Estuarine Indicator System for the Lower Columbia River and Estuary

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Abstract

The lower Columbia River and estuary is designated an "estuary of national significance" under Section 320 of the Clean Water Act, making it one of 28 National Estuary Programs. All NEPs are encouraged by the U.S. Environmental Protection Agency to develop and implement an estuary condition indicator system to guide status and trends monitoring, and regional partners are also interested in creating an indicator system for the lower Columbia. The overarching goal of the indicator system is to allow NEP partners to track ecosystem condition over time and to track the effectiveness of the implementation of actions listed within their Comprehensive Conservation and Management Plan (CCMP). Additionally, we feel an estuary condition index would enable monitoring and research results to be more easily translatable to the public, scientists and managers and garner support for long term data collection efforts. Finally, this effort overlaps well with features of Oregon and Washington salmon recovery efforts, including developing a monitoring strategy for the lower river.

The Estuary Partnership has been working with regional partners through the Science Work Group and a two-day workshop in April to begin developing the estuarine indicator system. Through these groups, we have developed goals, objectives, and focus questions that the indicator system will address. The U.S. EPA is collaborating with our effort by providing guidance on the use of their Biological Condition Gradient (BCG) framework as a basis for the indicator system. The BCG uses a conceptual model describing how a series of identified ecological attributes respond to a gradient of increasing stress, providing a context for the current condition of the lower river with respect to our management goals and its historical condition, whether the lower river is continuing to degrade or on a recovery trajectory.

Methods

Overview of BCG Framework

The Estuary Partnership, including the Science Work Group, is using U.S. EPA's BCG framework as a basis for the lower Columbia River estuary condition index. The BCG is based on a body of empirical science demonstrating that ecological response follows a predictable trajectory in response to generally increasing anthropogenic stress. The intent of the BCG is to use this trajectory to define a scientific framework for consistent bioassessment, meaningful goal-setting, and coordinated management decision-making. The intent of a BCG is to assist with the steps of:

1. Determining the environmental conditions that exist (assessment). The BCG defines an anchored consistent baseline of "minimally disturbed" and communicates current ecological condition relative to that baseline.
2. Deciding the environmental conditions that are desired (goal-setting). The BCG is a scientific framework that can be used with expert groups and stakeholders to set easily communicated environmental goals.
3. Planning for how to achieve these conditions (management). The BCG provides a scientific basis for planning, restoration, protection and monitoring by providing a common language and shared quantitative goals.
4. Communicating with stakeholders. When biological and stress information is presented in this framework, it is easier for the public to understand the status of the aquatic resources relative to the high-quality places that exist and those that have been lost.

The central components of the BCG framework are as follows:

1. One or more biological indicators are used to assess biological condition and ecological state.
2. The BCG defines up to six levels of biological responses to increasing stress (Figure 1), from the highest state of condition (least stress) to the lowest condition (most stress).
3. The highest level of condition is anchored in "as naturally occurs" or "minimally disturbed."
4. Expert best professional judgment is used to define the thresholds at each level.

The BCG framework applied in estuaries, such as Tampa Bay, FL have further refined the BCG by using a "Habitat Mosaic" approach. This approach assumes that productive estuaries in a undisturbed state are composed of a mosaic of living habitats, including submerged aquatic vegetation beds, emergent marshes, tidal forests, clam flats and benthic communities. The mosaic of habitats which most resembles the mosaic that would naturally occur in an estuary will provide the greatest benefit for the native communities of organisms that have evolved in that ecosystem over millennia. The "Habitat Mosaic" approach then incorporates the recognition that anthropogenic stress to an estuary leads to destruction of these living habitats, and recovery of the ecosystem will need to include protection or remaining intact habitats and restoration of those that have been lost relative to a historic period (Figure 2). Ecological priorities could include a "Restore the Historic Balance" of critical habitats in percent compositions of habitat mixes relative to an undisturbed historic benchmark, as well as to restore total acres of all living habitats, to the extent possible. The Tampa Bay Estuary Program (TBEP) has been working successfully with this concept for many years. We propose that this method can be used together with other approaches as an important component in the management of the lower Columbia River, and could provide many advantages by linking environmental goals to habitat structure and function metrics under the BCG framework.

Process for the lower Columbia River

The Estuary Partnership's Science Work Group (SWG) has established the following process for developing the estuary indicator system using the BCG framework and its application in Tampa Bay as an example:

1. Identify goal, objectives and assessment questions of interest to resource managers. (*Completed by SWG; March 27, 2012*)
2. Describe "minimally disturbed" lower Columbia River, identify ecosystem attributes for protection or restoration. (*Completed by April 4-5, 2012 workshop participants*)
3. Define the key ecological needs of attributes and quantifiable targets for ecosystem attributes (*Initiated by April 4-5, 2012 workshop participants; Continued work by Indicator Steering Committee and Focus Groups for Individual Attributes)*
4. Determine core indicators and metrics (*Initiated by April 4-5, 2012 workshop participants; Continued work by Indicator Steering Committee and Focus Groups for Individual Attributes*)
5. Determine population of interest (using Columbia River Estuary Ecosystem Classification) for each core indicator and minimum number of sites (*Future Work by SWG, Indicator Steering Committee*)
6. Determine what specifically we measure (metrics), frequency of sampling and sampling period (*Future Work by SWG, Indicator Steering Committee*)
7. Establish analysis methods, quality control and data management (*Future Work by SWG, Indicator Steering Committee*)
8. Match available funding and projects to list of core indicators (*Future Work by SWG, Indicator Steering Committee*)
    - Define roles and responsibilities for collection of individual metrics, quality control and data management
    - Incorporate results from other estuary RME into index as relevant
9. Develop decision support tools, incorporate targets and monitoring results into management activities of lower river (*Estuary Partnership staff, SWG, Indicator Steering Committee*)
10. Monitor and provide results, provide periodic updates to stakeholders (*Ecosystem Monitoring Program, AFEP research projects, other programs as applicable*)
11. Provide recommendations for diagnostic /BACI studies to better understand uncertainties, variability and reasons behind trends/results (*SWG, SRWG, CREC*)
12. Update to reflect new findings and emerging issues as necessary.

We hope to accomplish steps 1 through 8 in 2012, with step 3 being the key for developing long term management goals and undertaking subsequent steps. We accomplished key aspects of steps 2 through 4 at the April 4-5 , 2012 workshop, whereas developing quantifiable targets (step 3) will require detailed discussions and data analysis. We expect this to largely be accomplished through an overall Indicator Steering Committee and multiple focus groups. The results of this effort should provide focus to steps 4 and subsequent tasks.

Results

The SWG identified the program goal, objectives and assessment questions to be addressed by the estuarine indicator system. The questions are a composite of questions, related to status and trends monitoring and the estuary, that were previously identified in regional plans (i.e., Estuary Partnership, 1999a,b; Johnson et al., 2008; NMFS 2011a,b; NPCC 2011).

Program Goal: The goal of the Program is to track the status and trends of ecosystem condition to inform decisions for the purpose of conserving and restoring the lower Columbia River and estuary.

Program Objective: Use estuarine quality and condition index to track changes in LCRE; provide context for results of other RME efforts.

Focus Questions to be addressed by Estuarine Condition Index:

1. What is the biological integrity of the LCRE and is it improving or declining? Are Columbia River Basin ecosystems healthy?
2. What is juvenile salmon performance in the lower river, and is it improving or declining? What are the limiting factors and threats that affect the status of an ESU within the estuary and are they improving or declining?
3. What are the pollutants of concern, and are their concentrations increasing or decreasing? Are pollutant levels increasing or decreasing? Are concentrations of toxics in sediment and biota impair native species?
4. What are the ecosystem processes and are those processes improving or degrading?
5. What are the effects of climate change on estuary ecosystem condition and are they increasing or decreasing? How are the components adapting to stressors of climate change and how resilient are the components? Is climate change affecting fish and wildlife in the Columbia River Basin?

Participants of the April 4-5, 2012 workshop identified key ecological attributes and indicators for each of these.

Key attributes for the lower Columbia River and estuary:

1. Natural habitat mosaic, including water column and native biological communities
2. Pacific salmonids
3. Resident fish
4. Water quality
5. Ecosystem processes

Results (continued)

Attribute 1 – Habitat Mosaic – Habitats were lumped into the following classes:

- Forested
- Non-tidal forested wetland
- Tidal forested wetland
- Herbaceous
- Non-tidal herbaceous wetland
- Tidal herbaceous wetland
- Shrub scrub
- Non-tidal shrub scrub
- Tidal shrub scrub
- Tidal flats
- Deep water
- Other (bare ground)

Geomorphic River Reach	Priority Habitats
A	1. Tidal herbaceous wetland, 2. Tidal wooded wetland
B	1. Tidal wooded wetland, 2. Tidal herbaceous wetland
C	1. Tidal wooded wetland, 2. Tidal herbaceous wetland
D	1. Tidal herbaceous wetland, 2. Tidal wooded wetland, 3. Forested, 4. Herbaceous
E	1. Herbaceous, 2. Forested, 3. Shrub scrub, 4. Tidal herbaceous wetland
F	1. Forested, 2. Herbaceous, 3. Non-tidal herbaceous wetland, 4. Shrub scrub
G	1. Forested, 2. Herbaceous, 3. Tidal herbaceous wetland
H	Non-tidal wooded wetland

Table 1. The Estuary Partnership's Restoration Prioritization Strategy identifies the following habitats as priority by location (Estuary Partnership, *In Review*).

Additional indicators under this attribute include:

- Aquatic areas that support specific life stages:
    - Spawning habitats
    - Cold water refugia
    - Rearing habitats
    - Shallow, slow velocity
- Site or landscape specific mosaic, gradient along channel/slough; channel complexity, elevation gradient; description of this per reach;
- Landscape metrics, patch size, across lower river, averages

Attribute 2 – Pacific salmonids – supporting components and indicators of biological requirements for salmonids were into the following components: habitat opportunity; habitat capacity (food availability and quality); safety; and realized function. Indicators for each component are listed in Table 2.

Attributes 3 and 4 – Resident Fish and Water Quality – to be determined by focus groups

Attribute 5 – Ecosystem Processes – key ecosystem processes and indicators were identified as follows:

Natural Hydrologic Processes and Sediment Dynamics

- Timing, magnitude, duration, frequency, rate of change
- Recurrent, frequent flooding of floodplain, including freshet
- Sufficient bed material transport to facilitate bar formation and channel migration; dynamic channel migration, wider mouth, more sediment transport to the nearshore ocean
- Sufficient suspended material transport to enable widespread floodplain deposition
- Sufficient material transport of large woody debris and organic matter
- Connectivity between ecosystem types to mainstem, floodplain; fish opportunity
- Plume dynamics
- Natural stream bank processes such as erosion

Food web and trophic processes

- Local production of macrodetritus, transported by flows/connectivity to mainstem; vascular plants/macrodetritus – based food web
- Natural trophic cascades
- Natural habitat capacity
- Natural water properties such as nutrients, pH, DO, chlorophyll, turbidity
- Little invasive species impact on food web
- Natural inter and intra competition and predation amongst species

Habitats and habitat forming processes

- Natural habitat distribution and abundance - balance
- Habitat diversity -- high diversity, presumably
- Wetland marshes, swamps, etc. -- see historical condition in Keith's maps
- Shallow water sloughs and channels -- high productivity, cold water refugia.
- LWD trapping sediment, seeding, nurselogs
- Beaver dams/ponds – prevalent
- Natural barriers
- Natural stream bank processes such as erosion
- Abundance of riparian for nearshore cooling

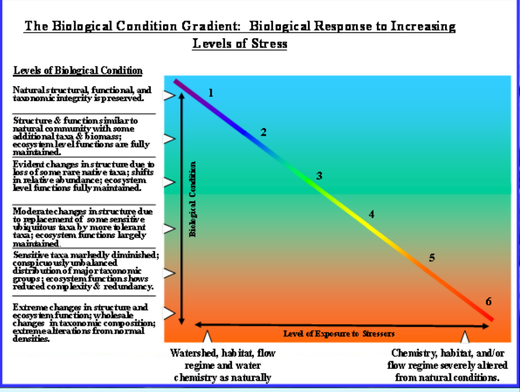

Figure 1. The conceptual model of the Biological Condition Gradient.

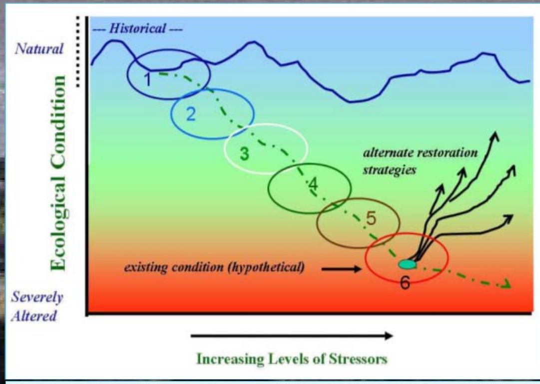

Figure 2. A hypothetical trajectory of degradation in a waterbody, also showing possible trajectories of recovery under alternate restoration strategies. Modified from Cairns et al. (1993).

Habitat opportunity	Capacity - food availability & quality	Safety	Realized function
Connectivity: to site for most ESUs	WQ: T, DO, pH, salinity, velocity, depth, contaminants, prey, other fish composition, vegetation composition & cover	WQ: T, DO, pH, salinity, velocity, depth, contaminants, other fish composition, vegetation composition & cover	Survival, residence time, growth, foraging success
Inundation	Complexity: Natural channel edge riparian habitats, LWD, pool ratio, Mix, natural habitat mosaic at site and landscape scale	Health – few parasites and pathogens	Fitness – genetic diversity
Coverage and distribution of habitats across landscape	Size of habitat (stability, resilience)	Refuge from predators	
	Indirect benefits from habitats (shading, LWD, predation, OM)		
Invasive species	Invasive species	Invasive species	

Table 2. Indicators for Attribute 2 – Pacific salmonids

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