New Jersey Monitoring Coordinating Council

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Efficacy of Estuarine Indicators

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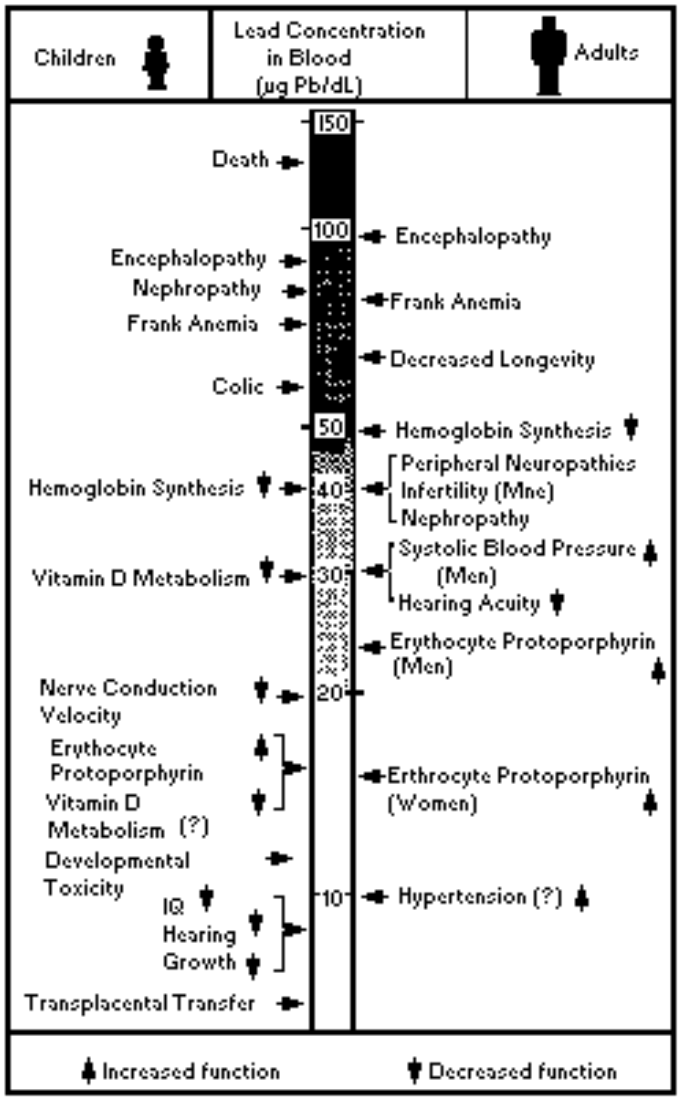
Effect of inorganic lead in children and adults: lowest observable adverse effects levels

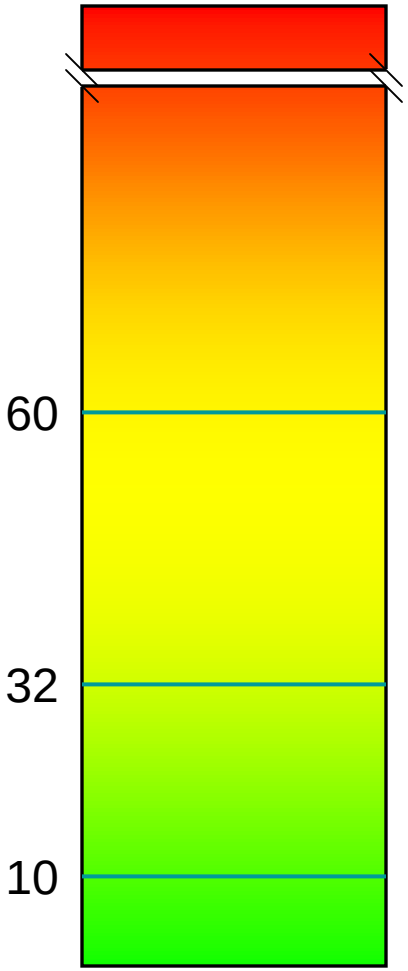
- *Level of concern: 10 μg/dL in blood (it does not mean intervention)*
- *Adverse but non-symptomatic effects at 4 μg/dL (current limit for accurate lead measurements); there is no "safe level" for children*
- *In the US, 20% of black children (living in old homes) had elevated blood levels, > 10 μg/dL (1997 data, CDC)*



Adapted from ATSDR, Toxicological Profile for Lead (1988)

HRGS Biomarker

(Anderson, et al., 2005)



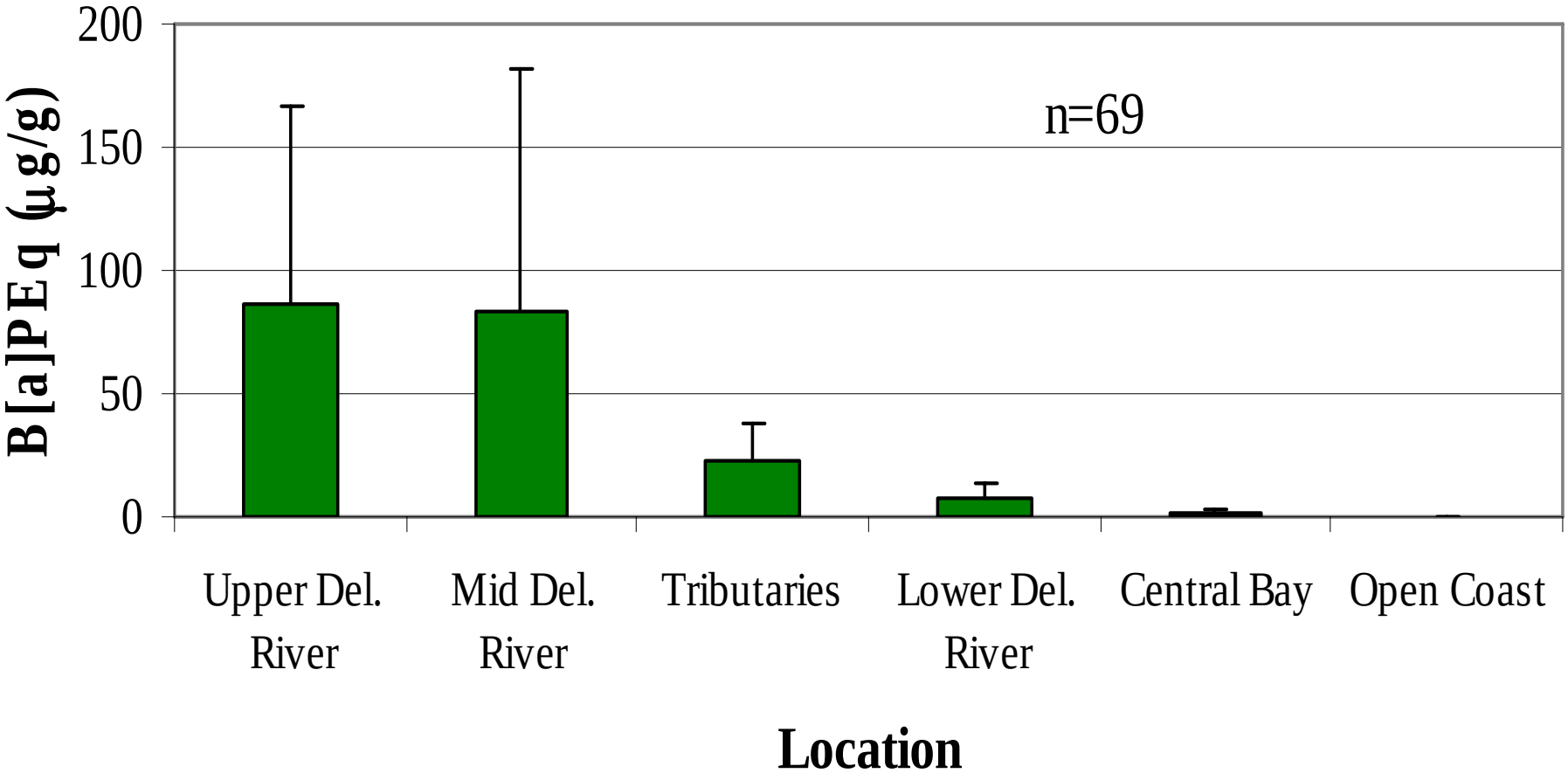
Responds to the presence of certain PAHs, planar PCBs, dioxins and furans

CCMA has data from 19 estuaries (over 1300 samples)

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

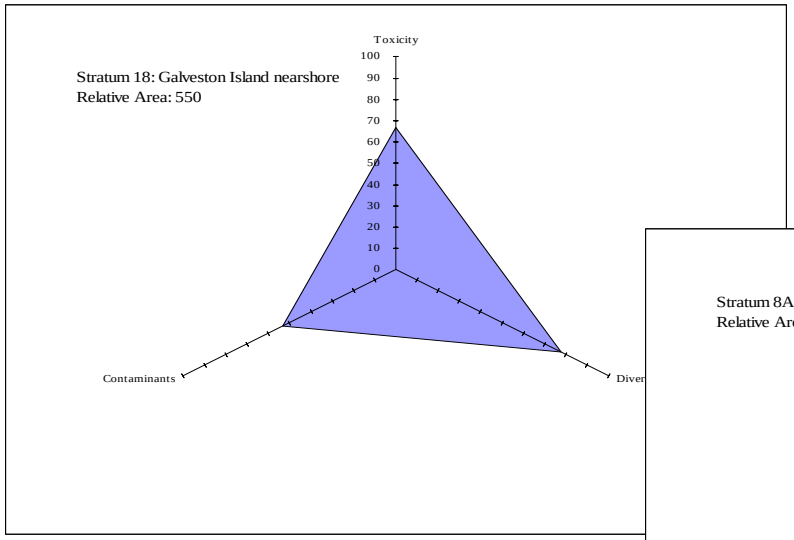
- Good Areas: N. Puget Sound, Biscayne Bay
- Bad Areas: NY/NJ Harbor, San Diego Bay, N. Chesapeake Bay

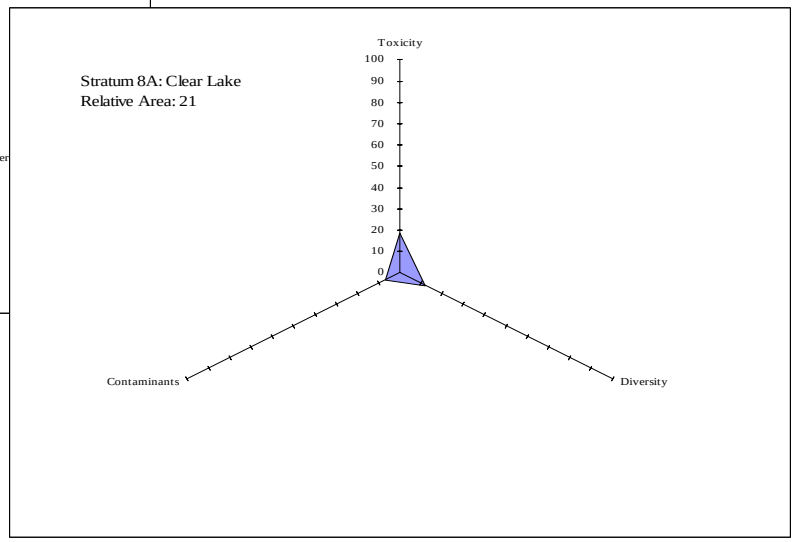
Mean B[a]P Equivalents of Sediments from Delaware River and Bay (highest and lowest values within each grouping removed)



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; Hameedi and Pait, in prep.)





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.

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

Indicators

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

- Ecosystem indicators … gauge “production, diversity, and variability” of ecosystems [fisheries management context]
- They should have the capacity to predict or document the results of management actions

Murawski (2000)

Other definitions of environmental indicators

- A parameter or an value derived from parameters that describes the state of the environment and its impact on human beings, ecosystems and materials, the pressures on the environment, the driving forces and the responses steering that system [an indicator has gone through a selection and/or aggregation process to enable it to steer action] – OECD/EEA
- Environmental indicator is a sign that relays complex message, potentially from numerous sources, in a simplified and useful manner (EPA)

Use of environmental indicators

- Indicators provide “unique public good” by bringing together diverse sources of information for benefit of a variety of audiences, and may also be linked to performance (GAO, 2005)

“How do we know that the minister has kept his promise?”

Indicators as assessment tools

- National Coastal Condition Report II
- Heinz Center Report “State of the Nation’s Ecosystems
  - ERL-ERM guidelines
  - Dissolved oxygen levels
  - Nitrate-N levels
  - Chlorophyll levels
  - Coastal armoring
  - Etc.
- Controversial

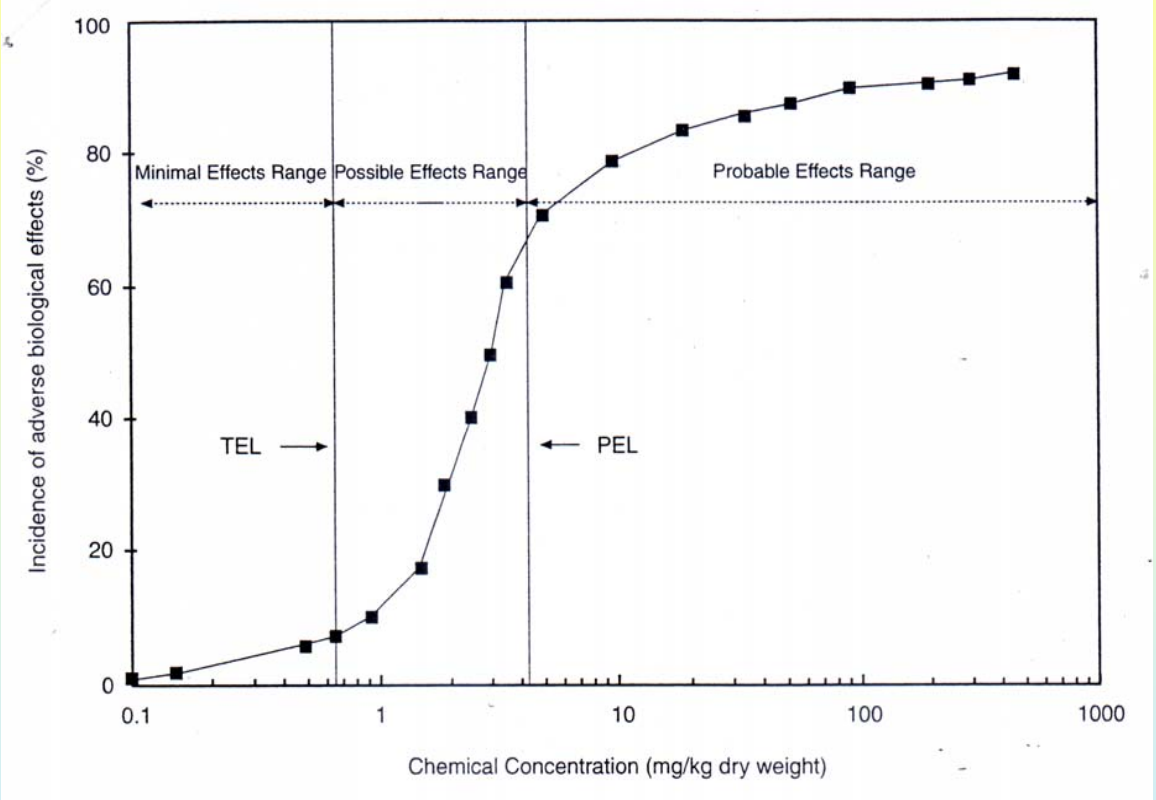
Dissolved Oxygen Levels – Open Coastal Waters

- Oxic (more than 1.5 mL/L)
- Sub-oxic (0.3 to 1.5 mL/L)
- Dysoxic (0.1 to 0.3 mL/L)
- Anoxic (less than 0.1 ml/L)

Notes:

- 1.5 mL/L is approximately equal to 2 mg/L
- In medicine, oxygen level below 90% saturation is termed hypoxic

Dose-Response Relationship – Logistics Curve



- ERL/TEL and ERM/PEL define thresholds (Long et al. 1995; Macdonald, et al 1996)
- Logistics curve defines probabilities of effect at a given concentration (Field, et al., 1999)

Environmental Indicators = Performance Measures

(Public Administration, Resource Management, GPRA, etc.)

- Suppose we spent $XX million to reduce over-enrichment of phosphate in the Everglades
  - Constructing 47,000 acres of synthetic wetlands (Stormwater Treatment Areas or STAs)
  - Assuring out flowing phosphate conc. of 50 ppb
- Then
- Was this target achieved? within a stated time-frame?? -- accomplishment
- What is its value? – communication

Information Pyramid

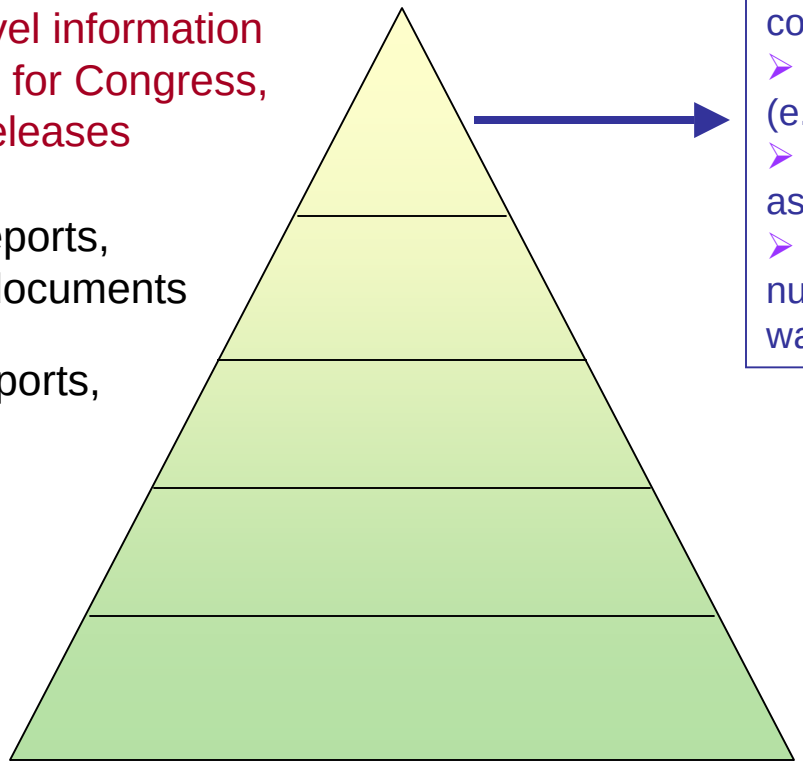
High level information suitable for Congress, press releases

Program reports, synthesis documents

Scientific Reports, publications

Summaries, graphics

Raw data and datsets



- Recision of a fish consumption advisory
- Forecasting capability (e.g., beach closure)
- New biomarkers to assure seafood safety
- Percent reduction in the number of impaired waterbodies

Environmental Indicators: obvious and demonstrated uses

- Defining the problem
- Ranking of Locations
- Trend Analysis
- Resource Allocation
- Scientific Research
- Risk Analysis
- Solutions

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

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

Impaired Reproduction

Gonadotropins
Steroids (plasma estradiol, testosterone)
Vitellogenin

Impaired Immune System

Hemocyte numbers and types
Killing index / phagocytic index
Serum lysozymes

Wellness and Condition

Darwinian "fitness parameters"
Atrophied organs and connective tissue
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
- Performance indicators established
- 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 plans for industrial effluents and emissions
- Emergency response plans
- More collaborative and transparent resource management

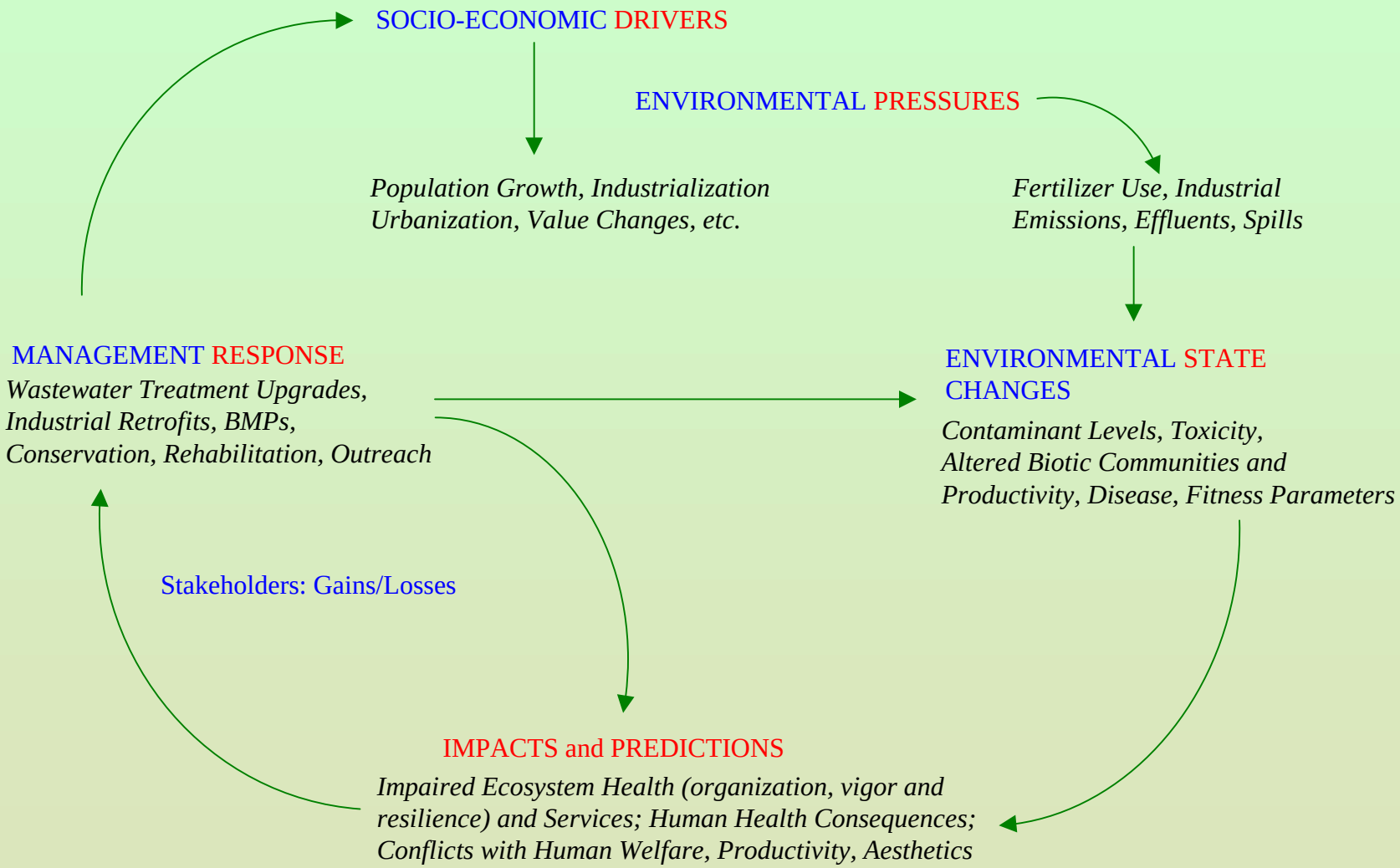
- Lots and lots of them!
- Strewn like bricks in a brickyard!!
- There is little in terms of a foundation for a temple of science.

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

ISSUES AND IMPEDIMENTS

- Most environmental indicators are designed as management tools; not necessarily ecological acumen
- Uncertainty about the spatial bounds for which an indicator is relevant
- Lack of transparency in the sensitivity of individual parameters that make up an index; often there is a need for disaggregation of parameters for more detailed examination. Resistance is based on disciplinary outlooks.
- Indices provide little or no information about cause-effect relationship without further testing

ISSUES AND IMPEDIMENTS (contd.)

5. Widening divide between mathematical and statistical approaches:
   - Mathematical approach is to devise dynamic models (set of differential equations, for example) based on reasonable postulates and abstractions. They run the risk of constructing interesting models divorced from reality
   - Statisticians prefer to take the world as they find it but data become enormous in volume and detail. They run the risk of providing clear answers to ecologically trivial questions
6. Unrealistic expectations regarding their use in coastal resource decision-making:
   - Scientists and analysts: we are not listened to and our research is not used
   - Policymakers: we do not get what we need and we do not hear what we want to listen to

What is ecosystem health?

ECOSYSTEM HEALTH is the "condition when a system's inherent potential is realized, its condition is stable, its capacity for self repair, when perturbed, is preserved, and minimal external support for management is needed" (Karr, et al., 1986)

Biological Integrity

BIOLOGICAL INTEGRITY implies "a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region." (Karr, 1991)

Ecosystem Health is sometimes defined by three parameters: Vigor (e.g., GPP, NPP, Metabolism), organization (e.g., Diversity, Average Mutual Information), and Resilience (e.g., population recovery time)

RESILIENCE

A measure of how fast the system returns toward its equilibrium following a perturbation. It has units of time; characteristic return time is taken for a perturbation to 1/e (ca. 37%) of initial value. Obviously, resilience is not defined for unstable systems.

- ***Healthy Ecosystem*** *(Costanza and Mageau, 1999):* An ecological system is healthy and free from "distress syndrome" if it is stable and sustainable – that is, if it is active and maintains its organization and autonomy over time and is resilient to stress

- ***Ecosystem Distress Syndrome*** *(Rapport, 1992):* Refers to the irreversible process of system breakdown leading to the termination of the system before its normal life span. To be healthy and sustainable, a system must maintain its metabolic activity level (vigor) and its internal structure (organization).

Ecosystem Health
Australia and New Zealand Environment and Conservation Council (ANZECC)

- Ecosystem Health is that:
  - Key processes operate to maintain stable and sustainable ecosystems;
  - Zones of anthropogenic impacts do not deteriorate ; and
  - Critical habitats remain intact.

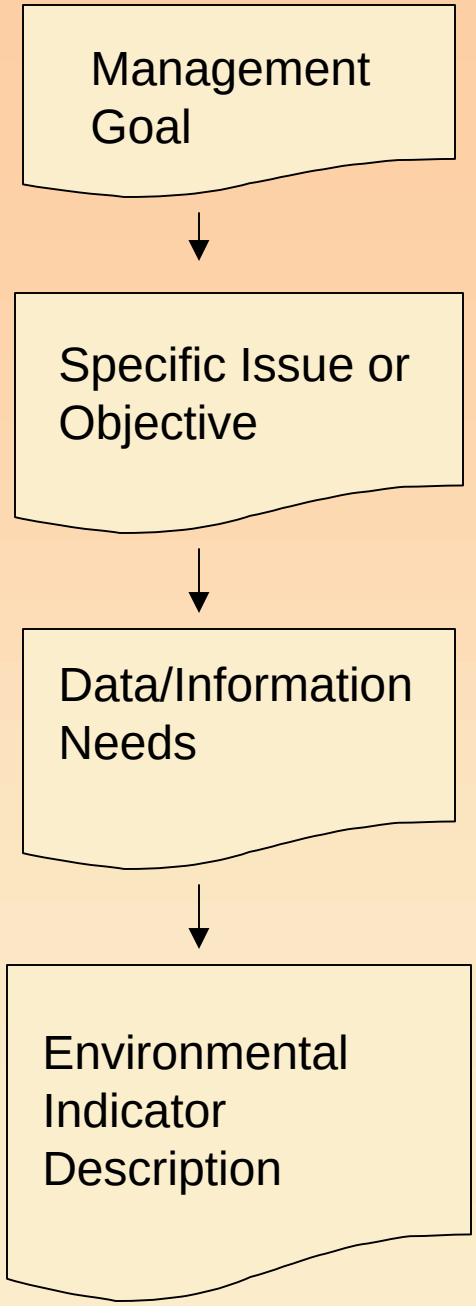
Subjective terminology
Chesapeake Bay Program

The entire system must be "balanced, healthy and productive"

- Balanced: sufficient population of prey species … apex predators … limit over-abundance
- Healthy: Diverse populations that fluctuate within acceptable bounds … free from impacts of toxics, parasites and pathogens … sufficient habitats
- Productive: sufficient production to serve human needs … functional balance is no disrupted

Glenn Suter – critiquing ecosystem health or integrity indices, such as the IBI and Benthic Index (Suter, 1993)

- Indices ... are justified on the basis of field studies rather than any theory of ecosystem health or any societal or ecological value of the index or its components. *That is, an ecosystem's health is bad because the index is low, and a low index value indicates bad health because the index is low for unhealthy ecosystems*.
- Now, that's tautology. It is like saying, either it will rain tomorrow or it will not rain tomorrow! You can't be wrong.



- Indicator name
- Descriptor
- Scientific basis, relevance
- Strengths and weaknesses
- Reliability, range and robustness
- Research needs
- Linked documents
- Metadata:
  - Data sources and sites
  - Methodology and sampling frequency
  - Geographical coverage
  - Temporal coverage
  - Data reduction and products

It is the mark of an educated man to look for precision in each class of things just so far as the nature of the subject admits .....

Our discussion will be adequate if it has as much clearness as the subject matter admits of; for precision is not to be sought for alike in all discussions.

Aristotle
(384-322 B.C.)