Long-Term Monitoring: Ecological Indicators

Jeffery A. Steevens
Elly Best, Ed Perkins, Gui Lotufo
ERDC, Environmental Laboratory
Vicksburg, MS

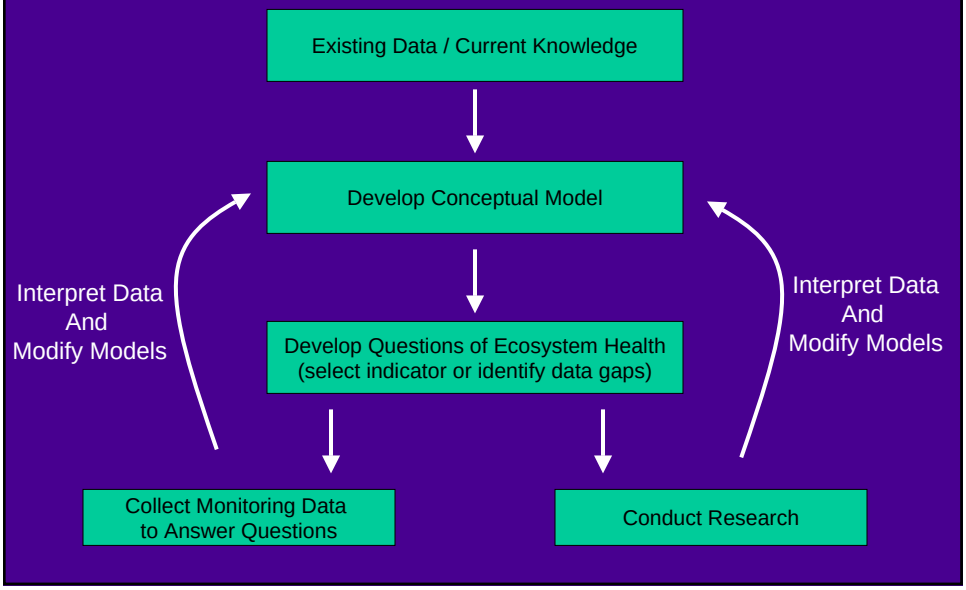
Long-Term Monitoring

- **Goal:**
  - Provide critical link between field personnel and decision-makers regarding the management of natural resources.
  - Balance between land use and ecological sustainability.
- **Environmental Technology Req.**
  - To develop techniques to monitor MUCs at DOD facilities.

LTM: Background

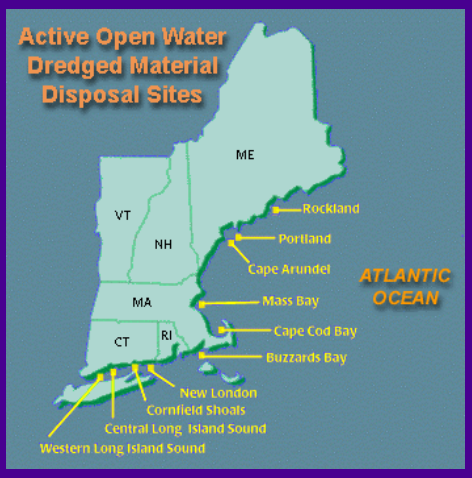
- **Currently Federal government spends $650 million/annually for over 36 monitoring programs.**
- **Examples:**
  - **Disposal Area Monitoring System (USACE)**
    - **Monitor effect of dredged material after open water disposal.**
  - **Environmental Monitoring and Assessment Program (EPA)**
    - **Regional and National assessment of marine waters.**
  - **National Status and Trends (NOAA)**
    - **Assessment of contaminant concentrations in sediment, water, tissue of aquatic organisms related to effects**
  - **Biomonitoring of Environ. Status and Trends (USGS)**
    - **Assessment of chemical concentrations related to effects in streams and rivers**

Long-Term Monitoring:
Approach to Ecosystems



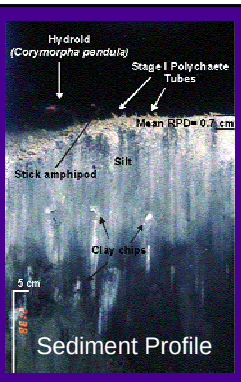
Disposal Area Monitoring System

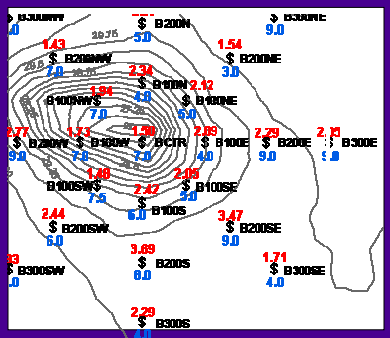
- Monitoring effort in New England District since 1977
- Focus on 10 DM disposal sites
- Objective: Monitor sites to insure no undesirable impacts
- Physical, chemical, and biological indicators



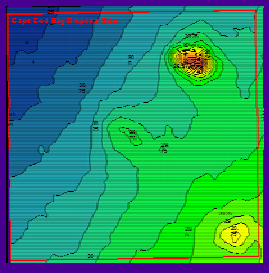
Adapted from NE District USACE

DAMOS: Cape Cod Bay Disposal Site





Organism Sediment Index



Bathymetry

Ecological Indicators

- Army has need to identify/develop indicators for monitoring MUCs
- Ecological Indicators

  A measure, or a collection of measures, that describe the condition of an ecosystem or one of its critical components

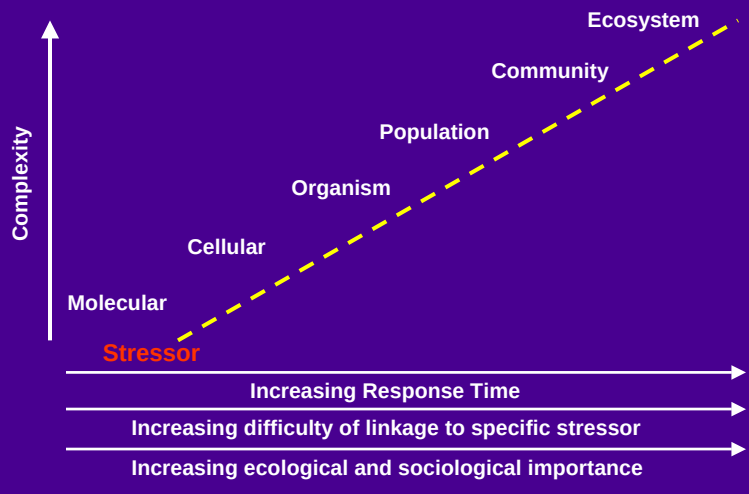
Ecological Indicators

- TYPE
  - Chemical, Biological, or Physical
- COMPLEXITY
  - Measurement or Index
- METHOD
  - Field Measure, Remotely-Sensed, or Model Output
- ASSESSMENT ENDPOINT
  - Status, Trend, Predictive, or Diagnostic

Considerations for development or selection of indicator

1. Practical to implement in field
2. Relevance of indicator to system
3. Specificity to a stressor
4. Correlation to the magnitude of stressor
5. Temporal and spatial relationships
6. Indicator should precede effect (predictive)
7. Accurate and reproducible
8. Costs should not outweigh benefits

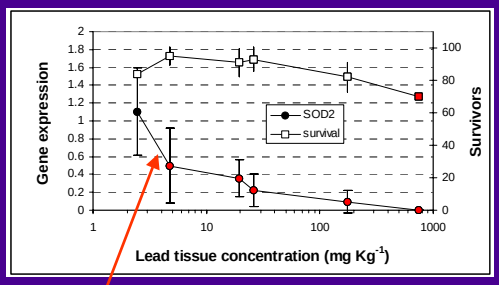
Ecological Indicators:
Level of Biological Organization



Adapted from Walker, 2001

Ecological Indicators:
Molecular Endpoints

- Molecular indicators of exposure and predicted effects
- Example: Aquatic invertebrates exposed to TNT and lead
- Real-time PCR used to measure gene expression



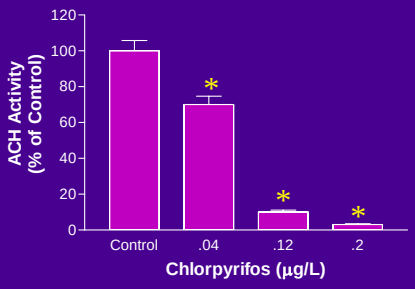
Predictive: Change in gene regulation observed before organism response observed

From Perkins, 2002

Ecological Indicators:
Cellular Endpoints

- Metabolism
  - Cytochrome p450
  - Monitor for metabolites
- Proteins
  - Metallothionein
  - Cholinesterase

Acetylcholinesterase activity in *Hyalella azteca* exposed to an organophosphate

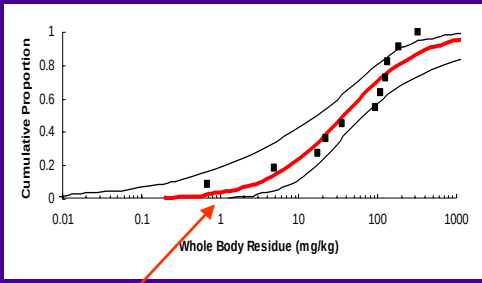


From Steevens, 2001

Ecological Indicators:
Whole Organism/Population Endpoints

- **Organism**
  - **Survival, growth**
  - **Reproduction**
- **Field surveys**
  - **Contaminant levels in tissues**
  - **Population surveys (abundance / diversity)**

Tissue Residue Benchmarks for the Protection of Fish and invertebrates Exposed to Total PCBs at Selected Probabilities of Adverse Effect



10% probability that adverse effect will occur at tissue concentration of 3.0 mg/kg

From Steevens, 2002

Ecological Indicators:
Whole Organism/Population Endpoints

- **Index of Biotic Integrity (EMAP)**

Pensacola Bay

- **IBI < 3**
  Ranges from 0 to 10

X **Hg concentrations elevated**

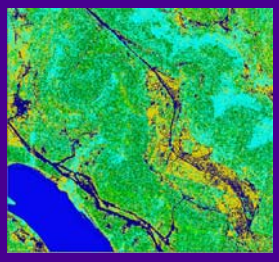
Co-located samples indicate poor ecological condition of Pensacola Bay

EPA, 2000

Ecological Indicators:
Community/System Endpoints

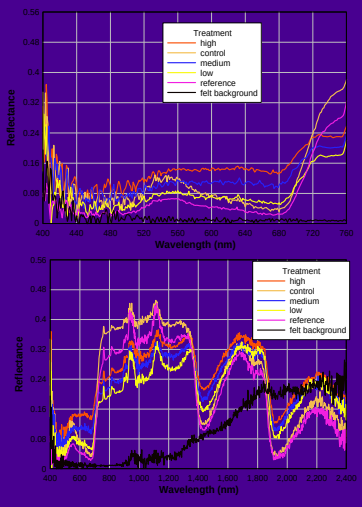
- Optical-biophysical relationships of vegetation spectra
- Reflectance spectra of common vegetation units
  - Grasses
  - Shrubs
  - Trees
- Derivation of spectral vegetation indices (VIs) specific for contaminant type and concentration (soil, sediment, water)
- Identification of contaminated vegetation units in remotely sensed images (monitoring)

Fort Hood, TX, maps. Identification points (above) by coordinates and vegetation units (below)



Ecological Indicators:
Community/System Endpoints

- Reflectance spectra of grasses and forbs available
- Reflectance spectra of vegetation from TNT and metals-contaminated soil indicate red (R; 630-690 nm) and near-infra red (NIR; 775-890 nm) as most important bandwidths
- Derived normalized difference vegetation indices (NDVIs) indicated significant differences between treatments, without interference by water vapor
- RS images available (Landsat VII) or currently collected (SPOT)



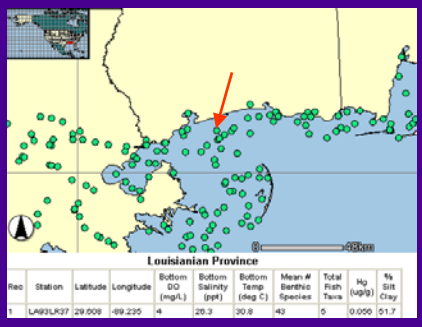
From Best & Sabol, 2002

Considerations for Development of Indicators:

1. Spatial scales
2. Temporal scales
3. Multiple stressors

Spatial Scales

- Spatial information provides
  - Distribution and magnitude of stressor
  - Relationship of stressor on indicator (trends)
  - Measure of variability

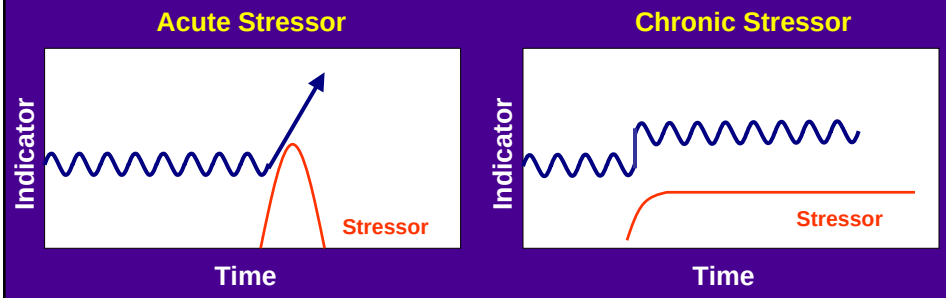


Rec	Station	Latitude	Longitude	Bottom DO (mg/L)	Bottom Salinity (ppt)	Bottom Temp (deg C)	Mean # Benthic Species	Total Fish Taxa	Hg (ug/g)	% Silt Clay
1	LA93LK37	29.009	-89.235	4	20.3	30.9	43	5	0.056	51.7

EMAP Data from epamap.epa.gov/

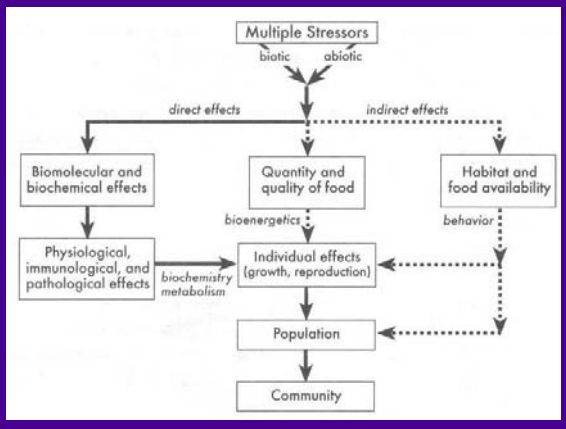
Temporal Scales

- Measurements over time:
  - Interpret indicator response (variability)
  - Recognize presence acute or chronic stressor



Multiple Stressors

- Physical, chemical, biological stressors
- Stressors can have effect on various levels of ecosystem
- Collectively, indicators should be sensitive to multiple stressors and be specific to individual stressors



From Di Giulio and Benson, 2002

What makes a good indicator?

- Conceptual relevance
- Feasibility to implement
- Low variability
- Interpretation and utility
- Cost benefit (time and money)

Conclusion:
Recommendations for Research

1. Linkage of stressor to different levels of biological organization (understand mechanisms)
2. Characterize indicator
   - Variability and baseline, sensitivity, specificity (MUC)
3. Interpretation and utility at management level