Biocriteria and Arizona Water Quality Standards

Patti Spindler
Arizona Department of Environmental Quality
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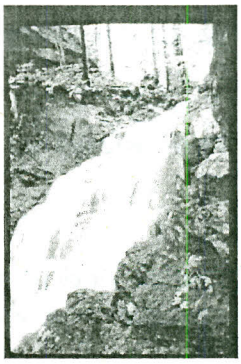
1

Primary Objective of the CWA

To restore & maintain the chemical, physical, & *Biological Integrity* of the nation's waters



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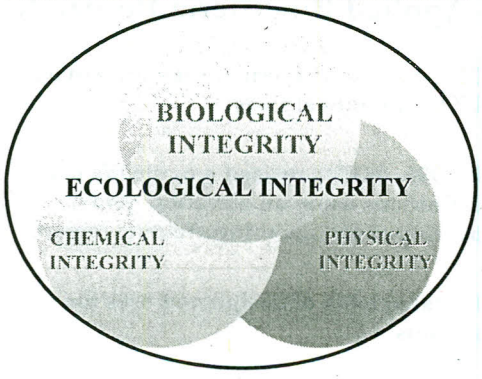
Elements of Ecological Integrity



3

WQS Are Fundamental

- WQS standards play a central role in Arizona's water quality management programs
  - **WQS establish water quality goals**
  - **Basis for 305(b) water quality assessments**
  - **Used to identify impaired waters on the 303(d) list**
  - **TMDLs**
  - **Water quality-based AZPDES permit limits**

4

What Are Water Quality Standards?

Two basic types: 1. Numeric
2. Narrative

Third major element of the water quality standards is an **antidegradation** policy.

5

Numeric Water Quality Standards

- **Water quality criteria** expressed as concentration limits on specific pollutants.
- Expressed in terms of protection of **designated uses.**
- Generally, established to protect human health, aquatic life, and agricultural uses.

6

Protection of Aquatic Life

- **Aquatic and wildlife (cold water) (A&Wc)**
- **Aquatic and wildlife (warm water) (A&Ww)**
- **Aquatic and wildlife (ephemeral) (A&We)**
- **Aquatic and wildlife (effluent dependent water) (A&Wedw)**

7

Applied Biocriteria Research

ADEQ has used biocriteria research in its WQS program already:

- **In 1996, ADEQ revised aquatic life use definitions using an elevation model developed for macroinvertebrate regions**
- **Updated table of designated uses for streams**

8

Revised A&Wc definition

- Aquatic and wildlife (cold water) means the use of a surface water by animals, plants, or other ***cold water*** organisms, including salmonids, ***generally occurring at elevations greater than 5000',*** for habitation, growth, or propagation.

9

Revised A&Ww Definition

- Aquatic and wildlife (warm water) means the use of a surface water by animals, plants, or other ***warm water*** organisms, excluding salmonids, ***generally occurring at elevations less than 5000',*** for habitation, growth, or propagation.

10

Oak Creek: Revised A&W Designated Uses

11

Numeric Water Quality Criteria for Arsenic to Protect Aquatic Life

A&Wc Acute (µg/L)	A&Wc Chronic (µg/L)	A&Ww Acute (µg/L)	A&Ww Chronic (µg/L)	A&W (edw) Acute (µg/L)	A&W (edw) Chronic (µg/L)	A&We Acute (µg/L)
360 D	**190 D**	**360 D**	**190 D**	**360 D**	**190 D**	**440 D**

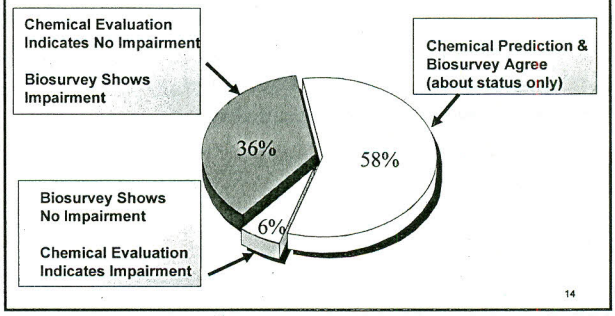
12

What's Wrong With Using a Chemical-Specific Approach in WQS?

- Addresses chemical integrity only.
- Based on limited toxicity data.
- Criteria are not available for many pollutants.
- Does not address additive, antagonistic and synergistic effects.

13

VALUE OF BIOLOGICAL CRITERIA: Ohio Comparison of Biosurvey with Chemical Evaluation

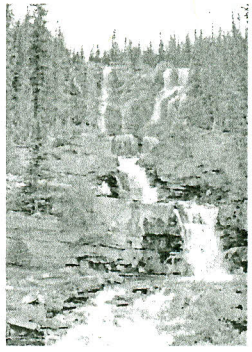


14

Advantages of Bioassessments

- Direct measure of biological integrity
- Focus on resource not pollutants
- Integrate stressors and synergistic impacts over time
- Taxonomy cost is 1/10 of chemical suite cost for ADEQ
- Biology may identify impact where chemical data misses impact

15



Section 303(c)2(B):

"...where numeric criteria are not available, States shall adopt criteria based on biological.. assessment methods..."

16

A Different Approach

"The true health of our aquatic environments is reflected by the biological communities that reside within them"

Prof. J. Karr
University of Washington

17

A Definition of Biological Integrity

The ability of an aquatic ecosystem to support and maintain a balanced adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region.

18

BIOLOGICAL CRITERIA (in the WQS Sense)

Definition: ***narrative descriptions or numerical values of the structure and function of aquatic communities in a water body necessary to protect the designated aquatic life use, implemented through water quality standards.***

19

NARRATIVE AND NUMERIC BIOCRITERIA

- ✓ ***Narrative Biocriteria***- General statements of the structure and function of aquatic communities in a surface water necessary to protect the designated aquatic life use.
- ✓ ***Numeric Biocriteria***- Specific quantitative measures of the structure and function of aquatic communities in a surface water necessary to protect the designated aquatic life use.

20

Narrative Biocriterion

- ADEQ has proposed a new narrative biocriterion in the current triennial review.
- Implementation procedures will accompany the standard and will include bioassessment protocols, indexes of biological integrity and guidance for identifying stressors
- Proposals will soon be on-line at www.azdeq.gov/environ/water/assessment/
- Comments accepted thru August
- Rules to be published in early 2006

21

Proposed Narrative Biocriterion

The biological integrity of wadeable, perennial streams, as determined by the Arizona Indexes of Biological Integrity, shall be protected at or above the 25th percentile of reference condition.

22

Biocriteria Implementation Procedures

- Applicable waterbodies
- Indexes of Biological Integrity
- Reference methods document (QAPP)
- Assessment and listing guidance (305b, 303d)
- Stressor identification

23

Applicable waterbody type

- Perennial streams or reaches
- Wadeable (rule of 9; 2.5' deep x 4ft/s)
- Non-effluent dominated
- Riffle/run; fast water or erosional habitat

24

Non-applicable conditions

- Recent high-flow conditions have scoured stream bottom
- Substrate is >50% bedrock, travertine or sand dominated
- Flow regime is not perennial

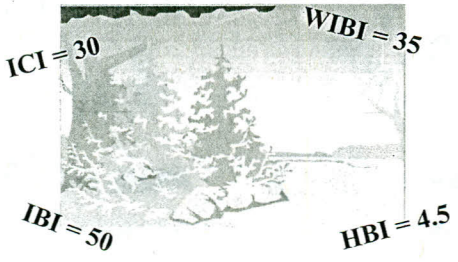
25

Non-applicable waterbodies

- Intermittent reaches
- Large, non-wadeable rivers
- Effluent dependent streams
- Ephemeral streams
- Lakes

26

PROCESS FOR DEVELOPING BIOLOGICAL CRITERIA



27

KEY COMPONENTS OF BIOLOGICAL CRITERIA

- ✓ **Bioassessment protocols**
- ✓ **Classification**
- ✓ **Reference conditions**

28

Developing Biocriteria

1. Develop standardized bioassessment protocols (Original protocols 1994, QAPP 2005)
2. Identify reference sites
3. Classify surface waters into similar groups or classes (1996, 2001)
4. Collect biological & habitat data at reference and non-reference sites

29

Creating the Biological Indexes

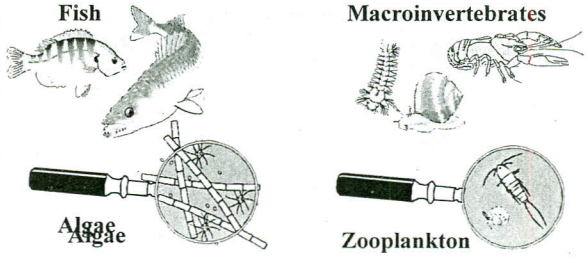
5. Test metrics for response to gradient of conditions
6. Select metrics that best discriminate between reference and non-reference conditions
7. Develop scoring criteria for each metric
8. Aggregate metrics to derive Index of Biological Integrity (IBI)
9. Develop & test Index for each aquatic life use
10. Apply biocriteria to surface waters to protect aquatic life uses, thru assessment process

30

Arizona Bioassessments for Wadeable, Perennial Streams

31

Community Components for wadeable perennial streams



32

Macroinvertebrate sampling methods

- 3-minute timed composite sample
- Approximately 3 m^2 sampled area
- D-frame 0.5 mm dip net
- Preservation with 99% isopropyl alcohol with 1 capful of 37% formalin per liter of sample
- Chemical & habitat data collected concurrently
- Field effort 3-4 hrs for 2 person team
- Spring index period (April-May for ww, May-June for cw)

33

Advantages of dip-net method compared with surber method

- Versatile – useable in deep water, most substrate types
- Cost effective – 1 composite sample vs. multiple samples
- Cost effective – no field sorting time required
- Greater counts of organisms collected
- Taxa richness greater (42% greater in dip net sample according to USEPA)

34

Macroinvertebrate Taxonomy

- Taxonomic identification of minimum 500 specimens
- Sub-sampling with Caton Tray recommended where ≥500 specimens/sample
- Identification of insects to genus level
- Chironomidae to family level
- Non-insects to family level or higher
- References: QAPP & Master taxa list

35

Taxonomy data consistency

- Current ADEQ contract lab for macroinvertebrates is EcoAnalysts, Inc.
- Recommend Split samples or Voucher specimen IDs checked by ADEQ contract lab
- Recommend using ADEQ tolerance values and functional feeding group standard values for ADEQ metric and index calculations

36

Algae - Diatom Sampling methods; Initial survey design

- Natural substrates
- High variability among reference sites
- Post-flood period & successional stage need to be standardized for among site comparisons (Lawson, 1999)
- Recommended artificial substrates

37

Algae-Diatoms New survey design

- Santa Cruz River Basin pilot study
- 10 sites ranging from reference to nutrient enriched
- Green flagging tape as artificial substrate
- 30 day incubation period, April-May
- Metric testing & analysis not yet completed

38

Fish community methods

- AGFD testing out USEPA's EMAP methods
- West-wide index for fish under development by USEPA
- Western EMAP Pilot Project - study to be released in 2006

39

Reference Sites Developed Statewide

- Approximately 100 sites statewide
- Distributed among 10 surface water basins
- Coverage of ecoregions

40

Initial Reference site selection criteria

- Sites represent least disturbed condition available for each basin
- >0.5 km downstream of road crossings
- No known discharges upstream
- No major impoundments upstream
- No channel alterations at the site
- Accessible (within a 2-hour walk or 3-4 mi from nearest 4WD road)

41

Field assessment of reference condition

- Site should be truly perennial (indicators: fish, univoltine insects, riparian indicators)
- Site should be free of local land use impacts
- Site should be free of channel alterations
- No violations of pH or dissolved oxygen water quality standards

42

Classification

✓ **Identifies Regions of Ecological Similarity from Which To Select Reference Sites for Index development**

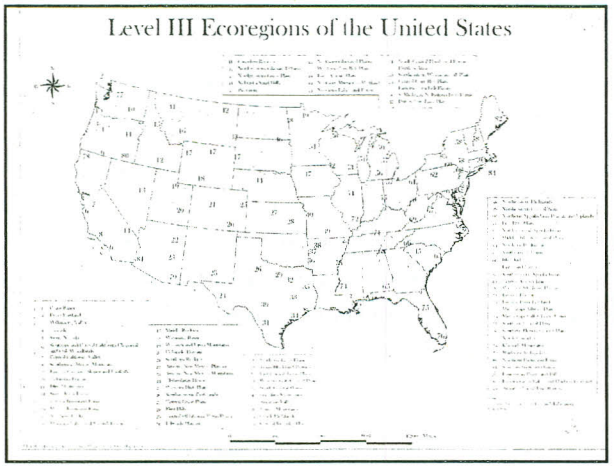
✓**Biological Conditions Expected to be Similar within a region**

43

Arizona Classification Analysis

- Evaluation of USEPA ecoregions
- Multivariate analysis of statewide macroinvertebrate data
- Elevation-based model developed to classify macroinvertebrate communities across AZ

44

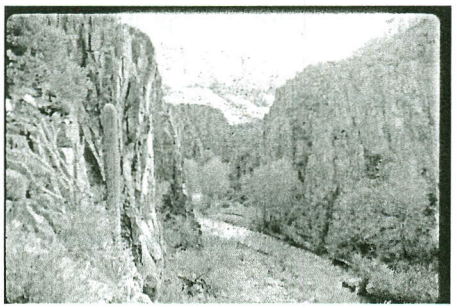


Problem with USEPA Ecoregions

- Five ecoregions in Arizona
- Mixture of macroinvertebrate community types in Southern Deserts & Arizona-New Mexico Mtns
- High topographic variability – Verde Valley lowland streams are warmwater, Sky islands of SE AZ are coldwater
- Model doesn't work unless you subdivide ecoregions

46

Desert Streams

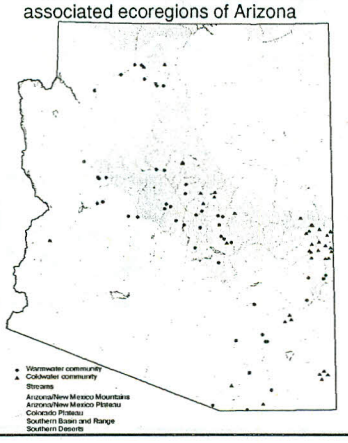


47

Mountain streams

48

Macroinvertebrate communities and associated ecoregions of Arizona

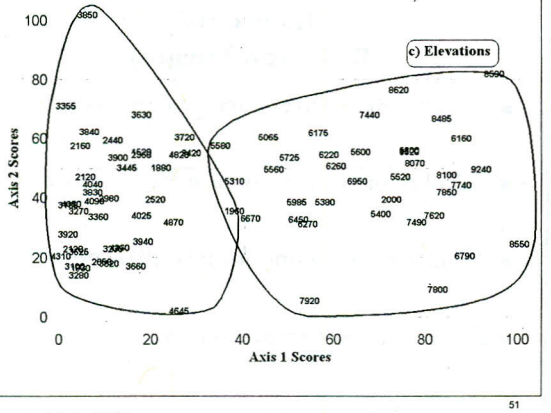


49

Multivariate analysis

- Statewide dataset of approximately 90 reference sites
- Detrended correspondence analysis
- Graphic of samples by elevation show elevation split at 5000' elevation
- Similar pattern over 3 year dataset
- Elevation map corrects for ecoregion error

50



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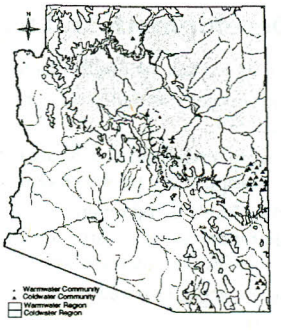


52

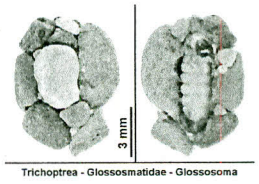
Elevation-based classification

- Warm water community found at elevations <5000'
- Cold water community found at elevations >5000'

53

Two Indexes of Biological Integrity

- Warmwater IBI
- Coldwater IBI



54

Multimetric Index Development and testing

- Testing of 30 metrics for discrimination ability
- Redundant metrics avoided (Pearson correlation coefficient <0.9)
- Selection of metrics from 4 attribute categories (richness, composition, tolerance & trophic metrics)
- Scoring thresholds based on either 5th percentile for metrics that increase with disturbance or 95th percentile value for metrics that decrease with disturbance
- Assessment categories based on 25th percentile of total reference score

55

Computing multimetric Indexes of Biological Integrity

- Calculate macroinvertebrate metric values
- Calculate metric percent of reference score
- Average metric scores for final IBI score
- Determine assessment category

56

Nine Metrics in Warmwater IBI

- Total taxa richness (ref. Value 34)
- Mayfly taxa richness (ref. Value 7)
- Caddisfly taxa richness (ref. Value 8)
- Diptera taxa richness (ref. Value 9)
- Percent dominant taxon (ref. Value 20.9)
- Percent composition by mayflies (ref. Value 70.8)
- Hilsenhoff Biotic Index (ref. Value 4.9)
- Percent Scraper composition (ref. Value 25.1)
- Scraper taxa richness (ref. Value 7)

57

Index Scoring

- For Sensitive indicator Metrics
- Metric score = (sample value/ref. threshold value) *100

- For tolerant indicator metrics
- Metric score = (100 - sample value)/
- (100 - ref. threshold value) *100

58

Warm water IBI Assessment categories

- Exceptional 73 - 100
- Good 53 - 72 (> 25% ile)
- Impaired 27 - 52
- Very Impaired 0 - 26

59

ADEQ Warmwater IBI scoring example; Sabino Cr abv E. Fork Sabino, 1994

Metric	Metric Value	Reference Scoring Threshold	Metric Score
Total taxa	22	34	78
Trichoptera taxa	2	8	23.8
Ephemeroptera taxa	5	7	71.4
Diptera taxa	6	9	66.7
Scraper taxa	5	7	71.4
Percent scraper	2.9	25.1	11.7
Percent Ephemeroptera	54.8	70.8	77.4
Percent Dominant Taxon	50	20.9	63.2
Hilsenhoff Biotic Index	5.0	4.9	98
WW IBI Score Assessment category			62.4 Good

60

Seven metrics in Coldwater IBI

- Total taxa richness (ref.value 23)
- Diptera taxa richness (ref.value 5)
- Intolerant taxa richness (ref.value 4)
- Hilsenhoff Biotic Index (ref.value 5.5)
- Percent stonefly composition (ref.value 1.3)
- Percent scraper composition (ref.value 8.8)
- Scraper taxa richness (ref.value 5)

61

Cold water IBI Assessment categories

- Exceptional 97 - 100
- Good 88 - 96 (> 25% ile)
- Impaired 44 - 87
- Very Impaired 0 - 43

62

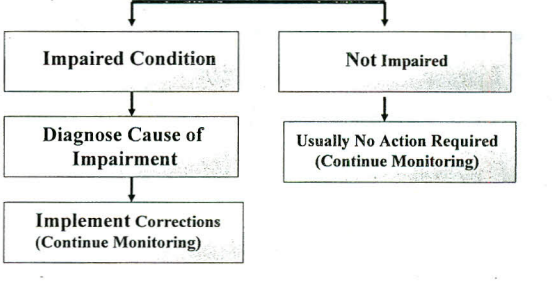
ADEQ Biological Database

- Ecological Data Application System (EDAS) in Microsoft ACCESS format (windows 2000) contains:
- Site/station information
- Sample description
- Taxonomy data and complete phylogeny for macroinvertebrates and algae
- Stream habitat data
- Queries to calculate Indexes

63

Applying Biocriteria

Sample test sites and compare to biocriteria



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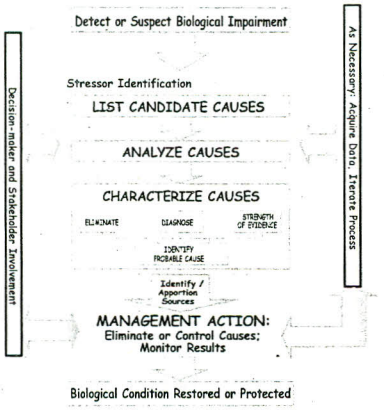
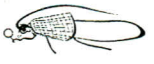


Stressor Identification

Identifying Unknown causes of biological impairment



65

Program Goals

✓Use bioassessments to **evaluate the health** of aquatic life in all surface waters

✓Use bioassessment data to **better define aquatic life designated uses**

✓**Develop quantifiable biocriteria** in water quality standards to protect aquatic life uses

✓Use biocriteria & bioassessments to **assess the effectiveness of water quality management efforts**

✓Use bioassessment data and biocriteria to better **communicate the health** of the Nation's waters

66

Current Biocriteria Program Objectives

- Propose narrative biocriterion in current triennial review
- Prepare to update ADEQ's Credible data policy to include bioassessment provisions for 305b and 303d purposes
- Conduct bioassessments and list of impaired waters for 2008 Water Quality Assessment Report

67

Future Biocriteria Objectives

- Develop index for fall sampling period
- Develop diatom (algae) bioassessments
- Examine EPA's EMAP methods for use in AZ
- Develop tolerance values for stressor ID purposes
- Test Stressor Identification process for AZ

68

Future Biocriteria Objectives

- Develop bioassessment methods for other surface water types:
  - Large Rivers
  - Intermittent Streams
  - Effluent dependent waterbodies

69