Monitoring Flowing Waters - Principles & Approaches in EMAP
EMAP Surface Waters Tools

- **Sample Survey Design**
  - Spatially-balanced probability design
  - Results extrapolated to target population with known confidence

- **Ecological Indicators**
  - Biological Indicators
    - Direct measures of ecological condition
    - Societal value
  - Stressor Indicators
    - Associations with ecological condition
    - Relative importance

- **Reference Condition**
  - Consistent approach to setting expectations for all indicators

- **Regional demonstrations**
  - Regional implementation (e.g., EMAP-West)
  - Example Ecological Assessments
EMAP-West
Assessment Questions

• What proportion of stream and river length is in good ecological condition across the Western U.S.?
  - In each state?
  - In focused geographic areas within each Region?

• What is the relative importance of stressors to stream ecological condition across the West?
  - In each state?
  - In focused geographic areas within each Region?
Example EMAP Assessment of Ecological Condition

Fish Index of Biotic Integrity example from Mid-Atlantic (90% CI = ± 10%)

- Western Appalachians: 35% (Insufficient Data), 32%, 30%, 3%
- No.-Central Appalachians: 43%, 32%, 15%, 10%
- Valleys: 28%, 44%, 14%, 15%
- Ridge and Blue Ridge: 35%, 32%, 28%, 15%

Ecoregions:
- Ridge and Blue Ridge
- No.-Central Appalachian
- North-Central Appalachian
- Valley
- Western Appalachian

Map showing distribution of ecological conditions across different regions.
EMAP-West
Assessment Questions

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• What is the relative importance of stressors to stream ecological condition across the West?
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Example EMAP Assessment - Ranking of Stressors

Stressor ranking example from Mid-Atlantic

- Sedimentation: 25%
- Riparian Habitat: 24%
- Mine Drainage: 14%
- Acidic Deposition: 11%
- Tissue Contamination: 10%
- Phosphorus: 6%
- Nitrogen: 4%
- Acid Mine Drainage: 1%
- Introduced Fish: 34%
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Sample Survey Design
Western Pilot

EMAP West Stream and River Survey
1999 - 2004
Sampling Uncertainty

90% CI = $1.645 \cdot (p \cdot (1-p)/n)^{1/2}$
Spatial Reporting Units

• Design for these:
  - Western Region (1)
  - EPA Regions 8, 9, 10 (3)
  - Subregions of interest (6)
  - States (12)

• Post-stratify for these:
  - Stream type (...)
  - Ecoregion (...)
  - HUC (...)
  - Other?
EMAP-West Design

• Sample sizes:
  - 50 per State
  - Special study areas
    • 160: N. Calif, OR John Day, Missouri Basin
    • 80: S. Calif
    • 60: WA Wenatchee, ID Rivers,

• Unequal probability sample
  - 5 Strahler order categories: $1^{st}$, $2^{nd}$, $3^{rd}$, $4^{th+}$, large rivers
  - Arid and mountainous aggregated Omernik ecoregions
EMAP-West Design

Primary Candidate Sampling Site: 2000-2003
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Indicator Approach

**Indicator Criteria**

- What can we (realistically) measure in a sample survey?
- How can we best measure it?
- How responsive is it?
- How variable is it?
- Can we score it?
Indicator Approach

What we can measure?

RIPARIAN
- Producer: woody plants
- 1° Consumer: birds
- 2° Consumer: birds
- Decomposers

BENTHIC
- Producer: algae
- 1° Consumer: benthos
- 2° Consumers: benthos, herptiles, fish
- Decomposers: microbes

WATER COLUMN
- Producer: macrophytes
- 1° Consumer: fish
- 2° Consumers: herptiles, fish
- Decomposers

ATMOSPHERE

STREAM, LAKE, WETLAND USE

LAND USE

WATER TABLE

Stressor Sources
Movement of Materials
Indicator Approach
How do we measure?

Fish Species Richness (% of Maximum)

Stream Length (Channel Width Units)
Indicator Approach
How responsive is it?

Mid-Atlantic Highlands Streams

Watershed Condition Class

Pristine ←------------------------------------------→ Degraded

Fish IBI Score

0 10 20 30 40 50 60 70 80 90 100

1 2 3 4 5
Indicator Approach

How variable is it?

Signal:Noise Ratio
(ratio of between-site variance/within-site variance)
Indicator Approach
Can we score it?

Watershed Condition Classes from Bryce et al., 1999, JAWRA
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Reference Condition
estimating distribution of sites in reference condition

Current Distribution
Historical Distribution

Percent of Sites
Perpendicular to Biological Index Score

40 50 60 70 80 90 100

Definitions of Reference Condition

For EMAP-W we recognize that multiple definitions exist, and that these 3 are especially pertinent:

- **Minimally Disturbed Condition** - condition of streams in the absence of significant human disturbance (e.g., “natural,” “pristine” or “undisturbed”)

- **Least Disturbed Condition** - found in conjunction with the best available physical, chemical and biological habitat conditions given today’s state of the landscape - defined by a set of explicit criteria to which all reference sites must adhere

- **Best Attainable Condition** - this condition is equivalent to the ecological condition of (hypothetical) least disturbed sites where the best possible management practices are in use
Reference Condition in EMAP-W

• Goal is to estimate the distribution of indicator values in sites of Least Disturbed Condition - the best of what’s left

• Estimating the distribution will require a sufficient sample size - minimum of 20 sites/state

• Multiple methods for finding sites in Least Disturbed Condition
  • Best Professional Judgment
  • “filtered” probability sites
  • GIS screening

• All sites (regardless of selection method) will need to meet our definition, i.e., they will need to represent the best of the current distribution
Reference Condition

estimating distribution of sites in reference condition

![Graph showing current and historical distribution of sites](image-url)
Reference Condition
Using estimates to set expectations

Restrictions on Reference Definition

Mean of 25th %tiles
Mean of 1st %tiles

<table>
<thead>
<tr>
<th>IBI Score</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
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What is EMAP West?

A monitoring demonstration of indicators and designs for measuring environmental progress

- unbiased estimates of condition of ecological resources - streams and rivers
- comparative ranking of stressors
- tools for biocriteria
- partnerships between EPA/States/Tribes

Clark’s Fork
Yellowstone River

Mesatchee Creek

Alsea River
Scope of EMAP West

• More than 300 sites/ year
• ~1300 sites over 4 years
  - 11 of 12 States
  - 3 EPA Regions
  - 2 EPA Contractors
• Biological Indicators:
  - Aquatic Vertebrates
  - Macrobenthos
  - Periphyton
• Chemical and Physical Habitat Indicators
Ultimate EMAP-W Goal: Unbiased Regional Assessments

- Field data forms
- Laboratory data
  - Chemistry (EPA-Corvallis)
  - Benthos (EcoAnalysts, CDFG)
  - Vertebrates (Smithsonian)
  - Periphyton (TBD)
  - Fish Tissue (EPA-Corvallis, EPA-Cincinnati)
  - Fish Pathogens (USFWS)
- Watershed stressors and Landscape data
  - EPA-Las Vegas and Corvallis
Ultimate EMAP-W Goal: Unbiased Regional Assessments

Fish IBI Results
- Good: 17%
- Fair: 36%
- Poor: 31%
- Insufficient Data: 17%

Ranking of Potential Stressors
- Sedimentation: 25%
- Riparian Habitat: 24%
- Mine Drainage: 14%
- Acidic Deposition: 11%
- Tissue Contamination: 10%
- Phosphorus: 5%
- Nitrogen: 5%
- Acid Mine Drainage: 1%

Introduced Fish: 34%

(Example from EMAP in Mid-Atlantic)