CRITICAL TECHNICAL ELEMENTS FOR A BIOASSESSMENT PROGRAM

Michael T. Barbour, Tetra Tech
Chris O. Yoder, MBI

Who are the Primary Users?

- State and Tribal program managers and staff who are responsible for monitoring and assessment and WQS programs. U.S. EPA WQS and Monitoring & Assessment coordinators who conduct review and oversight of State and Tribal programs.

Accuracy

- Biological assessments should produce sufficiently accurate delineations of condition so that Type I and II assessment errors are minimized. Type I errors are incurred when impairment is identified when it does not actually exist; Type II errors are incurred when an existing impairment is not identified due to the inability of the assessment tool to detect it.

Comparability

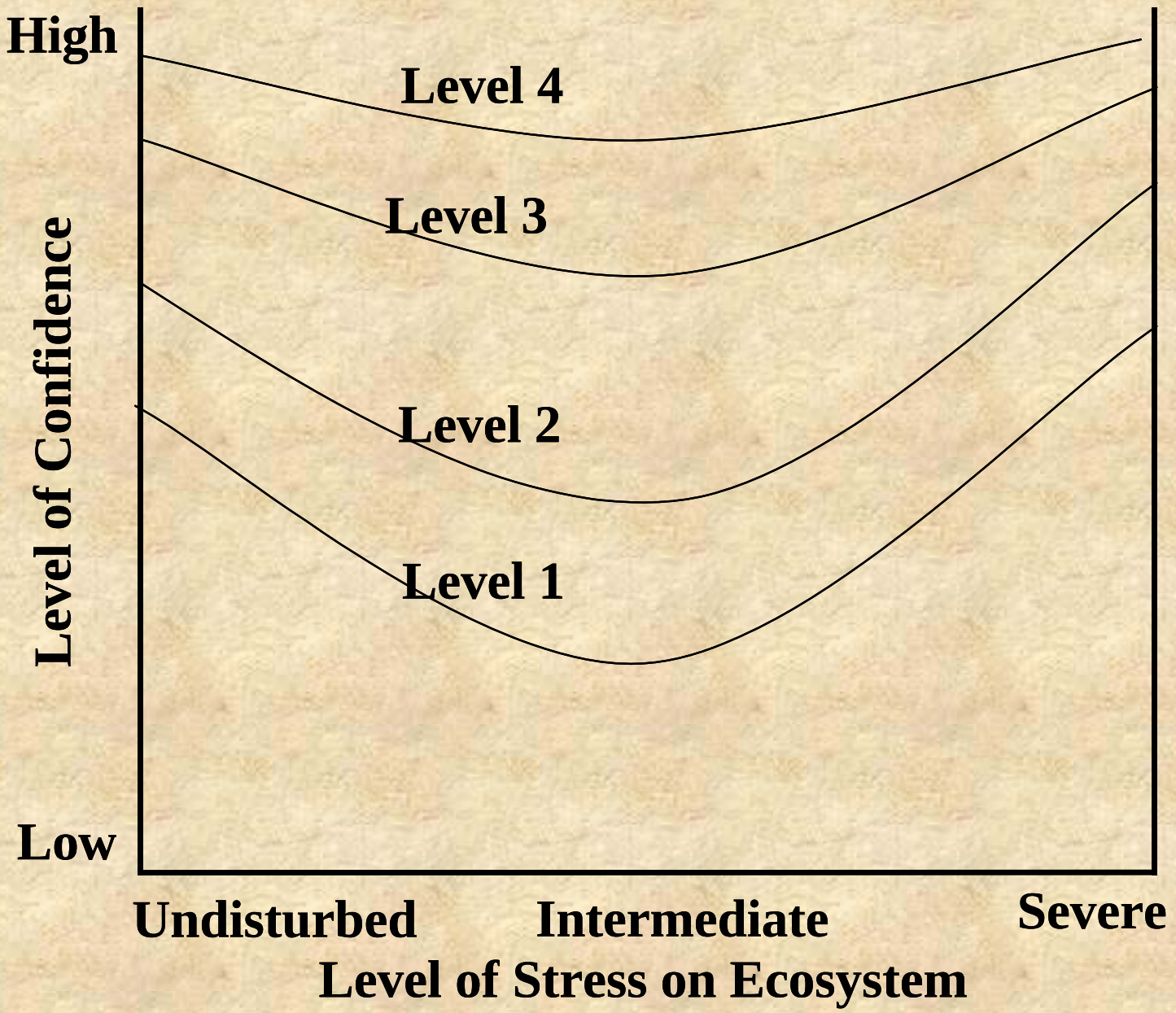
- Different programs that utilize technically different approaches should produce assessments that are comparable in terms of biological condition ratings, delineation of impairments, and diagnostic properties.

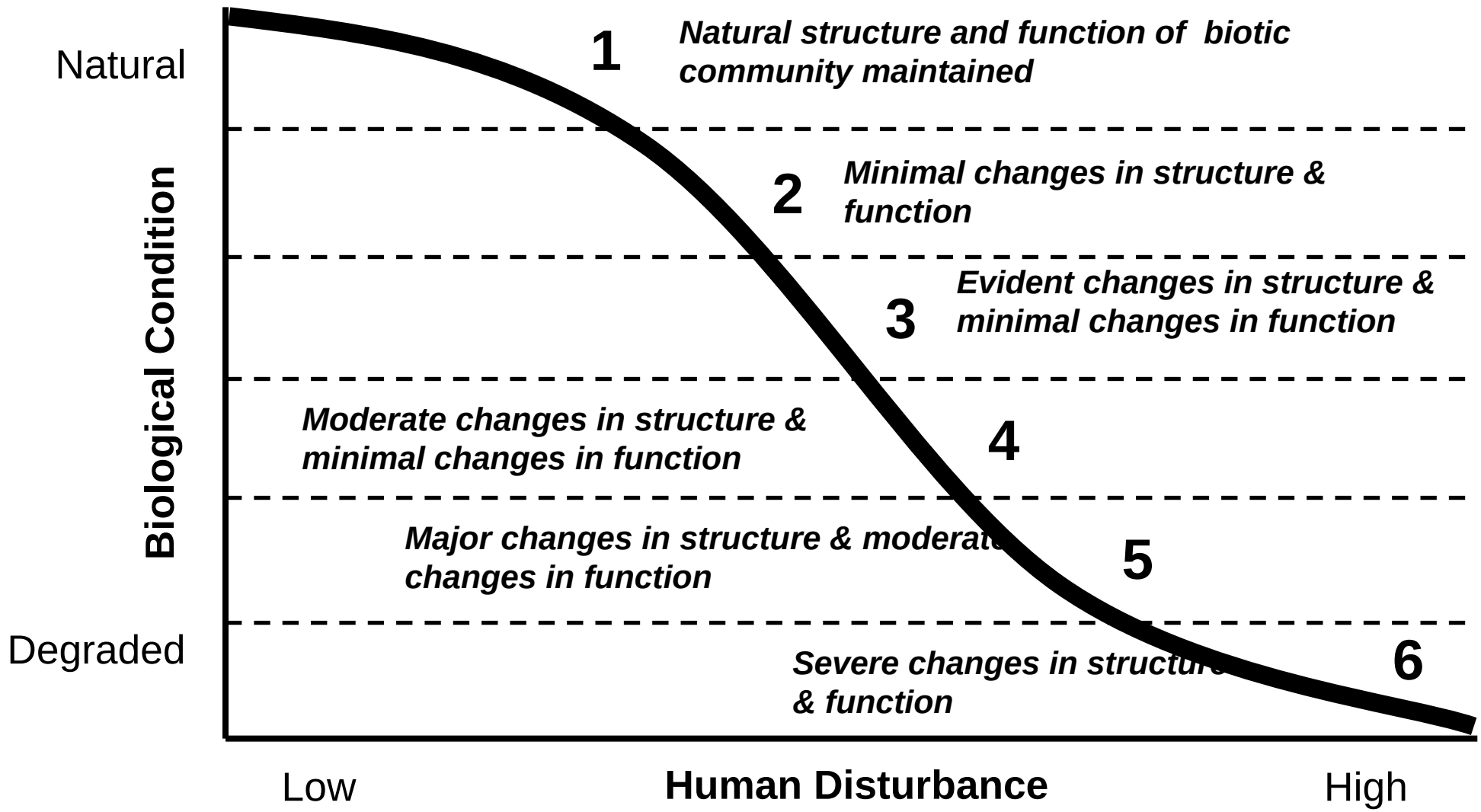
Comprehensiveness

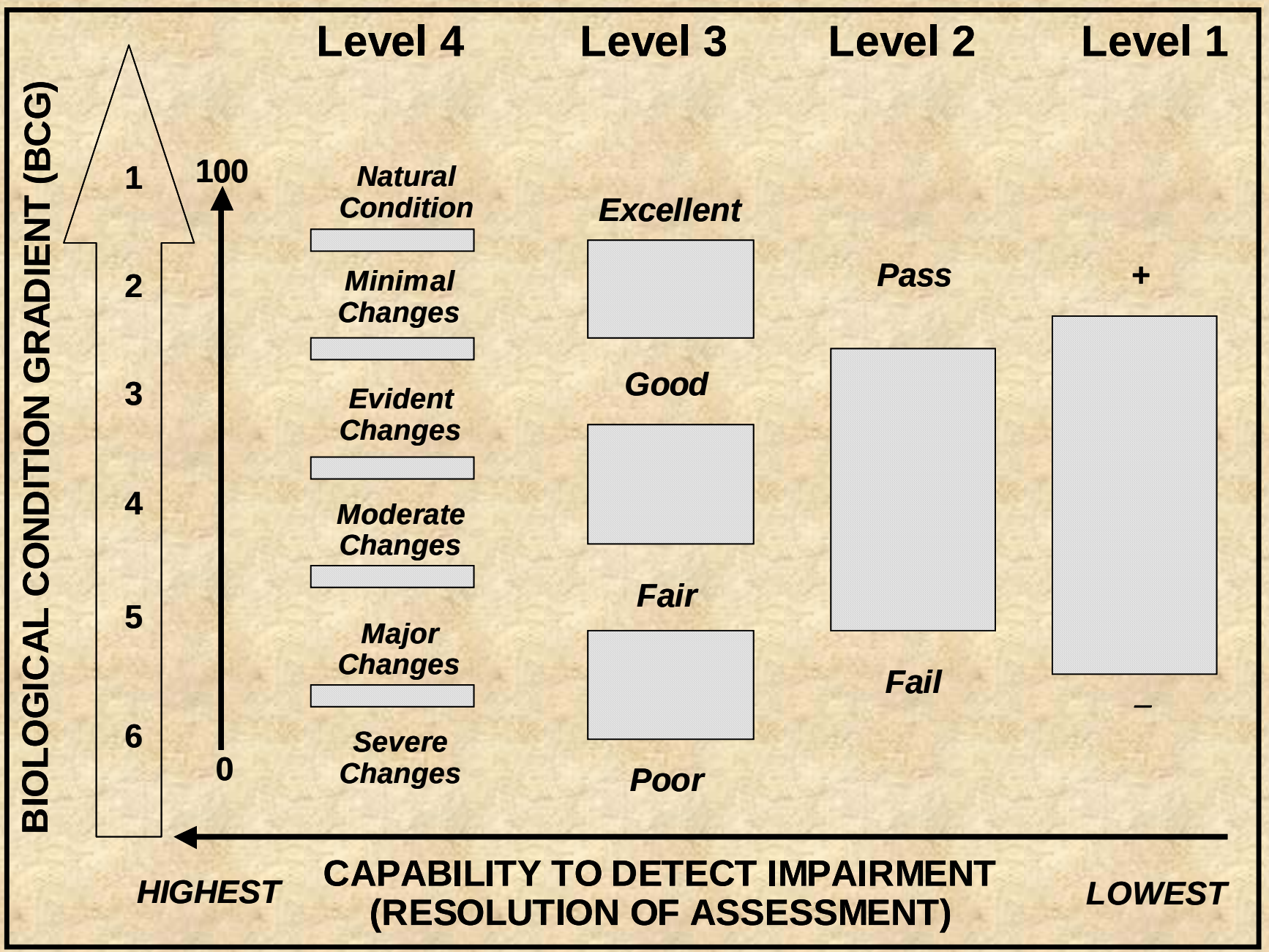
- Biological assessments are to be used in concert with chemical/physical and other stressor/ exposure indicators to develop an understanding of key limiting factors and their orders of importance.

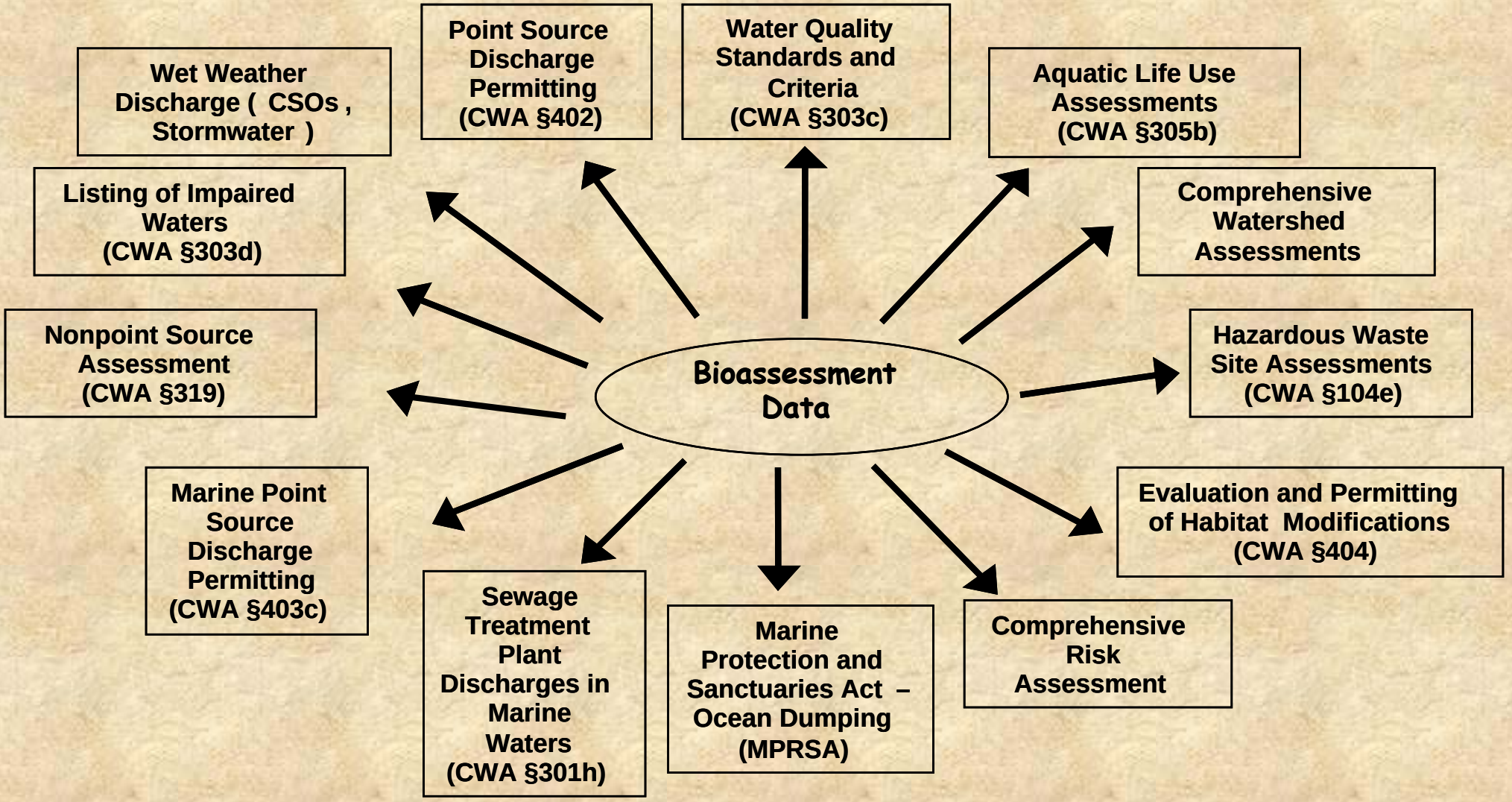
Cost-effectiveness

- The type of biological assessment envisioned here is attainable by State and Tribal programs and meets reasonable goals for the surface waters assessed on an annual basis. In addition, the benefit of having reliable biological data to support management decisions outweighs the intrinsic costs of development and implementation (NRC 2001).


High
Low
Level of Confidence
Level 4
Level 3
Level 2
Level 1
Undisturbed
Intermediate
Severe
Level of Stress on Ecosystem


Natural
Degraded
Biological Condition
1
Natural structure and function of biotic community maintained
2
Minimal changes in structure & function
3
Evident changes in structure & minimal changes in function
4
Moderate changes in structure & minimal changes in function
5
Major changes in structure & moderate changes in function
6
Severe changes in structure & function
Low
Human Disturbance
High


Level 4
Level 3
Level 2
Level 1
BIOLOGICAL CONDITION GRADIENT (BCG)
1
2
3
4
5
6
100
0
Natural Condition
Minimal Changes
Evident Changes
Moderate Changes
Major Changes
Severe Changes
Excellent
Good
Fair
Poor
Pass
Fail
+
–
HIGHEST
CAPABILITY TO DETECT IMPAIRMENT
(RESOLUTION OF ASSESSMENT)
LOWEST


Bioassessment Data
Wet Weather Discharge (CSOs , Stormwater)
Point Source Discharge Permitting (CWA §402)
Water Quality Standards and Criteria (CWA §303c)
Aquatic Life Use Assessments (CWA §305b)
Listing of Impaired Waters (CWA §303d)
Comprehensive Watershed Assessments
Nonpoint Source Assessment (CWA §319)
Hazardous Waste Site Assessments (CWA §104e)
Marine Point Source Discharge Permitting (CWA §403c)
Evaluation and Permitting of Habitat Modifications (CWA §404)
Sewage Treatment Plant Discharges in Marine Waters (CWA §301h)
Marine Protection and Sanctuaries Act – Ocean Dumping (MPRSA)
Comprehensive Risk Assessment

	Condition Assessment		Causal Associations		
Level	Impair/non	Multiple Condition	General	Categorical	Parameter Specific
1	*	–	–	–	–
2	**	*	*	–	–
3	**	**	**	**	*
4	***	***	***	***	**

*** Comprehensively fulfills program support role by providing robust and complete assessment including Best Available scientific certainty in accuracy (i.e., minimizing Type 1 and 2 errors) of condition assessment, and categorical causal associations.

** Condition assessments minimizes Type 1 error but does not adequately address Type 2; general causal associations.

* Condition assessments only address Type 1 error at extremes of condition and do not address Type 2 error; no causal association ability.

The Critical Elements "Checklist"

A. Which Waterbody Ecotype?		*B. Which Biological Assemblage(s)?*	
• **Perennial headwater streams**	☐	• **Aquatic macrophytes**	☐
• **Intermittent/Ephemeral streams**	☐	• **Algae/periphyton**	☐
• **Wadeable streams**	☐	• **Zooplankton**	☐
• **Small rivers**	☐	• **Macroinvertebrates**	☐
• **Large rivers**	☐	• **Fish**	☐
• **Great rivers**	☐	• **Amphibians**	☐
• **Lakes**	☐	• **Birds**	☐
• **Great Lakes**	☐	• **Other**	☐
• **Reservoirs**	☐		
• **Wetlands**	☐		
• **Estuaries**	☐		
• **Near-coastal areas**	☐		

Critical (Key) Technical Elements

		Critical to Foundation	Important for Program	Dependent on Other Elements
Design	1. Temporal coverage		✓	
Design	2. Spatial coverage		✓	
Design	3. Natural Classification		✓	
Design	4. Criteria for reference sites	✓		
Design	5. Reference conditions			✓
Methods	6. Taxonomic Resolution	✓		
Methods	7. Sample collection	✓		
Methods	8. Sample processing	✓		
Methods	9. Data Management	✓		
Interpretation	10. Ecological attributes	✓		
Interpretation	11. Biological endpoints			✓
Interpretation	12. Diagnostic capability			✓
Interpretation	13. Professional review		✓	

Score Weighting of Technical Elements

RESOLUTION	CRITICAL	IMPORTANT	DEPENDENT
LOW	2	1.5	1
	3	2.5	2
	4	3.5	3
HIGH	5	4.5	4

Critical (Key) Technical Elements

			LOW →			HIGH
Design	1.	Temporal coverage	1.5	2.5	3.5	4.5
	2.	Spatial coverage	1.5	2.5	3.5	4.5
	3.	Natural Classification	1.5	2.5	3.5	4.5
	4.	Criteria for reference sites	2	3	4	5
	5.	Reference conditions	1	2	3	4
Methods	6.	Taxonomic Resolution	2	3	4	5
	7.	Sample collection	2	3	4	5
	8.	Sample processing	2	3	4	5
	9.	Data Management	2	3	4	5
Interpretation	10.	Ecological attributes	1.5	2.5	3.5	4.5
	11.	Biological endpoints	1	2	3	4
	12.	Diagnostic capability	1	2	3	4
	13.	Professional review	1.5	2.5	3.5	4.5
		Total Score	**20.5**	**33.5**	**46.5**	**59.5**

Development of Thresholds for Determining Levels of Rigor: Max. Loss of Points Allowed

LEVEL OF RIGOR	CRITICAL	IMPOR-TANT	DEPEN-DENT	MIN. SCORE	%
4	-1	-1	-1	56.5	95%
3	-3	-3	-3	50.5	84%
2	-6	-6	-6	41.5	70%
1	-	-	-	20.5	<70%

Critical Technical Elements: Region V States (2004)

Critical Element	IL	IN	MI	MN	OH	WI
1. Temporal	4.5	3.5	4.5	4.5	5	5
2. Spatial Design	2.5	4.5	4	4	4	2.5
3. Natural Classification	3	3.5	3.5	3.5	4.5	3.5
4. Reference Condition	3.5	3	3	3	3	3
5. Reference Sites	5	4	4	4	4.5	4.5
6. Indicator Assemblages	5	4.5	3	5	5	4.5
7. Sample Collection	5	4	4	4.5	4.5	4
8. Sample Processing	4.5	4	4	4	5	4.5
9. Data Management	4	4	3.5	5	5	4
10. Ecological Attributes	3.5	3.5	3.5	3.5	4.5	3.5
11. Biological Endpoints	3	3	3	3	4	3
12. Diagnostics	2	3	2	3	4	2.5
13. Professional Review	2.5	3	3.5	3.5	4.5	4
CE Score	48	47.5	45.5	50.5	57.5	48.5
%CE Score	81	80	76	85	97	82
CE Level	L2	L2	L2	L3	L4	L2

L1	<70
L2	>70
L3	>85
L4	>=95

The Critical Elements "Checklist"

	L → H
Key Technical Elements for a Bioassessment Program	
6. Indicator Assemblages	
• Gross, visual observation	
• Single assemblage, low resolution (i.e., family level or higher)	
• Single assemblage, high resolution (i.e., genus/species); if multiple assemblages, others are low resolution or used infrequently	
• Two or more assemblages, both high resolution and applied together	

The Critical Elements "Checklist"

	L → H
Key Technical Elements for a Bioassessment Program	
10. Biological Endpoints and Thresholds	
• No formal index or assemblage-based endpoint; presence/absence of selected indicator taxa; no attainment threshold.	
• Non-calibrated index based on watershed-specific expectations; no regional context	
• Index calibrated for statewide usage; attainment thresholds based on regional reference data; single assemblage.	
• Index or models calibrated with regional reference dataset; quantitative numeric endpoints that correspond to BCG.	

The Critical Elements "Checklist"

	L → H
Key Technical Elements for a Bioassessment Program	
11. Diagnostic Capability	
• No diagnostic capability	
• Gross indications of response; not specifically diagnostic; not supported by extensive testing	
• Indicator guilds, single assemblage; supported by testing and case studies; single assemblage.	
• Response patterns fully developed; supported by integrated assessment of causal associations; extensive underlying testing; multiple assemblages.	

Programmatic Elements for WQ Management	
Basic Reporting	• Status • Trends
WQS Program	• Tiered Uses • UAA • Refined WQC • Anti-deg. • Site-specific crit. mod.
Watersheds/NPS	• NPS/BMP Effect. • Habitat • Stressor I.D.
TMDL/303d	• List/Delist • TMDL Dev. • Severity/Extent
NPDES/Other Permitting	• WQ BELs • Priority Setting • CSOs/SSOs • Stormwater Ph. I&II • WET Limits/Cond. • Enforcement • Dredge & Fill

Table 5. Defining levels of rigor for supporting specific water quality management programs with bioassessments and biocriteria.

WQ Program Support Attribute	Level 1 information	Level 2 information	Level 3 information	Level 4 information
Proportion of WQ Management Resources	Less than 1%, which indicates minimal support for bioassessment; thus extension to WQ management program support is minimal.	Greater than 1%, but less than 5%; some support of selected WQ management, but would likely occur after status/trends support is completed.	Greater than 5%, but less than 10%; more support of WQ management is likely, but may be less that statewide or regional in scope.	Greater than 10%; biological assessment programs considered core to WQ management.
Basin/Watershed Units	Selected basins/reaches, no statewide coverage.	Statewide coverage with no or minimal use of basin/reach scale assessment.	Rotating basin approach is used to allocate bioassessment resources; strategic allocation to support all WQ management programs at scale of management; statewide coverage >10 years.	Same as level 3 except statewide coverage is achieved in 10 years.
Sites Sampled (annually)	Fewer than 30 sites sampled annually; no delineation by watershed unit.	Fewer than 30 sites sampled per 8 digit HUC.	Adequate (>30) per 8 digit HUC.	Adequate per 11-14 digit HUC.
Aquatic Life Use Designation Structure	Single and general aquatic life use; non-specific to aquatic resource type.	General, but resource-specific uses (e.g., cold water, warm water); no refinement within categories.	Multiple uses, but no linkage to biological condition gradient; no numeric linkage to reference condition.	Tiered and refined uses linked directly to biological condition gradient; stratification is adequate to reflect regional patterns and resource classification; numeric criteria are linked directly toi reference condition.
Water Quality Criteria	Simple chemical criteria for conventional pollutants; no linkage to bioassessments or the BCG.	Conventional and selected toxic chemical criteria; no linkage to bioassessments or the BCG.	Acute/chronic criteria for toxics, comprehensive conventional criteria; no direct linkage to BCG.	Same as level 3 except linkage to BCG is direct for appropriate parameters including nutrients.
Biological Criteria	Narrative biocriteria; decision thresholds based on best professional judgment; not adopted in WQS.	Narrative biocriteria; decision thresholds based on qualitative measures; narrative adopted in WQS.	Narrative biocriteria adopted in WQS: supported by quantitative measures.	Numeric biocriteria based on regional reference condition adopted in WQS; quantitative measures correspond to BCG and include appropriate levels of regional stratification and waterbody classification.
Aquatic Life Use Arbiter	No usage of biological data.	The use of biological data is site specific and based on best professional judgement.	Bioassessment data is used to make assessment decisions based on a narrative assessment process.	Numeric bioassessment results are used to make assessment decisions.

INITIAL DEVELOPMENT PHASE
0-18 MONTHS

INITIAL IMPLEMENTATION PHASE
12-24 MONTHS

INITIAL ASSESSMENT PHASE
18 MO – 6 YEARS

FULL ASSESSMENT PHASE
5 – 10+ YEARS

1. Establish Conceptual Foundation

- Science
- Policy

2. Merge Scientific & Policy Foundations

- Link conceptual TALU tiers to regional BCG conceptual model
- Evaluate for consistency with existing WQS framework
- Draft or refine narrative ALU descriptions

Start-Up Tasks: Initial Technical Development Tasks

Acquire Staffing
- Professional biologists with taxonomic expertise & training
- Database manager
- Interns/technicians (field work, lab tasks

Acquire Facilities & Equipment
- Outfit laboratory and field facility
- Office accommodations
- Database support infrastructure

Methods Development
- Review and select candidate methods and protocols
- Consider MQO/DQO needs
- Test methods for applicability
- Analyze test results – select methods

Start-Up Tasks: Initiate Monitoring Strategy

Initiate Field Sampling
- Review spatial designs
- Develop QA/QC and QAPP
- Develop sampling plans in accordance with monitoring strategy
- Pilot assessments

Classification Issues
- Consider spatial stratification issues
- Develop and test reference condition approach
- Select and sample reference sites
- Develop index development and calibration strategy

Assessment Issues
- Use data for "makeable" decisions
- Initiate exploratory analysis of biological responses to stressors

Program Implementation

Biocriteria Development
- Select candidate metrics and/or assessment tools
- Develop refined uses - narratives
- Test metrics and develop calibrated indices
- Evaluate via bioassessments

Program Maintenance

Biocriteria Development
- Refine metrics and develop calibrated indices
- Develop reference benchmarks for calibrated indices according to classification scheme and by major aquatic ecotype
- Link to TALUs via BCG

5. Application in WQ Management

Water Quality Program Support
- Develop capacity to support WQ programs (WQS/UAAs, TMDLs, permits, planning)
- Formalize and increase water quality program support as capacity is developed (biological data should support more decisions)

Water Quality Program Support
- Fully functioning bioassessment program supports WQS (UAAs, ALU, biocriteria) and basic program needs (305b/303d)
- Program dev't should be fully initiated – e.g., integrated chemical, physical, and biological database supports tool, criteria, & policy dev't. (ongoing)

3. Establish Technical Program

4. Develop & Validate Quantitative Thresholds

Quality Improvement Process

Continuously evaluate program – develop and implement refinements

Evaluate effectiveness of initial decisions – make needed adjustments

n/barbour/timeline.ppt

What is the appropriate level of rigor?

Special Data Analyses Addressed these Questions:

1. What is the effect of using one vs. two indicator assemblages upon bioassessment outcomes?

2. How does taxonomic resolution (i.e., genus vs. family level) affect bioassessment outcomes?

3. What is required to use biological information as a basis for diagnosing problems?

4. How do criteria for reference site inclusion influence the calibration of a biological index or indicator, and our ability to derive biocriteria?

5. How does the number of reference sites (N) affect the characterization of biological expectations?

6. How does the level of macroinvertebrate subsampling affect the results of bioassessment metrics?

7. How does spatial design affect bioassessment outcomes and TALU applications?

Initial Conclusions

- Our analyses have provided quantitative examples that support the original differentiation of the levels of rigor, particularly between L3 and L4.
- There is an aggregate impact of detail in methods and practices that results in bioassessment that can better support multiple management needs.
- We can use the results of the technical analyses to refine the descriptions of the levels of rigor in the Critical Elements document.
- What we have learned should be helpful in the development of the bioassessment comparability concepts and methods.