR	RT
# native fish species (NTVSP)	-	-	-
# sucker species (SCKRSP)	-	-	(35.9)**
# sensitive species (SNSTVSP)	-	-	-
# benthic invertivore species (BINVSP)	-	-	-
% 3-dominant fish species (PTOP3)	-	-	(30.3)
% benthic invertivores (PBNV)	-	-	(30.3)
% omnivores (POMV)	3.5	12.5	3.6
% top carnivores (PTOPC)	(5.5)	-	(5.6)
% simple lithophil spawners (PLTH)	(3.7)	(322)	(35.9)
fish assemblage tolerance index (TOLINDX)	-	-	-
adjusted catch per unit effort (ACPUE)	-	-	-
Fish Index of Biotic Integrity (FIBI)	-	-	-
* Analysis Method: CP, Conditional Probability; QR, Quantile Regression; RT, Regression Tree			
** ( ) indicates direction of biological response opposite of expected			

Wadeable B(WW1), B(WW2)
Nutrient Stressor–Biological Response Data Analysis
Draft Benchmarks
Diurnal Diss. Oxygen Minima – Benthic Macroinvertebrate IBI

	Diurnal D.O. Minima (mg/L)		
Metric/Index	CP*	QR	RT
MH**-taxa richness (MHTTX)	-	-	-
SH**-taxa richness (SHTTX)	-	-	-
MH-EPT richness (MHEPT)	4.1	-	5.2
SH-EPT richness (SHEPTX)	4.1	-	4.2
MH-sensitive taxa (MHSEN)	4.1	-	5.2
SH-% 3-dominant taxa (SH3DOM)	4.2	-	4.8
SH-Mod. Hilsenhoff Biotic index (SHMHBI)	4.1	6.3	5.3
SH-% EPT (SHEPT)	4.1	6.8	6.0
SH-% Chironomidae (SHCHR)	5.3	-	6.0
SH-% Ephemeroptera (SHEPH)	5.9	-	6.1
SH-% Scrapers (SHSCR)	4.1	-	6.0
SH-% Dom. functional feeding grp, (SHDFFG)	5.9	-	6.0
Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI)	4.1	-	6.0
Range	4.1 - 5.9	6.3 - 6.8	4.2 - 6.1
Mean	4.5	6.6	5.5
Median	4.1	6.6	6.0
* Analysis Method: CP, Conditional Probability; QR, Quantile Regression; RT, Regression Tree			
** MH, Multi-habitat sample; SH, Standard-Habitat sample			

Wadeable B(WW1), B(WW2)
Nutrient Stressor–Biological Response Data Analysis
Draft Benchmarks
Diurnal Dissolved Oxygen Minima – Fish IBI

	Diurnal D.O. Minima (mg/L)		
Metric/Index	CP*	QR	CART
# native fish species (NTVSP)	-	-	-
# sucker species (SCKRSP)	5.2	-	-
# sensitive species (SNSTVSP)	-	-	-
# benthic invertivore species (BINVSP)	6.3	-	-
% 3-dominant fish species (PTOP3)	-	-	-
% benthic invertivores (PBNV)	(7.3)**	-	(7.2)
% omnivores (POMV)	-	-	-
% top carnivores (PTOPC)	5.2	-	5.8
% simple lithophil spawners (PLTH)	6.1	-	-
fish assemblage tolerance index (TOLINDX)	(7.4)	-	5.1
adjusted catch per unit effort (ACPUE)	(7.4)	(4.4)	(7.5)
Fish Index of Biotic Integrity (FIBI)	-	-	-
* Analysis Method: CP, Conditional Probability; QR, Quantile Regression; RT, Regression Tree			
** ( ) indicates direction of biological response opposite of expected			

Wadeable B(WW1), B(WW2)
Nutrient Stressor–Biological Response Data Analysis
Draft Benchmarks
Diurnal Diss. Oxygen Range – Benthic Macroinvertebrate IBI

	Diurnal D.O. Range (mg/L)		
Metric/Index	CP*	QR	RT
MH**-taxa richness (MHTTX)	(1.5)***	-	(1.5)
SH**-taxa richness (SHTTX)	(1.6)	-	-
MH-EPT richness (MHEPT)	5.8	-	5.8
SH-EPT richness (SHEPTX)	2.3	-	5.8
MH-sensitive taxa (MHSEN)	5.8	-	2.8
SH-% 3-dominant taxa (SH3DOM)	2.1	-	2.2
SH-Mod. Hilsenhoff Biotic index (SHMHBI)	1.6	-	2.5
SH-% EPT (SHEPT)	2.6	2.9	2.6
SH-% Chironomidae (SHCHR)	1.6	-	2.8
SH-% Ephemeroptera (SHEPH)	1.5	-	1.6
SH-% Scrapers (SHSCR)	1.6	4.3	5.9
SH-% Dom. functional feeding grp, (SHDFFG)	2.1	-	2.1
Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI)	2.6	-	2.6
Range	1.5 - 5.8	2.9 - 4.3	1.6 - 5.9
Mean	2.5	3.6	3.3
Median	2.1	3.6	2.6
* Analysis Method: CP, Conditional Probability; QR, Quantile Regression; RT, Regression Tree			
** MH, Multi-habitat sample; SH, Standard-Habitat sample			
*** ( ) indicates direction of biological response was opposite of expected			

Wadeable B(WW1), B(WW2)
Nutrient Stressor–Biological Response Data Analysis
Draft Benchmarks
Diurnal Dissolved Oxygen Range – Fish IBI

	Diurnal D.O. Range (mg/L)		
Metric/Index	CP*	QR	CART
# native fish species (NTVSP)	(1.4)**	-	-
# sucker species (SCKRSP)	(1.4)	-	(1.3)
# sensitive species (SNSTVSP)	(7.9)	-	(1.5)
# benthic invertivore species (BINVSP)	-	-	-
% 3-dominant fish species (PTOP3)	(1.4)	-	-
% benthic invertivores (PBNV)	(7.9)	-	(1.5)
% omnivores (POMV)	6.3	-	-
% top carnivores (PTOPC)	2.2	-	5.3
% simple lithophil spawners (PLTH)	-	-	-
fish assemblage tolerance index (TOLINDX)	(2.6)	-	-
adjusted catch per unit effort (ACPUE)	(2.4)	(7.2)	(2.5)
Fish Index of Biotic Integrity (FIBI)	-	-	-
* Analysis Method: CP, Conditional Probability; QR, Quantile Regression; RT, Regression Tree			
** ( ) indicates direction of biological response opposite of expected			

Wadeable B(WW1), B(WW2)
Nutrient Stressor–Biological Response Data Analysis
Benthic Macroinvertebrate IBI
Summary of Draft Benchmarks

Nutrient Response Variable	Benchmark mean, median (range)
Un-ionized Ammonia	-
Chlorophyll A – Benthic	-
Chlorophyll A – Seston	17.1, 12.2 (3.6 - 46.0)
Dissolved Oxygen – Diurnal Range	3.1, 2.6 (1.5 – 5.9)
Dissolved Oxygen – Diurnal Minima	5.1, 5.3 (4.1 – 6.8)
pH	-
TSS / Turbidity	-

Wadeable B(WW1), B(WW2)
Nutrient Stressor–Biological Response Data Analysis
Draft Benchmarks
Seston Chlorophyll A - Dissolved Oxygen Variables

	Seston Chlorophyll A (ug/L)		
Response Variable	CP*	QR	RT
Diurnal D.O. Minima (avgmindo)	15.0	21.2	13.4
Diurnal D.O. Range (avgrngdo)	18.2	1.4	19.6
Average	16.6	11.3	16.5
	range (all)	1.4 - 21.2	
	mean (all)	14.8	
	median (all)	16.6	
* Analysis Method: CP, Conditional Probability; QR, Quantile Regression; RT, Regression Tree			

Wadeable B(WW1), B(WW2)
Nutrient Stressor–Biological Response Data Analysis
Draft Benchmarks
Nutrient Variables
(stream nutrient samples typically collected June-October during non-storm runoff conditions)

Total Phosphorus as P	Benchmark (mg/L)	Derivation Method
	0.125	CP - maximum increased probability of D.O. minima < 5 mg/L
	0.105	CP - maximum increased probability of Seston Chlorophyll A > 15 ug/L
	0.080	QR (avg.P95-P75): TP v Seston Chlorophyll A (Chla target = 15 ug/L)
	0.130	WW wadeable stream reference sites - statewide median value (2002-2006)
range	0.080 - 0.130	
mean	0.110	
median	0.115	
Total Kjeldahl Nitrogen as N	Benchmark (mg/L)	Derivation Method
	0.86	CP - maximum increased probability of D.O. minima < 5 mg/L
	1.11	CP - maximum increased probability of Seston Chlorophyll A > 15 ug/L
	0.64	QR (avg.P95-P75): TP v Seston Chlorophyll A (Chla target = 15 ug/L)
	0.69	WW wadeable stream reference sites - statewide median value (2002-2006)
range	0.64-1.11	
mean	0.82	
median	0.77	
Analysis Method: CP, Conditional Probability; QR, Quantile Regression		

Adjacent State Stream Nutrient Benchmarks/Criteria

Geographic Area	Water Body Types	Seston ChlA (ug/L)	Benthic Chla (mg/m2)	DO (diel) (mg/L)	BOD5 (mg/L)	TN (mg/L)	TP (mg/L)
R7 RTAG (IA, KS, MO, NE) (draft)	all streams within Region 7	8	40			0.9	0.075
MN (proposed)	Southern Nutrient Region (bordering Iowa) - all streams	40	150*	5 flux	3.5		0.150
WI (final)	46 large river segments (statewide) including UMR						0.100
WI (final)	all other streams (statewide)						0.075
MO (draft rule)	Nutrient Zones 12, 14, 16, 17 (bordering Iowa) excluding UMR and lower MO					0.9	0.075

WQS Aquatic Life Use Designations
Criteria Development Issues

Class	Issues	Criteria Recommendations
B(CW1)	Biological reference framework under development / refinement	Yes
B(CW2)	Currently no designated segments exist	?
B(WW1) non-wadeable	Suboptimal biological data availability; reference condition unavailable	Yes?
B(WW1) wadeable B(WW2) wadeable	Accceptable data & reference condition framework	Yes
B(WW3)	Data availability is poor; reference condition not available; often effluent-dominated flow	?
B(WW3)	Data availability is poor; reference condition not available; often effluent-dominated flow	?

Stream Nutrient Criteria
Additional Classification Issues / Considerations

Class	Issue / Consideration	Criteria Recommendations
B(CW1)	Outstanding Iowa Waters – Exceptional Biological Condition; limited data	?
B(WW1) wadeable B(WW2) wadeable	Outstanding Iowa Waters – Exceptional Biological Condition; limited data Ecoregions	? ?
General Uses	Intermittant flow/aquatic habitat; narrative, “free from” criteria apply; limited data.	?

Next Steps

- Additional monitoring
  - CW & Non-wadeable WW streams
- Data analysis
  - stressor-response analysis (continued)
    - additional stream classes and parameters
  - nutrient data parameter characterization
    - flow, seasonality, other sources of variation
  - historical data summary
- TAC utilization
  - meetings?
  - communication via e-mail & discussion forum
  - data analysis and other assistance needs?
- Project completion
  - schedule, products, etc.

Questions & Discussion