Task 1: Identify the criteria and framework for selecting indicators

RATIONALE
Environmental indicators should be developed and selected in a logical, structured selection process that is scientifically rigorous and transparent, but also cost effective. Such a process should:

- increase both the value and scientific credibility of environmental assessment reports and ensure they meet management concerns,
- allow for conceptual validation of indicators, and
- help to identify indicators that link ecological dimensions with environmental, social and economic dimensions.

Achieving broad regional agreement on the indicator selection process for development and selection of indicators requires a substantial commitment of time but is essential to their successful implementation and use. A decision or guidance framework used in conjunction with indicator selection criteria should provide a rational basis for the indicator screening and selections.

METHODS
NOAA staff and a subgroup of the technical working group (TWG) volunteered to do a literature review and briefly summarize studies that identified general framework (i.e., a structure to guide structure evaluation) about indicator selection as well as specific criteria for selecting and evaluating individual environmental indicators. More emphasis was placed on general and more recent studies, which were crossed referenced with older studies as necessary. The documents identified by the group were posted on the Provisional Indicators Team web portal to be accessed by the general TWG.

Several general frameworks for selecting indicators (Table 1.1) were identified and presented to the TWG at the workshop that took place on March 18, 2008, along with limitations associated with their use. Additionally, a complete list of selection criteria and their definitions were extracted from the documents. This information was presented to the TWG at the workshop and subsequently was refined to reflect comments received at the workshop. Table 1.2 lists the resulting list of potential criteria for selecting indicators.

RESULTS of LITERATURE REVIEW (summarized in Table 1.1)
Niemeijer and de Groot (2008) provided an over-view of the types of environmental indicator frameworks commonly used to select indictors. They concluded the most common indicator selection process for evaluating indicators uses a specific set of criteria. In general, most of these studies dictate that the criteria for choosing indicators must be scientifically sound and reflect regional issues. Criteria associated with the practical implications of measuring indicators or the statistical properties of the indicators are also often included. For example, Schomaker (1997) suggests that indicators meet the following "SMART" criteria: specific, measurable, achievable, relevant, and time-bound. NRC (2000) based their selection of indicators on the following criteria: general importance, conceptual basis, reliability, statistical properties, data requirements, temporal and spatial scales of applicability, necessary skills, robustness, internal compatibility, costs, benefits, and cost–effectiveness. Criteria with social and policy relevance are sometimes included. For example, for the European Environmental Agency's core indicators, 4 of 9 criteria are related to policy (EEA 2005).

Although many studies provide rational for specific criteria, Niemeijer and de Groot (2008) point out that most do not include frameworks detailing how the criteria should be applied. A notable exception, Kurtz et al. 2000 provides a hierarchical set of evaluation guidelines for indicator election that asks questions about the indicator in a structured manner. Specifically, this framework asks: 1) is the indicator conceptually relevant 2) can it feasibly be implemented 3) is the response variability of the indicator understood, and finally 4) can the indicator be easily interpreted and used. Sets of criteria for selecting indicators, hierarchical or not, are generally applied to <u>individual</u> indicators, and as such, chosen indicators may not collectively provide a balanced assessment of the health of the environment or ecosystem in question (Niemeijer and de Groot 2008).

Studies assessing ecological condition suggest monitoring a suite of indicators that collectively reflect properties of functioning ecosystems. For example, ecological indicators selected by NRC (2000) assess one of three major aspects of ecosystems: 1) extent and status (e.g., land cover and land use), 2) ecological capitol (e.g. total species diversity, nutrient runoff), and 3) ecosystem functions or processes (e.g., carbon storage and net primary productivity). EPA (20002) lists a more extensive list of Essential Ecological Attributes (EEAs) that can be used to assess and report on the ecological condition, including some guidance on indicator selection. The EPA approach may provide a more balanced set of indicators, however, neither of these two studies attempts to address causal mechanisms underlying ecosystem function. Pajak (2000) builds upon the notion that the selected suite of indictors should reflect attributes of **ecological integrity** (i.e., properties associated with biological productivity, diversity, chemical cycling, and the ability to withstand natural disturbances) but also suggest including indicators associated with **social integrity** (i.e., self actualization, self-esteem, love and belonging, and physiological needs) and **procedural integrity** (i.e., results orientated, truth seeking, consent based and adaptable).

The dichotomy between indicator frameworks designed to monitor for ecological condition versus ones to assess the effectiveness of management actions are more fully explored by the IMST (2007). They conclude, "If the monitoring is to evaluate management effectiveness, the basis for the cause-and-effect determinations must be built into sampling design and analysis plans…. Attempting to make effectiveness determinations from status and trend monitoring without such a model can be highly problematic."

Causal chains linking human activities to changes in environmental conditions and the associated societal response is a commonly used indicator frameworks in Europe. A Driver-Pressure-State-Impact-Response (DPSIR) causal chain framework (Smeets and Wetering 1999; Niemeijer and de Groot 2008) clearly defines the causal links or relationships between ecosystem attributes we can measure and aspects of the ecosystem that have high relevance to humans (i.e. potential indicators for the Action Agenda). Specifically, the DPSIR framework defines the causal links between human activities (i.e. drivers), the stress or pressures they can put on the ecosystem, that cause changes in the state of ecosystem components, resulting in negative impacts to other ecosystem components. Ultimately, society can react (i.e. show a response), often with management actions that can regulate the driver, the pressure, state, or impact. Unlike the previous frameworks, DPSIR frameworks, selection criteria are applied to a <u>set of indicators</u> in a causal chain. Focus on the inter-relatedness of indicators through causality may provide insights on how to control a situation with multiple pressure and response indicators.

An enhanced DPSIR **(eDPSIR)** framework applies causal network that focus on the inter-relationship of indicators and is used as a structuring mechanism to select indicators (Niemeijer and de Groot 2008). Use of eDPSIR) framework facilitates the identification of the most relevant indicators for multiple pressures within a location. (Niemeijer and de Groot 2008) point out that if the objective is to know how serious a problem is, **state** and **impact** indicators are preferred, but if the objective is to know how best to control a situation, **pressure** and **response** indicators are preferred.

EARLY FINDINGS/ PROPOSED FRAMEWORK

The PSP Action Agenda by design will use the principals of adaptive management to assess the effectiveness of various management strategies at improving the health of Puget Sound. Thus, environmental indicators tailored to assess the effectiveness of the management strategies (i.e. effectiveness monitoring) will be needed. Theoretically, local status and trend monitoring efforts designed to document changes in conditions or pressures over time (i.e. PSAMP) can be combined with effectiveness monitoring to maximize efficiency. However, considerable care must be taken to ensure that the sampling designs and analytical frameworks are appropriate (IMST 2007).

Since we are working with a set of existing indicators that overwhelming represent **state** and **impact** indicators, with fewer pressure and response variables, we are not at a point when we can use DPSIR or eDPSIR frameworks. At best we can evaluate the existing individual indictors using an agreed set of criteria. A hierarchical framework (modified from Kurtz et al 2001) is proposed (see Figure 1). Also, the TWG felt strongly that in addition to using selection criteria framework, we should attempt to identify from the list of provisional indicators, any complete or near-complete DPSIR causal chains for specific pressures present in Puget Sound. These causal chains offer the most immediate likelihood of assessing the success of management strategies. The conceptual models we have generated (Task 2) will be used to identify indicators as drivers, pressures, state, impacts and responses. For each indicator to be evaluated the TWG will, record the results from the decision tree (Figure 1) into a spreadsheet (see Table 1.3) along with the recording the type of indicator (DSPIR) and which conceptual model it is associated with.

NEXT STEPS

The process for evaluation/selection of provisional indicators with the selected criteria and framework by the TWG will take place on several iterations starting April 21.

LITERATURE CITED

Cairns J, McCormick, P.V., and Niederlehner, B. R., 1993. A proposed framework for developing indicators of ecosystem health. Hydrobiologia 263:1-44.

EEA 2005. EEA Core Set of Indicators – Guide. European Environment Agency, Copenhagen. Report 1/2005, 37pp.

EPA 2002. A Framework For Assessing and Reporting on Ecological Condition: An SAB Report. Environmental Protection Agency Science Advisory Board, Washington, DC. Eds. T. F. Young and S. Sansone. OEPA-SAB-EPEC-02-009 June 2002.

IMST 2007. Considerations for the use of ecological indicators in restoration effectiveness evaluation. Independent Multidisciplinary Science Team, 2007 Technical Report 2007-1 Oregon Watershed Enhancement board, Salem, Oregon.

Kurtz, J. C., Jackson, L.E., and Fisher, W.S., 2001. Strategies for evaluating indicators based on guidelines from the Environmental Protection Agency's Office of Research and Development. Ecological Indicators1, pp 49-60.

Niemeijer D and de Groot, R.S., 2008. A conceptual framework for selecting environmental indicators sets. Ecological Indicators 8: 14-25.

Pajak P. 2000. Sustainability, Ecosystem Management, and Indicators: Thinking Globally and Acting Locally in the 21 st Century. Ecosystem Management. 25 (12): 16-30.

Rice J. 2003. Environmental health indicators. Ocean and Coastal Management. 46:235-259.

Schomaker, M. (1997). Development of environmental indicators in UNEP. In: Papers Presented at the Land Quality Indicators and their Use in Sustainable Agriculture and Rural Development, January 25-26, 1996, Rome, FAO, pp 35-36.

Smeets, E., and Wetering, R., 1999. Environmental Indicators: Typology and Overview. European Environment Agency, Copenhagen. Report No. 25, 19pp.

Thom R. M., and O' Rourke L.K., 2005. Ecosystem Health Indicator Metrics for the Lower Columbia River and Estuary Partnership. Prepared for the Lower Columbia River and Estuary Partnership. Portland, OR. Battelle, Pacific Northwest Division of Battelle Memorial Institute.