Reference Condition: Science and Regulatory Context

Stoddard et al. (2006)

- “... the primary focus of biological assessment is an evaluation of the effect of human activity ...”
- Requires the estimation of biological status in the “the absence of human disturbance”
- “Reference condition” – broadly used to describe “the state used to gauge the effects of human activity”
- Paper arises from “many hours of confusing discussion and dialogue on the topic among scientists, managers, and government regulators” (!!!)
Legislative Mandates-

UNITED STATES: Clean Water Act of 1972

• “restore and maintain the chemical, physical and biological integrity of [the] Nation’s waters”
  – “Naturalness is a key part of biological integrity were redundant”
  – Frey: “… community of organisms having a species composition, diversity, and functional organization as comparable as possible to that of undisturbed habitats within the region”
  – NRC (1992): “Restoration is defined as the return of an ecosystem to a close approximation of its condition prior to disturbance.”
From the U.S. House, Committee on Public Works (1972)

[Integrity] refers to a condition in which the natural structure and function of ecosystems is maintained. ...structure and function is “natural” ... [if] at levels believed to have existed before perturbations caused by man’s activities.

(Source: Dr. Paul Angermeier, Va. Tech Univ.)

• Preserve and restore the biodiversity of inland waters, wetland and coastal areas
• Need to gauge degradation and recovery and associate with human stressors
• “Reference” – no or minimal anthropogenic stress
• Develop stream “typologies” and reference sites are best localities within each typology to develop “ecological-quality” classes
Legislative Mandates-

AUSTRALIA: Water Reform Framework for Australia 2000

• Australia’s unique water resources being degraded

• “River health” is the ability of the aquatic ecosystem to support and maintain key ecological processes and a community of organisms with a species composition, diversity, and functional organisation as comparable as possible to that of undisturbed habitats within the region”
CHALLENGES

• Availability of sites that are “natural”, i.e., “pristine”
• “Natural” condition varies in
  – Space (site-to-site variability)
  – Time
    • Variation in species distribution and abundance
    • Environmental variation (interannual, decadal)
• We don’t know how much “reference” varies from “pristine” or “absence of human disturbance”
Reference Climate?

- Temperature

Holocene (last $10^4$ yr)

Average near-surface temperatures of the northern hemisphere during the past 11,000 years (after Dansgaard et al., 1969, and Schönwiese, 1995).

Last $10^2$ yr

+0.5°C
Runoff History

Colorado River at Lees Ferry, AZ

1922 – Colorado River Compact

Instrumental record

http://treeflow.info/upco/coloradoleesmeko.html
Applying Reference Condition

• Define “reference” based on key environmental (physical, chemical) drivers that regulate “biological integrity”. Don’t use biological species composition at sites to define reference.

• For a set of “reference” streams (i.e., minimally disturbed), each would have some biological index score. There is a distribution of index or indicator scores because there is natural variability among “similar” sites

• FIGURE 1
Fig. 1. The range of ecological condition (represented through a hypothetical biological index) found under reference conditions describes a distribution of values rather than an absolute value. The range of this distribution results from natural variability both in time and in space, and can be used to set criteria for assessing or defining classes of ecological condition.
Making “reference condition” practical, ... and consistent

• **RC(BI): Reference condition for biological integrity**
  – Term reserved for “naturalness” or “biological integrity” as per the Clean Water Act
  – Rarely observed in human-dominated landscapes

• **MDC: Minimally disturbed condition**
  – Absence of significant human disturbance
  – Best approximation of biological integrity
  – Baseline for MDC may change (climate change) but range of variation in MDC distribution should be stable and allow for long-term “reference” relative to current conditions.
Making “reference condition” practical, ... and consistent

• **HC: Historical condition**
  – Condition of streams at some point in their history
  – Need not be “natural”
    • Pre-intensive agriculture – distinguishes period of less intensive land use
    • Presettlement – allows for impact of indigenous peoples

• **LDC: Least disturbed condition**
  – Best available condition under contemporary landscape
  – Can vary over time (e.g., Central Valley in California, Corn Belt in midwestern U.S.)

• **BAC: Best attainable condition**
  – Expected ecological condition in LDC if BMPs are used
Regionalization

- Goal: Stratify landscape so that local site potential is expressed relative to regional context
  - E.g., steep forested streams versus low gradient plains streams
  - Recall litho-topographic and watershed hierarchical levels that se local “site potentials” (Beechie et al. 2010)
Types of regionalization

• Ecoregions?
  – Often used to stratify “normative” conditions
  – Terrestrial in focus
FIG. 2. The differing levels of human disturbance of the landscape in different ecological regions (or in different stream types or stream sizes) create a situation where the least-disturbed sites remaining in each region describe very different definitions of "reference condition." (The best attainable condition will never be better than the minimally disturbed condition or worse than the least disturbed condition but may be equivalent to either depending on the level of human disturbance in a region.) Here, Stream Group B is distinguished from Stream Group C in that the level of degradation is greater for C, and that a reasonable goal or "reference condition" for C might be a condition that does not presently exist, but could be achieved with reasonable management (illustrated as "best attainable"). In contrast, the condition at the least disturbed sites for Group B might be a reasonable goal or reference condition for these streams.
Regionalization

• Stream typologies

Temperature and Flow
(Seelbach et al. 1997)

Flow sources, geology, valley landform (Sneldor & Biggs 2000)
Regionalization

- Hydrological regime

Using criteria to define reference condition within a Region

- Environmental variables (drivers) used to define “minimally disturbed”
  - Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range of values in probability sample</th>
<th>Criterion for inclusion in LDC list</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid neutralizing capacity</td>
<td>-2000 to 5600 μeq/L</td>
<td>&gt;50 μeq/L</td>
</tr>
<tr>
<td>Sulfate</td>
<td>6 to 34000 μeq/L</td>
<td>&lt;400 μeq/L</td>
</tr>
<tr>
<td>Total P</td>
<td>0 to 700 μg/L</td>
<td>&lt;20 μg/L</td>
</tr>
<tr>
<td>Total N</td>
<td>45 to 22000 μg/L</td>
<td>&lt;750 μg/L</td>
</tr>
<tr>
<td>Chloride</td>
<td>7 to 20000 μeq/L</td>
<td>&lt;100 μeq/L</td>
</tr>
<tr>
<td>Rapid bioassessment habitat score</td>
<td>2 to 20</td>
<td>&gt;15</td>
</tr>
</tbody>
</table>
Statistical vs. Expert Judgment?

- Panel A – 500+ sites ‘randomly’ selected in mid-Atlantic
- Panel B – 31 sites ‘filtered’ by criteria in Table 1, and associated biological index scores
- Panel C – 31 (or less) sites ‘filtered’ by Best Professional Judgment and associated biological index scores
Reference-site approach

- Quantify the biological condition at a set of sites that are either minimally disturbed or least disturbed.
- Variety of different “metrics” of biological integrity.

Reference sites are near top of range.

Whittier et al. (1987)
Fig. 3. Two different approaches for establishing a regional reference-condition value for freshwaters. Reference-condition values can be selected from waters that are representative of the most pristine (or least disturbed) condition. If this goal is unrealistic, or if undisturbed water bodies no longer exist in the region, the reference-condition value can be selected from among the least disturbed and lowest-nutrient-concentration water bodies found in the region. Surveys of existing water quality from a broad range of water bodies are necessary in order to establish realistic water quality goals. (Figure modified from EPA 2000: Fig. 6.1.)
Fig. 1. Conceptual model of major driving forces that influence freshwater ecosystems.
Relations between Restoring Historic Flow Regime and Determinants of Ecological Integrity

<table>
<thead>
<tr>
<th>Energy Base</th>
<th>greater productivity, availability, diversity of foods</th>
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<tbody>
<tr>
<td>Water Quality</td>
<td>greater dissolved oxygen in river, floodplain</td>
</tr>
<tr>
<td></td>
<td>smaller nutrient loads in river</td>
</tr>
<tr>
<td>Habitat Quality</td>
<td>more extensive wetlands, floodplain</td>
</tr>
<tr>
<td></td>
<td>greater habitat diversity</td>
</tr>
<tr>
<td>Biotic Interactions</td>
<td>greater species diversity, community complexity</td>
</tr>
<tr>
<td></td>
<td>fewer local extinctions in river</td>
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</tbody>
</table>

Flow regime is critical in sustaining or restoring native biodiversity and ecosystem services

MISCONCEPTION
More diversity = More integrity

Biotic Integrity...???
INTEGRITY VS DIVERSITY

Heavily polluted stream

Pollution abatement

Increased species diversity

Greater biotic integrity
INTEGRITY VS DIVERSITY

Heavily polluted stream

- Pollution abatement

Naturally oligotrophic stream

- Nutrient enrichment

Increased species diversity

Greater biotic integrity

Reduced biotic integrity