

Sixth National Monitoring Conference
Atlantic City, NJ
21 May 2008

USE OF INDICATORS IN ENVIRONMENTAL DECISION-MAKING

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Saprobic Index

Kolkwitz and Marsson(1908) Oekologie die pflanzlichen saprobien. Berlin dt. Bot. Ges., 26: 505-519

- ◆ The original biomonitoring assessment index, based on relative abundance specific taxa of microbes, phytoplankton, periphyton, etc.
- ◆ Value ranged from less than 0.5 (xenosaprobic) to more than 3.5 (polysaprobic)
- ◆ Still used in variant forms in Eastern Europe.

Horton's Water Quality Index (1965)

- ◆ Based on linear, weighted sum of eight (8) variables plus two coefficients (temperature factor and "obvious pollution" factor).
- ◆ *Horton's index did not consider toxic substances because he believed that "under no circumstances streams would contain substances that are injurious to human, animal or plant life."*

National Environmental Policy Act (of 1969)

- ◆ A key goal: Attain the “widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable or unintended consequences.”
- ◆ Policy making neither can nor should become totally scientific ... but we must strive to make maximum use of scientific evidence available ... and *development of environmental indices is one important way of doing this* (Train, 1972).

City of New York vs. EPA

US District Court – 1981

- ◆ Judge Abraham Sofaer ruled that “EPA must revise its presumption that materials that do not pass EPA’s environmental criteria will unreasonably degrade the marine environment.”
- ◆ Consequently 11 different indices were developed in order to define “unreasonable degradation,” of the environment, ranging from oxygen depletion to reproductive success in birds to human health consequences of eating contaminated fish (O’Connor and Dewling, 1986)
- ◆ The Ocean Dumping Ban Act of 1988 (Public Law 100-688) marked an end to almost a century of waste dumping into the ocean.

Now, we have many, many indicators or indices about the environment! The toolbox is loaded!!
Strewn like bricks in a brickyard!!!

- Over 200 indicators of ecosystem status (Rice 2000)
- Over 20 biomarkers just relating to NOAA's NS&T (Hameedi, 2005)
- Nearly 25 in integrative assessment approaches used by NOAA/NCCOS (Hameedi, 2007)
- Over 30 recommended at the National Core Coastal Indicators (2007) workshop

Based on information theory, largely abstract, and generally not useful

- ◆ **Integrative biological measures such as biological diversity and ecosystem health**
 - **Difficult to interpret by managers and communicate to the public**
 - ◆ What is ascendancy? Or resiliency (one of three parameters that define "ecosystem health")
 - ◆ What does diversity of order 2 mean to a decision-maker (or what does Hill's N_2 value of 2.42 suggest?)
 - ◆ What is alpha, beta or gamma diversity?
- ◆ **Numeric values of most indices are not comparable (derived differently - number of spp., biomass, probability, bits per species, etc.)**
- ◆ **"Any index of diversity can be misleading" (Rice, 2003); the concept of diversity is "meaningless" (Hurlbert, 1971)**
- ◆ **You are better off by simply describing species richness or status of biota (particular species or groups of species)**

Pressure Indicators

- Altered coastline
- Freshwater dams
- Industrial sites, jetties, ports and marinas
- Resource extraction, oil and gas
- Contaminant discharges and dumping sites
- Cables and corridors
- Commercial fishing
- Recreational fishing
- Aquaculture
- Tourism and recreation uses
- Dredging and shipping lanes

Stress Indicators

Cellular Integrity and Cytogenetic Damage
Lysosomal destabilization
DNA adducts
DNA Strand Breakage

Stress Proteins / Detoxification Response
Phase I enzymes (CYP1A, BPH)
Phase II enzymes (GST)
Multi-xenobiotic resistance proteins

Stress proteins (hsp70, hsp76, chaperonin)
(MXRs)
Metallothioneins
Antioxidants

Impaired Reproduction
Gonadotropins
Steroids (plasma estradiol, testosterone)

Impaired Immune System
Vitellogenin
Hemocyte numbers and types
Killing index / phagocytic index
Serum lysozymes

Wellness and Condition
Darwinian "fitness parameters"
Atrophied organs and connective tissues
Parasitic infection
Disease and abnormalities
Lesions and tumors

Ecological Indices
Diversity

Species Richness
Index of Biotic Integrity
IBI-Benthos
Invertebrate community index
Modified Index of Well-Being
Habitat Suitability Index
Qualitative Habitat Evaluation Index

Response Indicators

- Enabling legislation or an Executive Order
- Steering committees and advisory panels
- Constituency and stakeholders involved
- Completion of studies established
- Performance indicators
- Alternative management strategies
- Cost-benefit analysis of alternative strategies
- Improved public access to information
- Rehabilitated sewer network
- Improved waste treatment equipment
- Monitoring and laboratory management
- Management plans for industrial effluents and emissions
- Emergency response plans
- More collaborative and transparent resource management

Examples of Measures of Diversity (Jost, 2006)
-- some with reasonable application to biological communities, some not.

- ◆ Species Richness
- ◆ Shannon-Wiener Index (entropy)
- ◆ Simpson's Reciprocal Index
- ◆ Gini-Simpson Index
- ◆ Renyi entropies
- ◆ HCDT (Havrda-Charvat-Daroczy-Tsallis) or Tsallis entropy
- ◆ Patil and Taillee average rarity index
- ◆ Varma entropy

Other indicator concepts

- ◆ **Vitality** -- based on Gompertz and Weibull survival dynamics models and actuary analyses – (Anderson, 2000)
- ◆ **Developmental Instability** -- based on the concept of a genotype to consistently produce a given phenotype; that ability is degraded with stress (fire, grazing, Chernobyl, etc.), including environmental stress and can be measured, including by fractal geometry (Emlen, Freeman, Mills and Graham, 1999)

BIG ISSUE: Numerous definitions
(sustainability has 100 different ones!),
disparate data sets, and different methods

Purpose: to simplify and
communicate complex data,
e.g., CPI, SQT Index

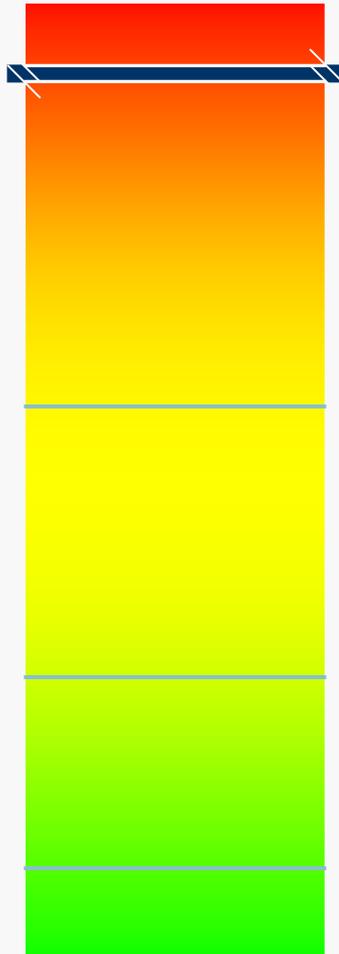
INDICATORS

An indicator is something that provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable (Hameedi, 2002; 2005)

- Ecological Indicators -- measurements are at population, community or ecosystem level
- Biomarkers -- measurements are the individual, cellular, or sub-cellular level

HRGS Biomarker

(Anderson, et al., 2005)



Responds to the presence of certain PAHs, planar PCBs, dioxins and furans

CCMA has data from 19 estuaries (over 1300 samples)

Based on a threshold value of 32 mg benzo[a]pyrene equivalent / g (sediment)

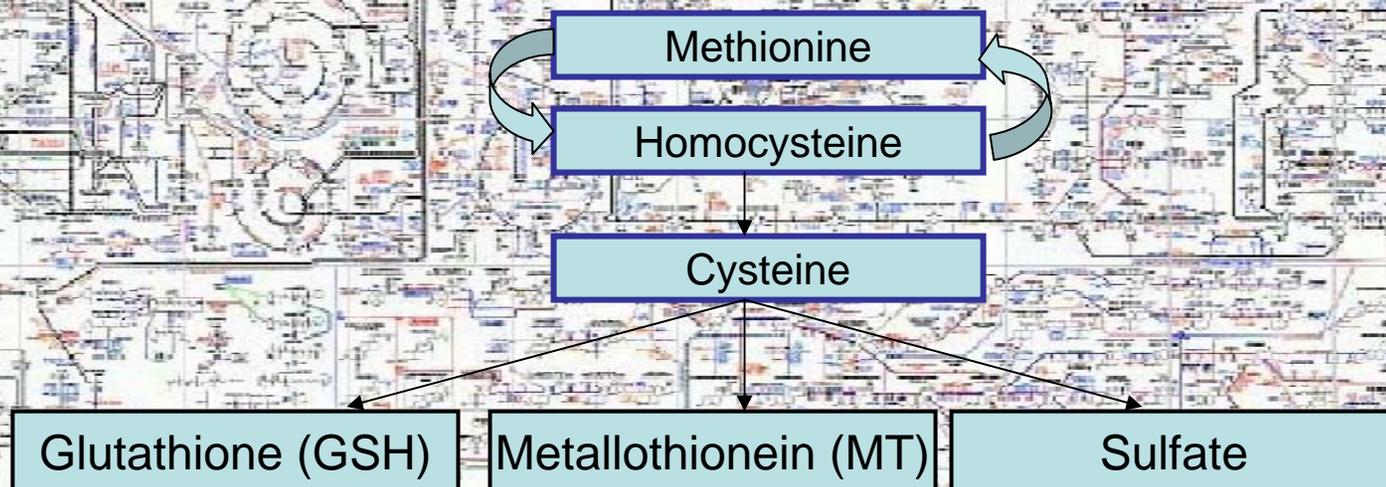
Good Areas: N. Puget Sound, Biscayne Bay

Bad Areas: NY/NJ Harbor, San Diego Bay, N. Chesapeake Bay, parts of Delaware Bay

Cellular Metabolic Pathways

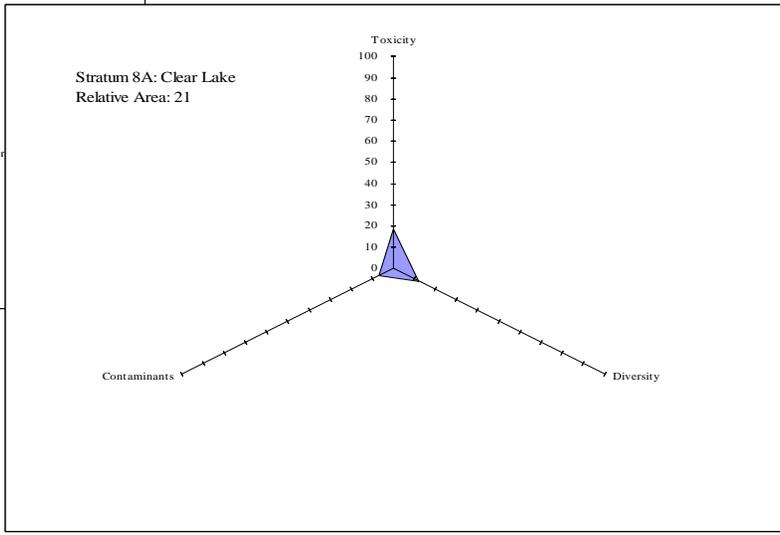
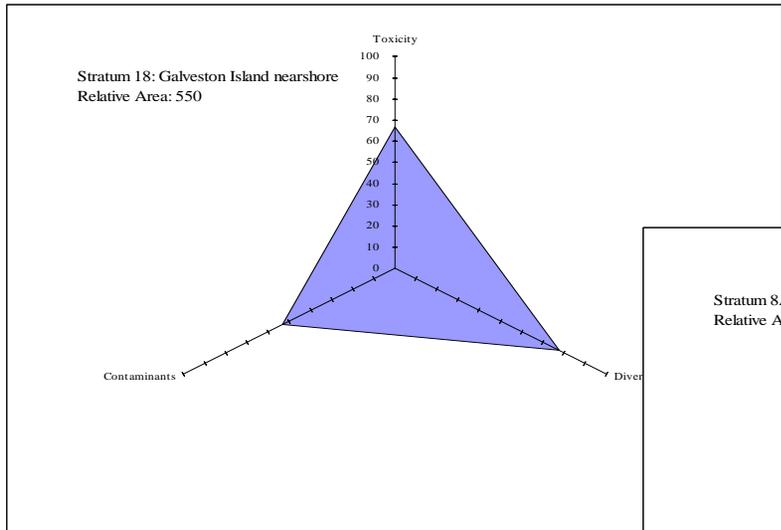
You Are Here

Methionine Transsulfuration Metabolism



From, James (2005)

Aggregated SQT values for two sampling strata in Galveston Bay. Note the relative sizes and numerical values of the two strata (550 and 21) (Hameedi, 2004; Hartwell and Hameedi, 2007)



Environmental Sustainability Index

- ◆ Consistent methodology
- ◆ Disparate data sets; missing information
 - 76 variables
 - 21 indicators, grouped into 5 components
- ◆ Numerical values to derive ESI score for each country

Assuring Efficacy of Indicators

- ◆ Few in number; too many result in a lack of focus and minimize their usefulness
 - *Include something that is newsworthy and perceptible in political circles*
- ◆ Chosen on the basis of some desirable features, e.g., SMART
- ◆ Based on tacit agreement for their use
- ◆ Effective when used within a framework that includes broad societal interests
- ◆ Vague and largely introspective indicators will be ineffective!

Filters or Criteria for Selection: SMART Indicators (Hameedi, 2005)

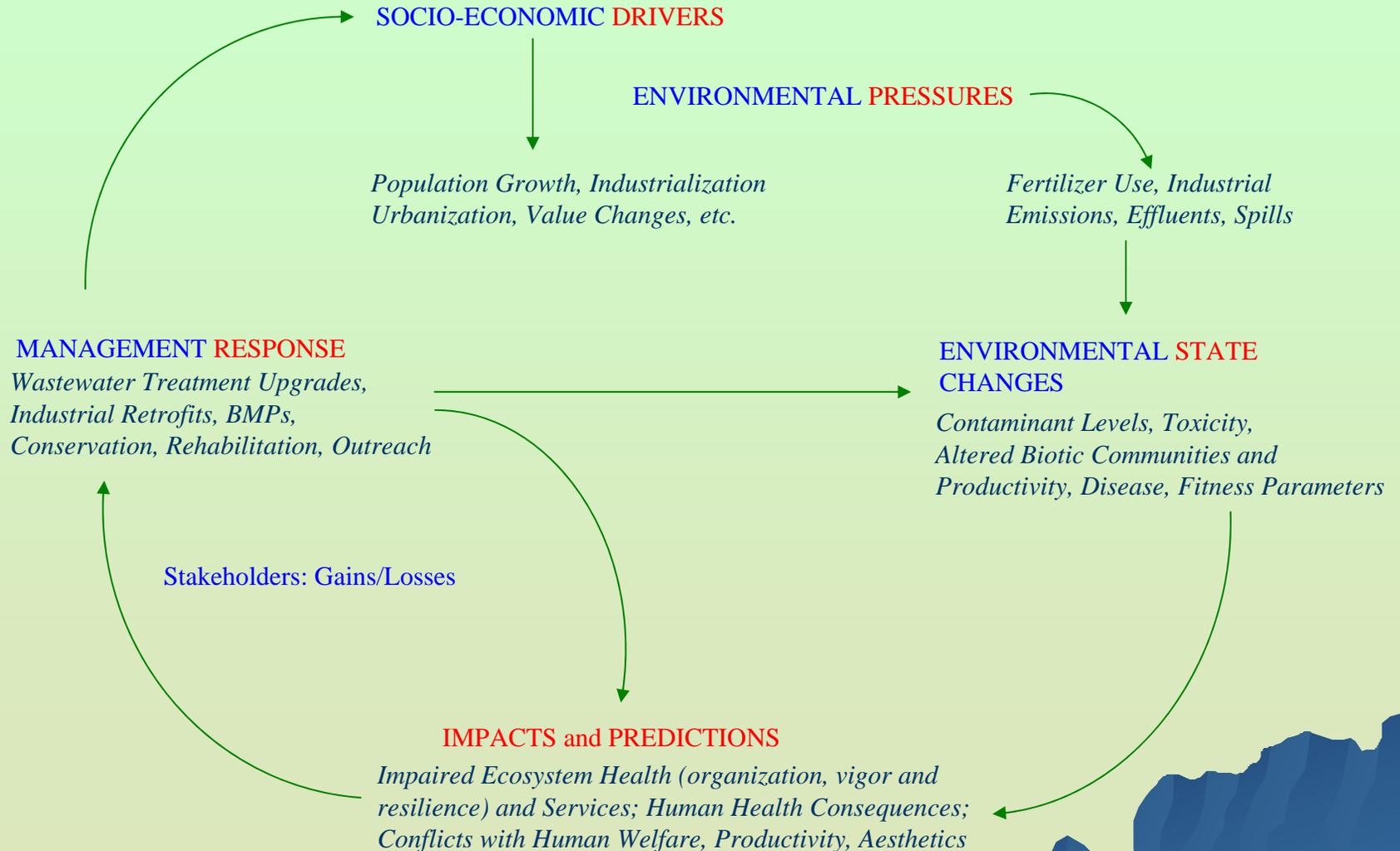
- ◆ **S**pecific (with a clearly stated objective)
- ◆ **M**easurable (both in time and quantity)
- ◆ **A**chievable (within available resources and intellectual capital)
- ◆ **R**elevant (to elucidate the issue at hand)
- ◆ **T**rackable (amenable to evaluation and determining progress)

Environmental Indicators Frameworks

- ◆ Pressure-State-Impact-Response Framework (Hameedi, 1997; Turner, et al., 1999; Hameedi, 2005)
- ◆ Objective-Input-Output-Outcome-Impact Framework (Segnestam, 1999)
- ◆ Four Orders of Outcome (Olsen, 2003)
 - Enabling conditions
 - Change in behavior
 - The "harvest"
 - End outcome: Sustainable Coastal Development
- ◆ Integrative models of ecological and socio-economic indicators (Russell, 1995; Turner, et al., 1999)

Framework and a Common Platform

DPSIR Framework (Hameedi, 2002; modified from Turner, et al., 1998)



PSIR Framework (PSR, PSIR, DPSIR)

- ◆ Simple
- ◆ Intuitive
- ◆ Adaptable and iterative
- ◆ Transparent
- ◆ Broad societal [biophysical and socio-economic] considerations
- ◆ Showcase the environment and environmental goals

Coming back to square 1?

US Comptroller General (at OECD in June 2004; at NAS in Sep 2007)

- Policy makers lack the information needed to understand the potential impacts of their decisions and the economic implications of changes to the environment
- Need to develop an “indicator system” at the national level to inform society on key changes in societal, economic and environmental conditions (“Informing Democracy”)
- ◆ Indicators can be a powerful driving force for environmental decision-making; poor indicators can be a basis for bad decisions

National Academy of Public Administration, October 2007

- ◆ Undertake an intensive pilot to select *cross-cutting indicators* for an issue that is nationally significant, multi-agency in scope, and of immediate interest to state and local governments and the private sector.
- ◆ Agencies should provide strong support for senior staff to play leading roles in advancing progress.

A possible new, interagency effort?

- ◆ A pilot project on national status and trends indicators of water availability, in collaboration with non-Federal partners
 - Water quantity
 - Water Availability
 - Water Quality
- ◆ Part of an effort for developing a set of National Environmental Status and Trends (NEST) indicators [previously known as “Principal Indicators for the Nation’s Environment (PINE)"]

A large, dark, textured fish, possibly a shark or a similar predator, is shown from a top-down perspective. Its mouth is wide open, revealing several sharp, pointed teeth. The fish's skin is covered in a complex, almost crystalline or fibrous pattern. It is resting on a bright blue, textured surface, which could be a tarp or a piece of fabric. The background is slightly out of focus, showing more of the blue surface and some reddish-brown material.

Now, do you have any questions?