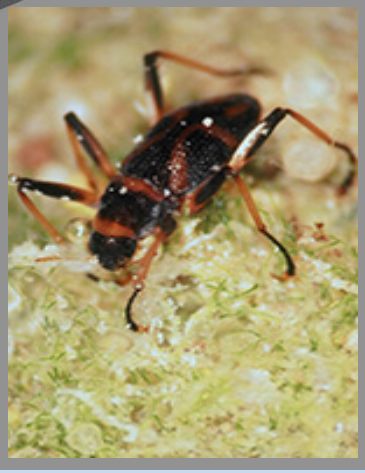
Update: Regionalization of the Index of Biotic Integrity for Benthic Macroinvertebrates Collected in Freshwater Streams According to Rapid Bioassessment Protocols in SWQM Procedures Volume 2

Bill Harrison
TCEQ Surface Water Quality Monitoring Team



Presentation Outline

- Background:
  - What is Aquatic Life Monitoring (ALM)?
  - Rationale for conducting Aquatic Life Monitoring

- Index of Biotic Integrity (IBI) overview
  - Linking IBIs to the Texas Surface Water Quality Standards
  - History of development of IBIs for Texas

- Overview of derivation of the regionalized benthic macroinvertebrate IBI

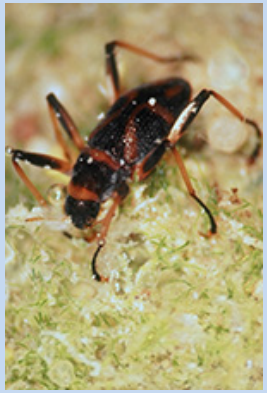
TCEQ Surface Water Quality Monitoring Program: Biological Monitoring

- What is biological monitoring/bioassessment:
  - The collection and analysis of **biological data**, primarily fish, benthic macroinvertebrates, and **physical habitat data**, as a tool to evaluate the effectiveness of TCEQ regulatory programs in maintaining water quality in states waters as described in the Texas Surface Water Quality Standards.

Major Groups of Freshwater Macroinvertebrates

Hydracarina

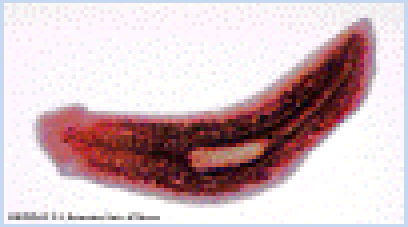
Insecta



Arthropoda

Crustacea

Platyhelminthes

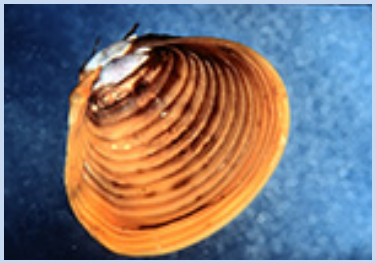


Turbellaria

Gastropoda

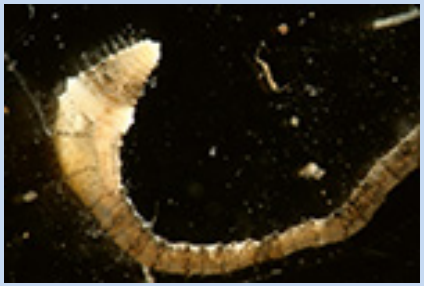
Bivalvia

Mollusca



Annelida

Hirudinea



Oligochaeta

Nematoda

Why Use Biological Assessment Data?
Legal/Regulatory Requirements:

- **Federal Clean Water Act Section 101(a).** The objective of this Act is to restore and maintain the chemical, physical, and **biological integrity** of the Nation's waters.

- **Title 40, Chapter 130 CFR.** States must establish appropriate monitoring procedures to collect, compile and analyze…data on, chemical and **biological components** of water quality…

- **Texas Water Code Sec. 26.0135.** WATERSHED MONITORING AND ASSESSMENT OF WATER QUALITY. (a) To ensure clean water, **the commission (TCEQ) shall establish the strategic and comprehensive monitoring of water quality and the periodic assessment of water quality in each watershed and river basin** of the state;

- **TAC, Title 30, Part 1, Chptr 220, Subchapter A, Rule 220.1:** The monitoring program shall provide data to identify significant, long-term water quality trends, characterize water quality conditions, support the wastewater discharge permitting process including support for the total maximum daily load process as necessary, and classify unclassified streams. The assessments must include a review of..., **biological health of aquatic life**, …, and other factors that affect water quality within the watershed.

- **Texas Surface Water Quality Standards Section 307.1.** General Policy Statement: ***It is the policy of this state…to maintain the quality of water in the state consistent with public health,…and protection of terrestrial and aquatic life.***

Why Use Biological Assessment Data?: Ecological/Biological Rationale

- Biological assemblages reflect overall ecological integrity (i.e., chemical, physical, and biological integrity). Therefore, bioassessments directly assess the status of a water body relative to the primary goal of the Clean Water Act (CWA).

- Bioassessment provides a direct measure of what aquatic life use criteria (e.g. D.O., toxics) in the TSWQS's are meant to protect.

- **Biological assemblages integrate the effects of different stressors and provide a broad measure of their aggregate impact over time.**

- Routine biological monitoring of assemblages can be relatively inexpensive, particularly compared to cost of assessing toxic pollutants.

Aquatic Life Use Subcategories

- Aquatic life use subcategories first included in TSWQS revisions adopted by the state in 1984.

- Narrative descriptions of biological and habitat characteristics associated with each aquatic life use subcategory were added in the 1988 TSWQS revisions.

Characteristics and associated dissolved oxygen criteria for aquatic life use (ALU) subcategories in freshwater systems. Excerpt from Table 3, section 307.7, TSWQS.

ALU Subcategory	Dissolved Oxygen Criteria, mg/L	Aquatic Life Attributes **Texas initially developed narrative descriptions in the Texas Surface Water Quality Standards to evaluate and protect aquatic communities in the revisions adopted in 1988.**					
	Freshwater mean/min	Habitat Characteristics	Species Assemblage	Sensitive Species	Diversity	Species Richness	Trophic Structure
Exceptional	6.0/4.0	Outstanding natural variability	Exceptional or Unusual	Abundant	Exceptionally High	Exceptionally High	Balanced
High	5.0/3.0	Highly Diverse	Usual association of regionally expected species	Present	High	High	Balanced to Slightly Imbalanced
Intermediate	4.0/3.0	Moderately Diverse	Some expected species	Very low in abundance	Moderate	Moderate	Moderately Imbalanced
Limited	3.0/2.0	Uniform	Most regionally expected species absent	Absent	Low	Low	Severely Imbalanced

Index of Biotic Integrity

- **In 1986, Karr developed the "Index of Biotic Integrity" (IBI)**
  - a set of metrics which integrate structural and functional aspects of aquatic assemblages in deriving measures of community health which are useable in managing aquatic resources. Quantitative expression of biological integrity.

- **Biological Integrity**: The species composition, diversity, and functional organization of a community of organisms in an environment relatively unaffected by pollution.

- **IBI provides a useful tool to reduce/compress complexities of biological assemblages (e.g taxa richness, trophic structure, relative abundance, etc.) to more easily interpretable set of metrics that can be used in a regulatory framework to assess the condition of aquatic communities.**

Aquatic Life Use Subcategory	Aquatic Life Attributes					
	Habitat Characteristics: Habitat Quality Index (HQI)	Species Assemblage	Sensitive Species	Diversity	Species Richness	Trophic Structure
Exceptional	Available Instream Cover	**Fish**: Number of native cyprinid spp.	**Fish**: # Intol spp. **Benthics**: # EPT taxa	**Fish & Benthics**: Taxa Richness	**Fish & Benthics**: Taxa Richness	Balanced
High	Number of riffles	**Fish**: Percent of individuals as non-native spp.	**Fish**: # Individuals as Tolerant **Benthics**: Ratio IT/T	**Fish**: # Native Cyprinid spp. **Benthics**: # Non-insect taxa	High	Balanced to slightly imbalanced
Intermediate	Bank Stability	**Fish & Benthics**: Taxa Richness	**Fish**: # Native Cyprinid spp. **Benthics**: Biotic Index (HBI)	**Benthics**: Percent dominant taxon	Moderate	Moderately imbalanced
Limited	Channel Sinuosity	**Fish**: # of Sunfish spp. **Benthics**: # of EPT taxa	**Fish & Benthics**: Taxa Richness	**Benthics**: Percent Chironomidae	Low	Severely imbalanced

IBI's provide a quantitative link to narrative Aquatic Life criteria in section 307 TSWQS

Statewide vs Regionalized IBI

- Statewide IBI: Derivation based on fish and/or benthic macroinvertebrate assemblage samples collected at the state scale.
- Regionalized IBI: Derivation based on fish and/or benthic macroinvertebrate assemblage samples collected at the ecoregion specific scale.

TCEQ Aquatic Life Monitoring: Statewide Fish and Benthic Macroinvertebrate IBIs

- 2000 Integrated Report first to use IBI's to assess aquatic communities Initial Fish and Benthic Macroinvertebrate IBI's based on samples collected at a Statewide Scale.

- Statewide Fish IBI applied in 2000 Integrated Report.

- Statewide Benthic Macroinvertebrates IBI applied in 2000 – 2018 Integrated Reports.

TCEQ Aquatic Life Monitoring: Regionalized Fish and Benthic Macroinvertebrate IBIs

- TPWD finalized the Regionalized IBI for Fish in 2002 based on aquatic life monitoring conducted in each of the seven aggregated Level III ecoregions for the Texas Least Disturbed Streams Project.
  - Regionalized fish IBI 2002 to present

- TCEQ developed draft Regionalized IBI's for benthic macroinvertebrates in 2015 based on aquatic life monitoring in least disturbed streams in each of the seven aggregated Level III ecoregions.
  - Testing and refining since 2015 and proposed to use for benthic macroinvertebate assemblage assessments in the 2020 Integrated Report.

Texas Regionalized IBI for Fish and For Benthic Macroinvertebrates

- Derived based on sampling conducted in each ecoregion in Texas for the Aquatic Ecoregion Project: *Water Quality, In-stream Habitat, Biotic Integrity and Riparian Characteristics of Least Disturbed Streams in Texas.*

- Allows development of a “composite” reference condition for each ecoregion, represented by the metric set values.

- The more similar study sites are to the “composite” reference condition represented by the IBI metric set, the higher the total IBI score/biotic integrity.

Development of the Regionalized Benthic IBI

- Quantitative methods used to derive the scoring criteria for the regionalized benthic macroinvertebrate IBI essentially the same as method used for fish IBI.
- Regionalized macroinvertebrate IBI developed in the context of the TCEQ/TPWD interagency workgroup for Aquatic Life Monitoring.

TCEQ and TPWD Interagency Bioassessment Workgroup

Mission Statement

- To cooperatively participate in the development and refinement of methods for the collection and analysis of data to characterize the biotic integrity and physical habitat of aquatic systems in Texas.

Workgroup Members:

- TPWD Water Quality Program;
- TPWD River Studies Program;
- TCEQ Surface Water Quality Monitoring Team;
- TCEQ TMDL Team;
- TCEQ Water Quality Standards Development Team;
- TCEQ Water Quality Standards Implementation Team;
- TCEQ Central Office Clean Rivers Program Team; and
- TCEQ Field Operations Regional Biologists.

Primary Reference: Development of Ecoregion Specific IBIs

- Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish

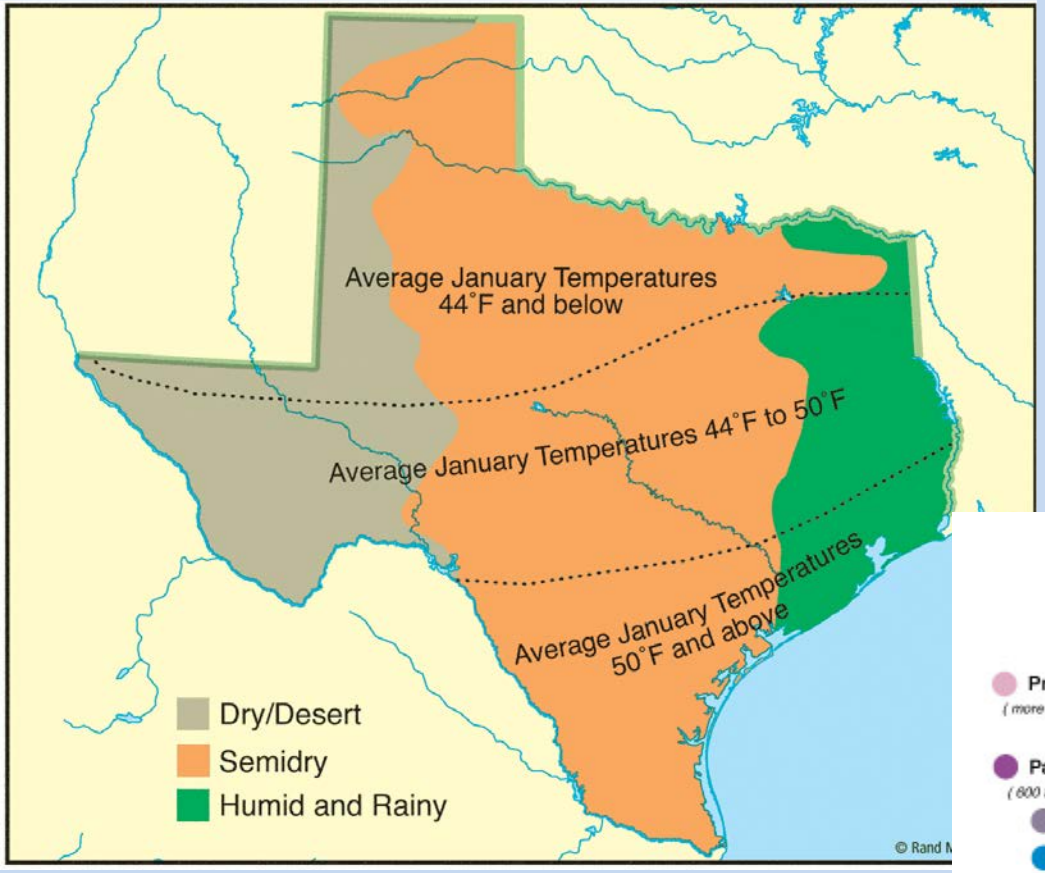
  Second Edition. EPA 841-B-99-002
  - Chptr 9. BIOLOGICAL DATA ANALYSIS
    - Section 9.1 THE MULTIMETRIC APPROACH
    - Section 9.1.1 Metric Selection, Calibration, and Aggregation into an Index
    - Section 9.1.2 Assessment of Biological Condition

Statewide Metric Set
Richness and Composition Metrics
1. Total Number of Taxa
2. Number of EPT Taxa
3. % Chironomidae
4. % Dominant Taxon
5. % Total Trich. As Hydropsychidae
6. No. Non-Insect Taxa
7. % Elmidae
Trophic Composition Metrics
8. % Dominant Functional Group
9. % Predators
10. % Collector-Gatherers
Tolerance Metrics
11. Hilsenhoff Biotic Index (HBI)
12. Ratio Intolerant to Tolerant Taxa

Statewide Metric Set (1996):

- Derived from samples collected across the state;
- Essentially treats aquatic habitats across the state as relatively homogeneous;
- Less effective than regionalized IBI in reflecting intrinsic differences in biotic assemblages due to ecological variation across Texas;
- As with the fish IBI, statewide benthic IBI developed/used initially since too few samples to allow developing regionalized metrics.

ALU Category	Score Range
Exceptional	>35
High	31 - 35
Intermediate	25 - 30
Limited	<25

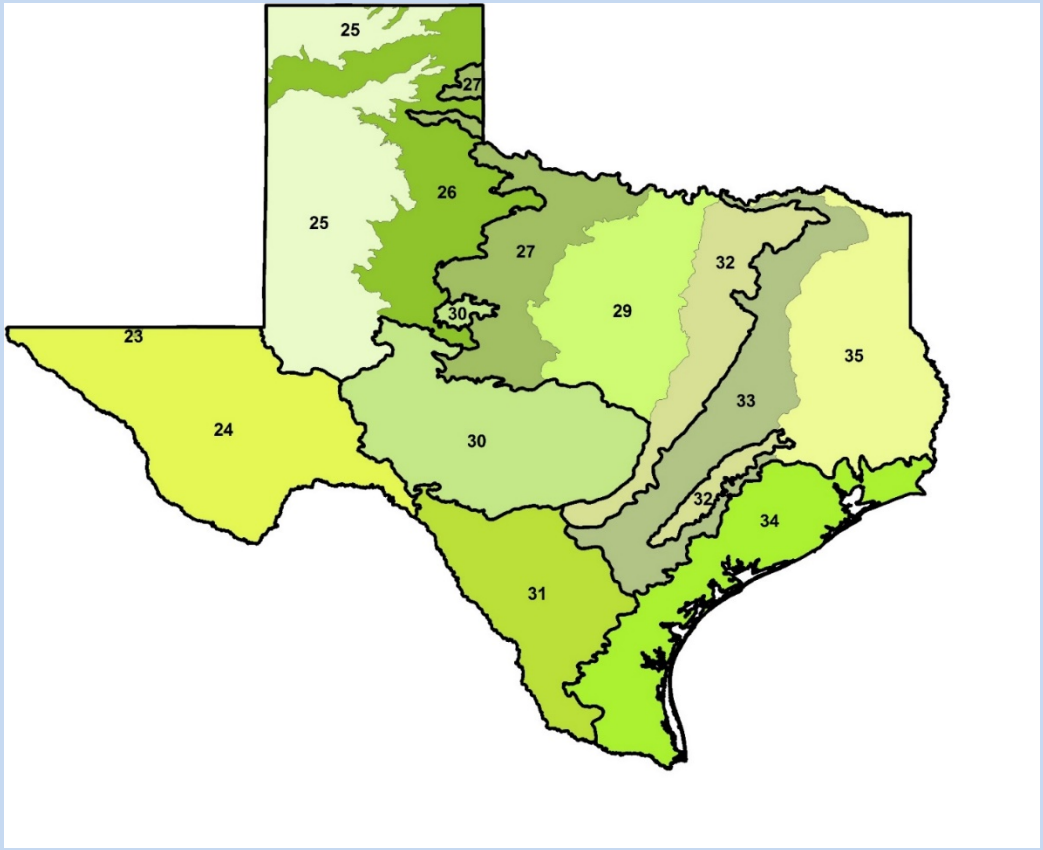


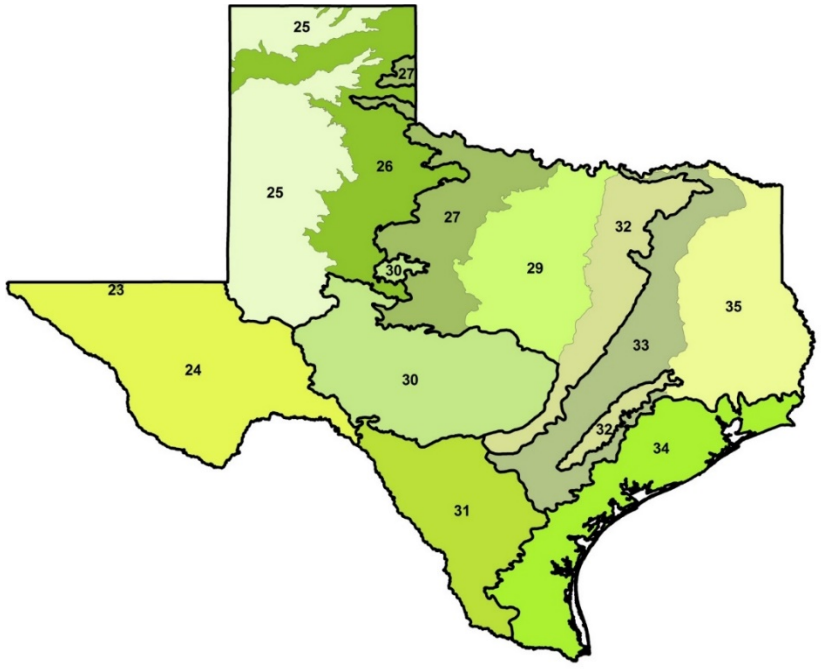
Biological Communities Across Texas Adapted to Different Ecological Settings Related to Changes in Climate and Geology Across Texas

Omernik, J.m. 1987. *Ecoregions of the conterminous United States*. Annals of the Association of American Geographers.

Then refined in Texas by Griffith, *et al. 2007.* Ecoregions of Texas

1. 23 Arizona/New Mexico Mountains
2. 24 Chihuahuan Deserts
3. 25 High Plains
4. 26 Southwestern Tablelands
5. 27 Central Great Plains
6. 29 Cross Timbers
7. 30 Edwards Plateau
8. 31 Southern Texas Plains
9. 32 Texas Blackland Prairies
10. 33 East Central Texas Plains
11. 34 Western Gulf Coastal Plain
12. 35 South Central Plains





- ***Hornig et al. 1995. Development of Regionally Based Biological Criteria in Texas, In W.S Davis & T.P. Simon (eds.), Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making***
- **Identified seven "aggregated" Level 3 Ecoregions in Texas using multivariate statistical analysis to be used in developing regionalized IBI's for benthics and fish.**

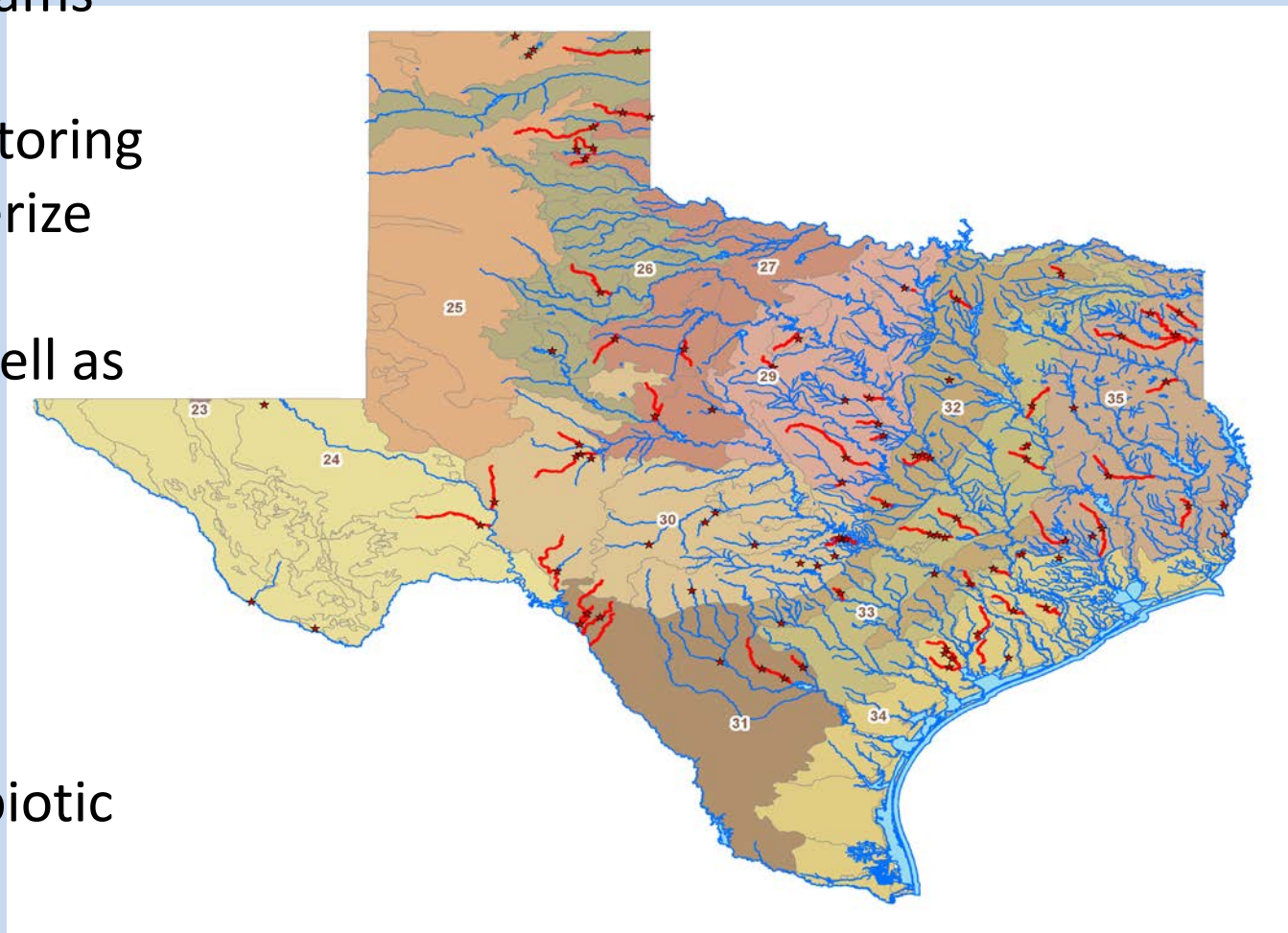
Aggregated Level 3 Ecoregions:

- **Chihuahuan Deserts (24);**
- **High Plains/Southwestern Tablelands (25/26);**
- **Central Great Plains/Cross Timbers/TX Blackland Prairies (27/29/32);**
- **Edwards Plateau (30);**
- **Southern TX Plains (31);**
- **Western Gulf Coastal Plains (34);**
- **E. Central TX Plains/S. Central Plains (33/35);**

Development of Regionalized IBIs Based on Aquatic Life Monitoring Targeting Least Disturbed Reference Streams In Each Ecoregion

Least Disturbed Streams Project:

- Aquatic Life Monitoring (ALM) to characterize benthic and fish assemblages as well as physical habitat;
- Derive metrics;
- Describe range of expectations for biotic integrity in each ecoregion.



Least Disturbed Reference Streams

Least Disturbed Streams exhibit the following characteristics:

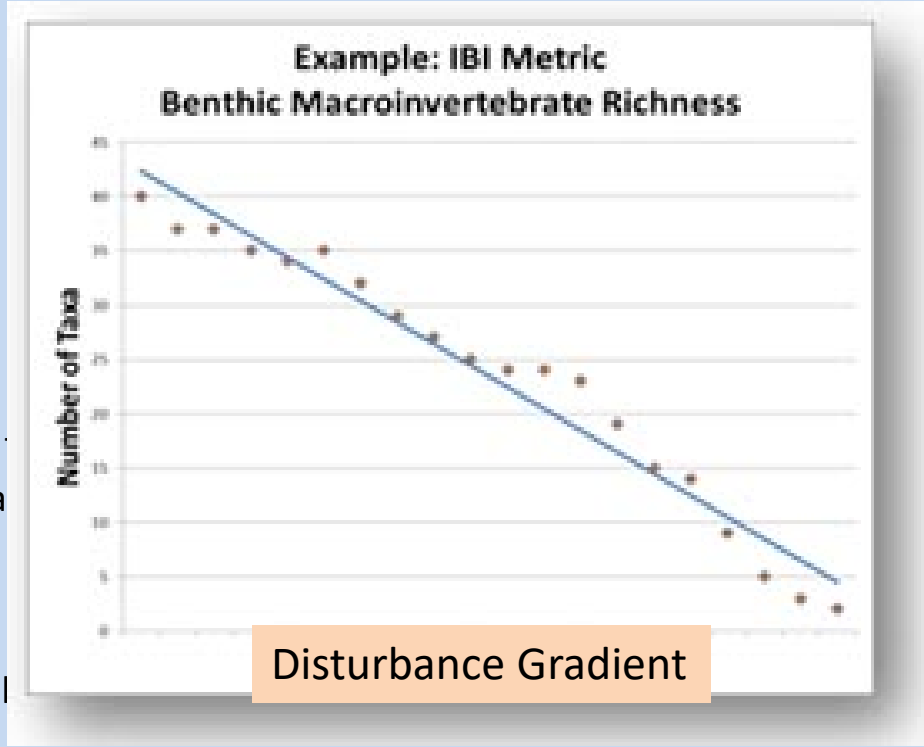
- Stream characteristics representative/typical of the Level III ecoregion where located;
- Little or no urban development in the watershed;
- No major point sources of pollution;
- No atypical sources of non-point pollution;
- Not channelized, or have not had major physical habitat modifications;

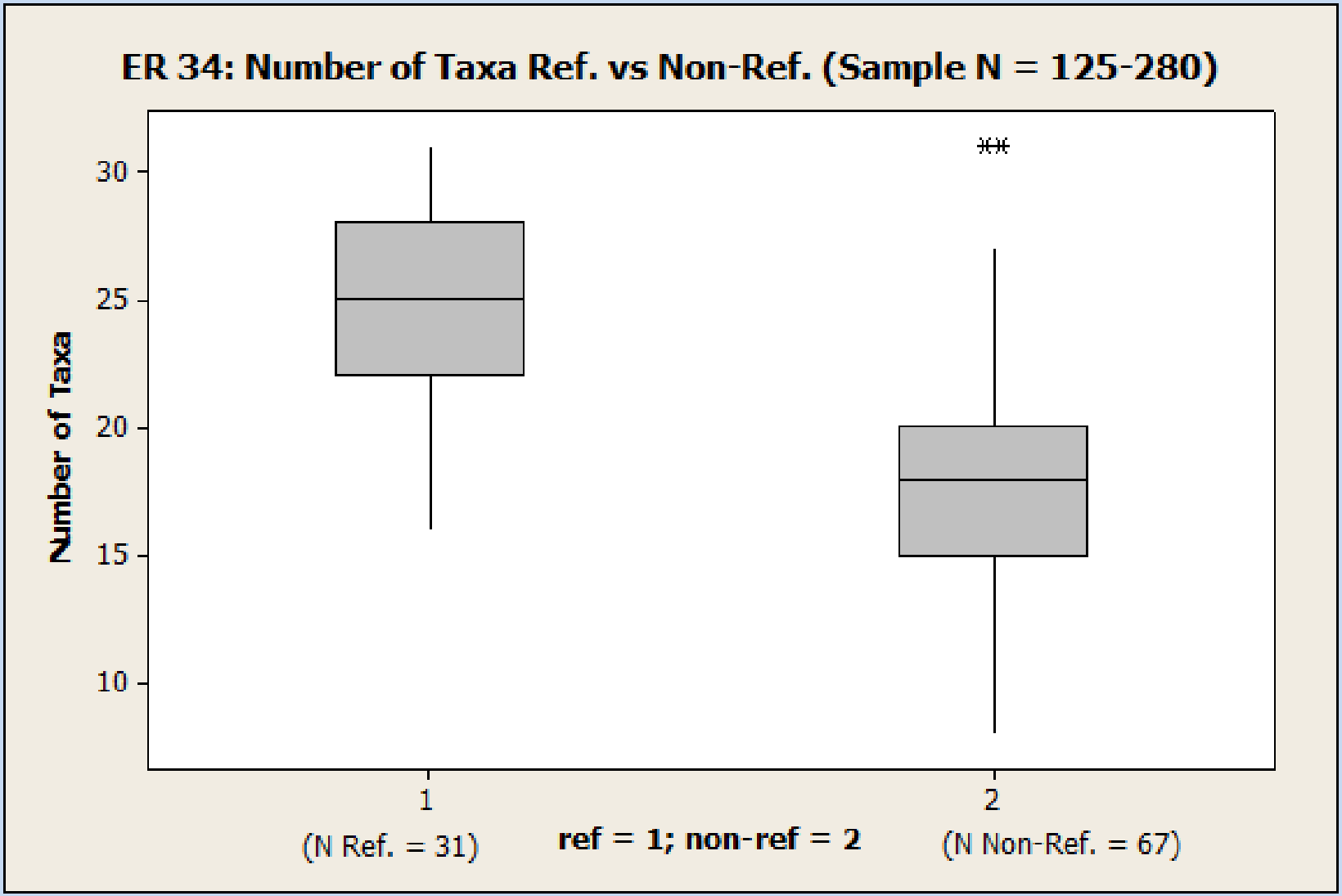
	Number of Samples		Number of Sample Sites		Number of Individuals Counted/Identified	
Ecoregion	Reference Streams	Non-Reference Streams	Reference Streams	Non-Reference Streams	Reference Streams	Non-Reference Streams
Central Great Plains, Cross Timbers, TX Blackland Prairies (27, 29, 32)	37	154	15	57	6,573	32,811
Edwards Plateau (30)	139	191	39	54	25,359	34,913
E. Central TX Plains (33, 35)	121	251	39	89	22,641	42,201
Western Gulf Coastal Plain (34)	32	75	9	26	6,588	13,995
Chihuahuan Deserts (24)	40	16	9			
Total	369	687	111	226	61,161	123,920
Grand Totals	1,056		337		185,081	

Regionalized IBI for RBA Benthic Macroinvertebrate Samples: 32 Candidate Metrics

- % Tanytarsini
- Count Chironomid Taxa
- Count Diptera Taxa
- % Diptera
- % Dominant Taxon
- % Diptera and Non-Insect Taxa
- Count Non-Insect Taxa
- % Corbicula
- % Oligochaeta
- % of Trichoptera as Hydropsychidae
- Ratio IT/T
- Count Intolerant Taxa
- % Tolerant Taxa
- Biotic Index
- Count Collector-gatherer Individuals

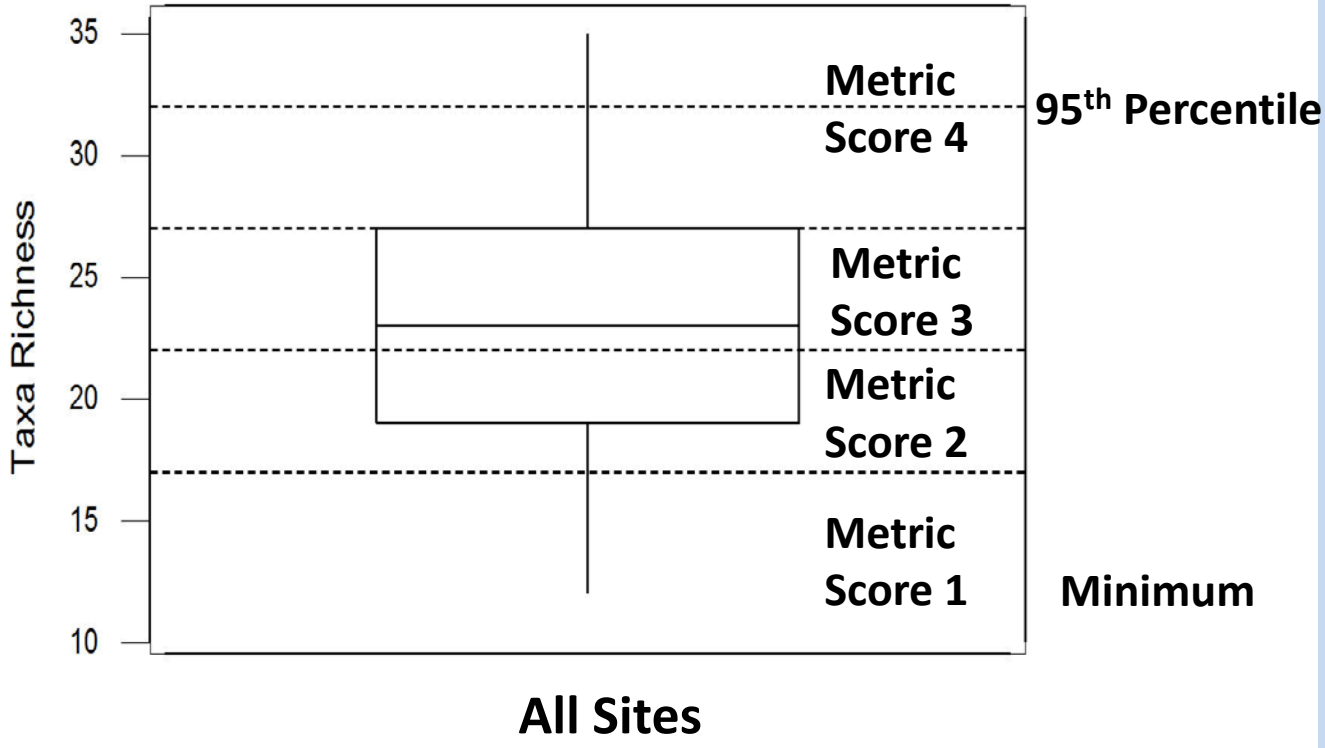
- Taxa Richness
- % Predator
- % Collector-Gatherers
- % Scraper-Collectors
- % Shredders
- % Filtering Collectors
- Count EPT Taxa
- % EPT
- Count Ephemeroptera
- Count Trichoptera Taxa
- % Ephemeroptera
- % Trichoptera
- % Chironomidae
- Count CG/FC individual
- % CG/FC
- Count Predator Individuals
- % Elmidae





Usually inadequate data to quantitatively describe a disturbance gradient with associated biological condition indicators.

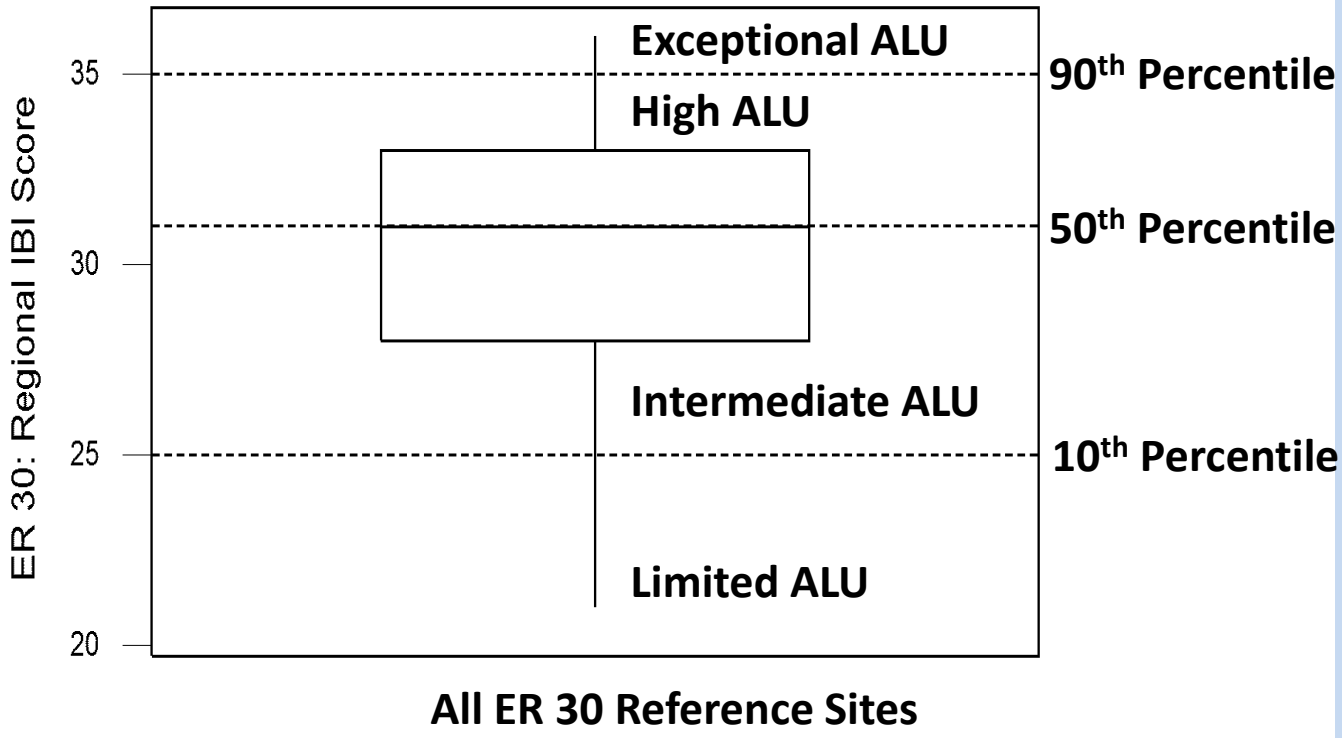
Derivation of metric scores using the 95th Percentile as a standard to eliminate extreme outliers



1. Rank metric values from all sample sites in descending order.
2. Compute the 95th percentile.
3. Determine the minimum metric value from all sites.
4. Quadrasect the interval between the minimum and the 95th percentile.
5. Assign scores to each interval.

Metric	Scoring Criteria			
Richness and Composition Measures	4	3	2	1
1. Total Number of Taxa	>28	18-28	8-17	<8
2. Number of EPT Taxa	>13	9-13	4-8	<4
3. % Diptera and Non-Insects	1.92-18.92	18.93-35.93	35.93-52.93	<1.92 or >52.93
4. % Dominant Taxon	<21.46	21.46-32.58	32.59-43.71	>43.71
Functional Composition				
5. % Dominant Functional Group	<36.68	36.68-45.68	45.69-54.69	>54.69
6. % Shredder	0.31-3.84	3.85-7.36	7.37-10.87	<0.31 or >10.87
7. % Scraper	0.21-7.92	7.92-15.63	15.64-23.34	<0.21 or >23.34
Tolerance Measures				
8. Hilsenhoff Biotic Index (HBI)	<4.26	4.26-5.18	5.19-6.12	>6.12
9. Number of Intolerant Taxa	>28	22-28	15-21	<15
10. % Tolerant Organisms	<2.69	2.69-5.38	5.39-8.07	>8.07

Derivation of Aquatic Life Use Category Thresholds using Percentiles of the LDS IBI Scores in each Ecoregion



1. Rank the total IBI scores from all reference sites in descending order
2. Compute the 90th, 50th, and 10th percentiles for the ranked total IBI Scores.
3. Exceptional ALU defined as any IBI score equaling or exceeding the 90th percentile.
4. High ALU defined as any IBI score equal to the 50th and less than the 90th percentile.
5. Intermediate ALU defined as any IBI score less than the 50th percentile and greater than or equal to the 10th percentile.
6. Limited ALU <10th percentile

Barbour et al. 1999. Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers. EPA 841-B-99-002: "*If due to natural variability, a low score should occur 10% of the time or less*."

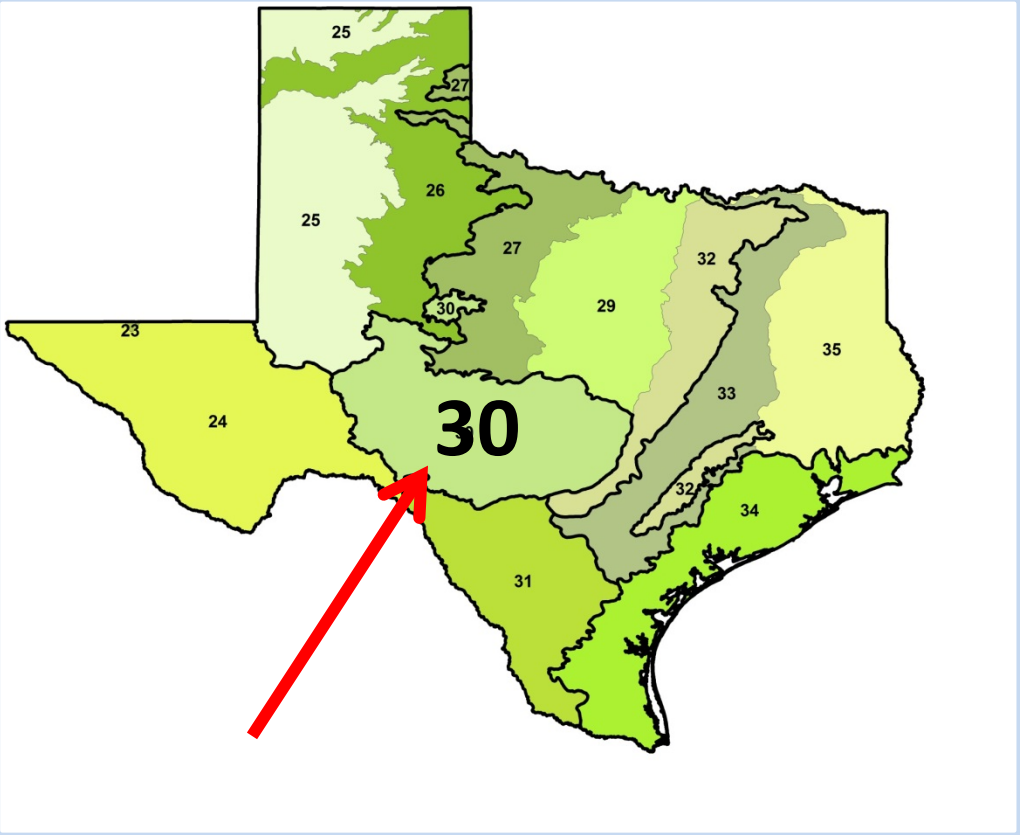
Metric	Scoring Criteria			
Richness and Composition Measures	4	3	2	1
1. Total Number of Taxa	>28	18-28	8-17	<8
2. Number of EPT Taxa	>13	9-13	4-8	<4
3. % Diptera and Non-Insects	1.92-18.92	18.93-35.93	35.93-52.93	<1.92 or >52.93
4. % Dominant Taxon	<21.46	21.46-32.58	32.59-43.71	>43.71
Functional Composition				
5. % Dominant Functional Group	<36.68	36.68-45.68	45.69-54.69	>54.69
6. % Shredder	0.31-3.84	3.85-7.36	7.37-10.87	<0.31 or >10.87
7. % Scraper	0.21-7.92	7.92-15.63	15.64-23.34	<0.21 or >23.34
Tolerance Measures				
8. Hilsenhoff Biotic Index (HBI)	<4.26	4.26-5.18	5.19-6.12	>6.12
9. Number of Intolerant Taxa	>28	22-28	15-21	<15
10. % Tolerant Organisms	<2.69	2.69-5.38	5.39-8.07	>8.07
Aquatic Life Use Category	Benthic Macroinvertebrate IBI Score Range			
Exceptional (≥ 90th percentile)	≥35			
High (≥50th & <90th percentile)	30-34			
Intermediate (≥10th & <50th percentile)	23-29			
Limited (<10th percentile)	<23			

Benthic macroinvertebrate taxa collected from San Gabriel River at SH 29; Station ID 12102; 07/21/2008'; 5-MIN. KICKNET	Value	Score
Taxa Richness	23	4
EPT	8	3
Biotic Index	4.72	2
% Chironomidae	2.283105	4
% Dominant Taxon	18.26484	4
% Dominant Functional Group	26.56012	4
% Predators	24.04871	3
Ratio Intolerant to Tolerant Taxa*	1.12	1
% of Total Trichoptera as Hydropsychidae	39.66	3
Number of Non-insect taxa	4	3
% Collector-Gatherers	26.56	3
% of n as Elmidae	33.33	1
Total Score		35

Point Score Ranges	
Exceptional	>36
High	29 - 36
Intermediate	22 - 28
Limited	<22

Edwards Plateau (ER 30) Metric Set
Richness and Composition Metrics
1. Total Number of Taxa
2. Number of EPT Taxa
3. % Diptera and Non-Insects
4. % Dominant Taxon
Trophic Composition Metrics
5. % Dominant Functional Group
6. % Predators
7. % Collector-Gatherers
Tolerance Metrics
8. Hilsenhoff Biotic Index (HBI)
9. % Tolerant Organisms
10. Number of Intolerant Taxa

ALU Category	Score Range
Exceptional	>35
High	31 - 35
Intermediate	25 - 30
Limited	<25



Edwards Plateau Ecoregion Draft Metric Set:

- Scoring Criteria derived for each metric;
- Score Ranges Established for Each Aquatic Life Use Category.

Summary

- The Index of Biotic Integrity (IBI) provides a quantitative link to narrative ALU descriptions in Table 3 in section 307.7 TSWQS;

- Statewide IBIs to determine attainment of designated ALU category were first used for fish and benthic macroinvertebrates in the 2000 Integrated Report

- Recognizing the ecological diversity of Texas, a regionalized fish IBI was developed around 2002 has been used in the IR to assess attainment of designated uses for fish assemblages since then.

- The statewide benthic macroinvertebrate IBI has been used in the IR to assess benthic macroinvertebrate assemblages 2000 thru 2018.

Summary

- Using data from the Least Disturbed Streams Project, Ecoregion specific benthic macroinvertebrate IBI's have been developed for 8 of 12 Level III Ecoregions in Texas:
  - 24: Southern Deserts
  - 33, 35: South Central & Southern Humid, Mixed Land Use Region
  - 27, 29, 32: Subhumid Agricultural Plains
  - 34: Western Gulf Coastal Plains
  - 30: Edwards Plateau
- We propose to implement this regionalized benthic macroinvertebrate IBI in the 2020 Integrated Report;
- Regionalized macroinvertebrate IBI's will be developed for the remaining ecoregions when adequate data from the Least Disturbed Streams Project are available, until then we will continue to use the statewide benthic IBI:
  - the High Plains (ER 25),
  - the Southwestern Tablelands (ER 26)
  - and Southern Plains (ER 31)

Questions?

- Contact Information:
- Bill Harrison
- Telephone: 512/239-4602
- Email: bill.harrison@tceq.texas.gov