What’s The Score?  
Considerations for Developing Metrics and Indices  

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Got Data? Cool Tools for Effective Data Management

Friday, November 16th, 2007
EPA New England Regional Laboratory
11 Technology Drive, North Chelmsford, MA

* In particular: Jerry Schoen, Sue Flint, Tony Williams
A few definitions…

**Environmental Parameter**
- defining characteristic
- a measurement
- a test

**Examples?**
- Temperature, pH, dissolved oxygen, nitrogen, phosphorus

**Indicator**
- measurable feature that provides *useful* evidence of system quality
- a sign, symptom or index of …
- provides evidence of something else
- Something used to show visually the condition of a system

**Examples?**
- Housing starts, fecal coliform, percent impervious surface
Useful bacterial indicators

- Present whenever intestinal pathogens are present
- Alive longer than the hardiest intestinal pathogen
- Found in a warm-blooded animal’s intestines
- Analyzed with an easy testing method
- Directly correlated with the degree of fecal contamination
- Useful in fresh and marine waters

A few more definitions…

Metric
- a standard of measurement
- a measure of (a biological) attribute.
- an attribute with empirical change in value along a gradient of human disturbance.
- data analysis summary

Examples?

<table>
<thead>
<tr>
<th>Biological</th>
<th>Chemical</th>
<th>Physical</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPT</td>
<td>pH</td>
<td>(river) channel length, sinuosity</td>
</tr>
<tr>
<td>% Sensitive Diatoms</td>
<td>Temperature</td>
<td>(land use type) area, density</td>
</tr>
<tr>
<td>plant/animal condition</td>
<td>DO ppm or %Sat</td>
<td></td>
</tr>
</tbody>
</table>
(Water Quality) Index

- An aggregated number used to judge condition (e.g. IBI, RBP, TSI, GDP)

- A summary of large amounts of information
  - simple terms (e.g., good, fair, poor)
  - consistent
  - easily understood by your audience (and you): consider the 3 P’s

  - Public,
  - Policy makers,
  - Politicians
Advantages of an index

- Represent a number of variables in a single number,
- Combine various measurements in different measurement units in a single metric
- Convey relative differences in water quality between sites (or at one site) over time
- Effective as a communication tool.
Disadvantages

- Not always easy to understand its basis
- Effect of missing parameters
- Components & weighting can be judgmental

Talberth, Cobb and Slattery. The Genuine Progress Indicator 2006
## Air Quality Index (AQI)

<table>
<thead>
<tr>
<th>Air Quality Index Levels of Health Concern</th>
<th>Numerical Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Good</strong></td>
<td>0-50</td>
<td>Air quality is considered satisfactory, and air pollution poses little or no risk.</td>
</tr>
<tr>
<td><strong>Moderate</strong></td>
<td>51-100</td>
<td>Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.</td>
</tr>
<tr>
<td><strong>Unhealthy for Sensitive Groups</strong></td>
<td>101-150</td>
<td>Members of sensitive groups may experience health effects. The general public is not likely to be affected.</td>
</tr>
<tr>
<td><strong>Unhealthy</strong></td>
<td>151-200</td>
<td>Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.</td>
</tr>
<tr>
<td><strong>Very Unhealthy</strong></td>
<td>201-300</td>
<td>Health alert: everyone may experience more serious health effects.</td>
</tr>
<tr>
<td><strong>Hazardous</strong></td>
<td>&gt;300</td>
<td>Health warnings of emergency conditions. The entire population is more likely to be affected.</td>
</tr>
</tbody>
</table>

http://airnow.gov/index.cfm?action=static.aqi
AQI caveats:

How AQI Calculated:
Daily concentrations of major pollutants at many locations
  - ground-level ozone
  - particle pollution
  - carbon monoxide
  - sulfur dioxide
  - nitrogen dioxide

Formula used to convert raw values into numeric scale.
  100 ~ air quality standard for that pollutant

Highest – rated pollutant becomes AQI for that day.
  E.g. ozone = 90, Sulfur dioxide = 68; AQI = 90.

Problems. If you are
  • Sensitive to one type of pollution.
  • need to know where pollution types are coming from
Trophic State Indices

Attempt to provide a single quantitative index for the **purpose of classifying and ranking lakes, from standpoint of nutrient influence on water quality**.

Carlson TSI useful for
- comparing lakes within a region
- assessing changes in trophic status over time.
  - Scale is 0 to 100
  - Higher values correspond to increased trophic state.
  - 10 unit increase = halving of Secchi depth & doubling of P concentration.
Carlson’s Trophic State Index

Phosphorus, Nitrogen → Algae → Water Clarity

Oligotrophic Mesotrophic Eutrophic

Important to emphasize the continuum not compartmentalize

The Great North American Secchi Dip-in
http://dipin.kent.edu/index.htm
Carlson TSI Formulae:

TSI = 9.81 Ln Chlorophyll a (ug/L) + 30.6
TSI = 14.42 Ln Total phosphorus (ug/L) + 4.15
TSI = 60 - 14.41 Ln Secchi disk (meters)

Because these are interrelated by linear regression models, any one of the variables can be used to derive a TSI score.

- CHL>TP>Secchi
- For northern temperate lakes
- Lakes with few rooted aquatic plants
- Little non-algal turbidity

Does trophic state = water quality?

NO! Trophic state is based on an absolute scale, water quality describes a condition in relation to (human) needs and values

The Great North American Secchi Dip-in
http://dipin.kent.edu/index.htm
A list of possible changes that might be expected in a north temperate lake as the amount of algae changes along the trophic state gradient.

<table>
<thead>
<tr>
<th>TSI</th>
<th>Chl (ug/L)</th>
<th>SD (m)</th>
<th>TP (ug/L)</th>
<th>Attributes</th>
<th>Water Supply</th>
<th>Fisheries &amp; Recreation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;30</td>
<td>&lt;0.95</td>
<td>&gt;8</td>
<td>&lt;6</td>
<td><strong>Oligotrophy:</strong> Clear water, oxygen throughout the year in the hypolimnion</td>
<td>Water may be suitable for an unfiltered water supply.</td>
<td>Salmonid fisheries dominate</td>
</tr>
<tr>
<td>30-40</td>
<td>0.95-2.6</td>
<td>8-4</td>
<td>6-12</td>
<td>Hypolimnia of shallower lakes may become anoxic</td>
<td></td>
<td>Salmonid fisheries in deep lakes only</td>
</tr>
<tr>
<td>40-50</td>
<td>2.6-7.3</td>
<td>4-2</td>
<td>12-24</td>
<td><strong>Mesotrophy:</strong> Water moderately clear; increasing probability of hypolimnent anoxia during summer</td>
<td>Iron, manganese, taste, and odor problems worsen. Raw water turbidity requires filtration.</td>
<td>Hypolimnent anoxia results in loss of salmonids. Walleye may predominate</td>
</tr>
<tr>
<td>50-60</td>
<td>7.3-20</td>
<td>2-1</td>
<td>24-48</td>
<td><strong>Eutrophy:</strong> Anoxic hypolimnina, macrophyte problems possible</td>
<td></td>
<td>Warm-water fisheries only. Bass may dominate.</td>
</tr>
<tr>
<td>60-70</td>
<td>20-56</td>
<td>0.5-1</td>
<td>48-96</td>
<td>Blue-green algae dominate, algal scums and macrophyte problems</td>
<td>Episodes of severe taste and odor possible.</td>
<td>Nuisance macrophytes, algal scums, and low transparency may discourage swimming and boating.</td>
</tr>
<tr>
<td>70-80</td>
<td>56-155</td>
<td>0.25-0.5</td>
<td>96-192</td>
<td><strong>Hypereutrophy:</strong> (light limited productivity). Dense algae and macrophytes</td>
<td></td>
<td>Rough fish dominate; summer fish kills possible</td>
</tr>
<tr>
<td>&gt;80</td>
<td>&gt;155</td>
<td>&lt;0.25</td>
<td>192-384</td>
<td>Algal scums, few macrophytes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Multimetric Indices (IBI, RBP)

- integrate several biological metrics to indicate condition.
- designed to be sensitive to a range of physical, chemical, and biological stressors.
- are relatively easy to measure and interpret.

Indices - Multimetric approach

Each metric is given a rating according to whether its value

- approximates,
- deviates *somewhat* from, or
- deviates *strongly* from

values measured in least-disturbed ecosystems of a particular type within a region.

These ratings (e.g., excellent, moderate, fair, and poor) can be used to make decisions about how well aquatic life is being supported by the water body.
To make multimetric biological indexes effective you must:

- **Classify environments** to define homogeneous sets within or across ecoregions (e.g., streams, lakes, or wetlands; large or small streams; warm-water or cold-water lakes; high- or low-gradient streams).
- **Select measurable attributes** that provide **reliable and relevant signals** about the biological effects of human activities.
- **Develop sampling protocols** and designs that ensure that those biological attributes are measured accurately and precisely.
- Devise analytical procedures to **extract and understand relevant patterns** in those data.
- **Communicate the results** to citizens and policymakers so that all concerned communities can contribute to environmental policy.

Multimetric Indices to Prepare and Analyze Data
http://www.epa.gov/bioindicators/html/multimetric.html
Selecting/Creating metrics and indices

Good Metrics:
- Sensitive to change
- Predictable, consistent

Metrics vary in their scale--they can be:
- integers
- percentages
- dimensionless numbers
- qualitative observations (e.g. grassland vs. forest).

Translation into unitless scores must address this.

Standardization assumes that each metric
- has the same value and importance (i.e., they are weighted the same), and that
- a 50% change in one metric is of equal value to assessment as a 50% change in another.
Lessons from the European Union*

Presenting Water Quality Data ... the usual way

- **Annual WQ reports**
  - *Text, graphs, tables*
  - *Executive summaries containing demands and/or recommendations*

- **Shift observed in target group’s WQ background**
  - From directors knowledgeable about water quality
  - Appointed executives

Dr Peter G Stoks, RIWA/IAWR, stoks@riwa.org
2007 Enhancing the States’ Lake Management Programs
2006 NWQMC San Jose’ CA
Management is not too bright...

...and has the attention span of a hamster
Lessons from the European Union

**Compliance**
- above standard
- 0.8-1.0 of standard
- below 0.8 of standard

**Trend**
- uptrend
- downtrend
- no trend or not detectable

**Quantity**
- \( n \geq 20 \)
- \( 20 > n \geq 10 \)
- \( n < 10 \)

Dr Peter G Stoks
Assn of Rhine Water Works
RIWA/IAWR
stoks@riwa.org
What it looks like

Ammonia in the Rhine 1972 – 2004
Assabet River in Aug:
Green but flowing

Nashoba Bk. in Aug:
Cleaner but flow-stressed (1.0 cfs)
StreamWatch Project

- Evaluate streamflow, water quality, and habitat availability.
- Communicate timely, accurate data.
- Raise awareness of the need to protect in-stream flows.
# Reporting Ranges

<table>
<thead>
<tr>
<th>Index Score Ranges</th>
<th>Range Description</th>
<th>Stream Health Index Graphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>81-100</td>
<td>Excellent (optimal conditions)</td>
<td></td>
</tr>
<tr>
<td>61-80</td>
<td>Good (some effects observed)</td>
<td></td>
</tr>
<tr>
<td>41-60</td>
<td>Fair (light habitat impairment)</td>
<td></td>
</tr>
<tr>
<td>21-40</td>
<td>Poor (moderate habitat impairment)</td>
<td></td>
</tr>
<tr>
<td>1-20</td>
<td>Very Poor (severe habitat impairment)</td>
<td></td>
</tr>
</tbody>
</table>
### Danforth Brook Index Readings - Summer 2007

#### for the week ending

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WQ</strong></td>
<td>100</td>
<td>93</td>
<td>93</td>
<td>93</td>
<td>93</td>
<td>80</td>
<td>73</td>
<td>73</td>
<td>nr</td>
<td>nr</td>
<td>63</td>
<td>63</td>
<td>63</td>
<td>63</td>
<td>63</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td><strong>Flow</strong></td>
<td>100</td>
<td>96</td>
<td>82</td>
<td>81</td>
<td>34</td>
<td>51</td>
<td>39</td>
<td>38</td>
<td>nr</td>
<td>nr</td>
<td>10</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>10</td>
<td>17</td>
<td>9</td>
</tr>
<tr>
<td><strong>Habitat</strong></td>
<td>100</td>
<td>85</td>
<td>65</td>
<td>65</td>
<td>40</td>
<td>70</td>
<td>50</td>
<td>50</td>
<td>nr</td>
<td>nr</td>
<td>20</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>35</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td><strong>Stream Health</strong></td>
<td>100</td>
<td>91</td>
<td>78</td>
<td>78</td>
<td>46</td>
<td>65</td>
<td>50</td>
<td>50</td>
<td>nr</td>
<td>nr</td>
<td>18</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>29</td>
<td>13</td>
<td>9</td>
</tr>
</tbody>
</table>
Upstream 4.99 cfs
Upstream: 0.04 cfs
simple, short, educational...

The Buzzards Bay Health Index

Good to Excellent (65-100)
Fair (35-65)
Poor/Eutrophic Conditions (<35)

The Bay Health Index measures the relative health of each of Buzzards Bay’s major harbors and coves. It does not include bacteria monitoring and is not an index of swimmability or shellfish bed status.

The Index is calculated from scores of mean summertime water clarity, phytoplankton pigments, organic nitrogen, inorganic nitrogen and the lowest 20% of dissolved oxygen concentrations. Central Buzzards Bay - which exhibits excellent water quality - would score close to 100 percent on the Index.

...show long-term ecological trends and as a method to improve the public and town elected officials understanding of local water quality
<table>
<thead>
<tr>
<th>Parameter</th>
<th>0 Point Value</th>
<th>100 Point Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest 20% Oxygen Saturation</td>
<td>40%</td>
<td>90%</td>
</tr>
<tr>
<td>Transparency (Secchi)</td>
<td>0.6 meter</td>
<td>3.0 meter</td>
</tr>
<tr>
<td>Chlorophyll</td>
<td>10.0 µg/L</td>
<td>3.0 µg/L</td>
</tr>
<tr>
<td>DIN</td>
<td>.14 ppm</td>
<td>.014 ppm</td>
</tr>
<tr>
<td>TON</td>
<td>.6 ppm</td>
<td>.28 ppm</td>
</tr>
</tbody>
</table>
Maps, index color, pictures, text.

Poor Water Quality = Loss of eelgrass, fish habitat, species diversity.
Buzzaards Bay’s health declines

Nitrogen pollution from land development cited as major reason in environmental report

By JEFF W. VANDAL

The Coalition for Buzzards Bay — in its annual report released today — says nitrogen pollution from land development is the major factor affecting Buzzards Bay’s health.

The report, titled "State of the Bay 2010," is released annually by the Coalition for Buzzards Bay, a nonprofit environmental organization that works to protect the bay.

The report found that nitrogen pollution, which comes from sources such as sewage treatment plants and agricultural runoff, is responsible for 80 percent of the bay’s nitrogen load. This is up from 70 percent in 2009.

The report also found that the bay’s water quality has improved in recent years, with fewer areas classified as "worse than normal." However, the overall health of the bay remains "good to excellent."
Presenting Indices

Know your target audience
- Expertise level
- Particular interest

Know your objectives
- Personal: resource use
- Education
- Resource management/regulation
  - Where to target resources
  - Impaired waters designation
  - TMDL development
  - Etc.
A few general rules…

- The overall “score” is valuable,
- but make supporting detailed information accessible.
- Print score/color on web site home page, familiar icon/box (like weather info)
- Provide clickable links to more detailed information.
Create your own indices!

Jerry Schoen’s examples.

- **Trout comfort zone** (Combine DO, temperature, volume of lake containing suitable values. … add duration/frequency of excursions?)

- **Boating recreation index** (Number of days when water levels, water quality, weather, etc. (absence of duckweed on lake surface, open channels) combine for “pleasant” boating experiences… add economic impact?)

- **Fishing recreation index** (Similar to boating - # of days when water levels, bug hatches, etc. afford quality fishing)

- **Beach closure days** (see fishing, boating above… for added economic impact, consider extra weight for scores on holiday / high traffic periods).

- **Water clarity / home value index** (Combine Secchi disk data with real estate prices).
Thanks!
Hope this is becoming more clear!