Environmental Indicators for the Oregon Plan for Salmon and Watersheds

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by

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Prepared for the Oregon Watershed Enhancement Board by
Institute for Natural Resources

May 2005

Acknowledgments

We would like to thank other major contributors to this report, including Ken Bierly with Oregon Watershed Enhancement Board, Rick Hafele with Oregon Department of Environmental Quality, Phil Larsen with Environmental Protection Agency, Jeff Tryens with the Oregon Progress Board, and Steve Lanigan with USDA Forest Service, who provided valuable feedback throughout the development of the paper. These contributors, along with the November 2003 workshop participants listed below, donated valuable time in shaping the content of and reviewing this document.

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Acronyms

AREMP	Aquatic and Riparian Monitoring Program
BOD	Biological oxygen demand
CLAMS	Coastal Landscape Analysis and Modeling Study
DEQ	Departmental of Environmental Quality
DSL	Department of State Lands (Oregon)
EMAP	Environmental Monitoring and Assessment Program
EPA	Environmental Protection Agency
FIA	Forest Inventory and Analysis (USDA Forest Service)
HGM	Hydrogeomorphic
HUC	Hydrologic unit classification
IBI	Index of biotic integrity
ODA	Oregon Department of Agriculture
ODF	Oregon Department of Forestry
ODF&W	Oregon Department of Fish and Wildlife
OWEB	Oregon Watershed Enhancement Board
PIBO	PACFISH INFISH biological Opinion
PACFISH	Pacific Anadromous Fish Strategy
INFISH	Inland Fish Strategy
TMDL	Total maximum daily load(s)
TNC	The Nature Conservancy
USF&WS	US Fish and Wildlife Service
WQI	Water quality index

Executive Summary

Introduction and Background

The Oregon Plan for Salmon and Watersheds (Oregon Plan), initiated in 1997, is a state-led effort to restore watersheds and recover fish and wildlife populations to productive and sustainable levels while providing substantial environmental, cultural, and economic benefits. Through the Oregon Plan, Oregonians have established that we value environmental quality, not only for the use of the natural resources that are vital to the state's economy and social values, but also for the ecological sustainability of fish and watersheds. These social, economic, and environmental values can be, and in some cases currently are, tracked with indicators.

The Oregon Watershed Enhancement Board (OWEB) has several key statutory responsibilities in its implementation, including a requirement to report to the Governor and the Legislative Assembly biennially on environmental trends. Although a huge volume of data about the environment is available, much of it is so site-specific that it cannot be used to assess the condition of broad geographic regions. In order to provide a mechanism to assess Oregon's collective restoration investments (state, federal, and private dollars), OWEB partnered with the Institute for Natural Resources (INR) to develop and institutionalize a system of tracking a small set of environmental indicators throughout Oregon. Once defined and agreed on, these indicators will allow Oregonians to answer the question *Is Oregon's environmental condition stable, declining, or improving over time?* More specifically, *Are environmental conditions improving under current land management and restoration practices?* The answers are important because they are reflected in environmental policies, regulatory laws, and investments in environmental restoration. Ultimately, indicators of environmental condition should support resource management policies and management programs that will lead to more effective use, protection, and restoration of Oregon's natural resources.

Our ability to evaluate sustainability depends on the availability of sound social, economic, and environmental indicators. Only environmental indicators are treated in this report because currently there are no data and agreed-on indicators to characterize ecological conditions at meaningful scales. Conversely, social and economic indicators are generally agreed on, and data exist for reporting at meaningful scales.

A process to describe existing social and economic indicators within the same hierarchical framework proposed in this document has been initiated by the Oregon Progress Board. Social, economic, and environmental indicators will then be linked in a framework that can be used to assess if we are achieving sustainable communities and watersheds.

There has been an abundance of valuable thinking and implementation on the topic of environmental, social, and economic indicators. Such work has taken place at the state, regional, national, and international scales. Of these efforts, the Oregon Progress Board Benchmarks, the

Willamette Initiative, and the State of the Environment Report form the foundation for this project. This project starts where these efforts left off by putting proposed indicators into a framework to evaluate the Oregon Plan and proposing a sampling design for a subset of indicators.

Priority Indicators

The conceptual framework that we used links Oregon Plan goals with environmental indicators. Within this framework, the indicators are grouped into four environmental classes: Aquatic and Riparian Ecosystems, Terrestrial Ecosystems, Estuarine Ecosystems, and Ecosystem Biodiversity. This classification provides the information and framework necessary to allow decision makers to determine whether environmental conditions are improving under the implementation of the Oregon Plan.

During an INR-hosted workshop in November 2003, technical staff from state and federal agencies, local governments, and nongovernmental organizations specified 15 environmental indicators of basin condition, identifying five (in bold print) as an immediate priority:

Aquatic and Riparian Ecosystems

1. **Anadromous fish abundance, distribution, and life histories**
2. **Coldwater Index of Biotic Integrity (IBI) for fish and for macroinvertebrates** (With the same data, we can report native and nonnative species numbers and distributions for Indicator 15.)
3. **Water Quality Index (WQI)** (miles or percent of streams with rating of poor, fair, or good WQI)
4. **Area, distribution, and types of riparian and wetland vegetation**
5. Riparian function index based on vegetation and site capability (e.g., large wood recruitment, shade, and nutrient input) and wetland function index based on hydrogeomorphic (HGM) typing
6. Physical aquatic habitat and estuarine habitat condition
7. Access to freshwater and estuarine habitat (miles of habitat accessible or limited; further analyze by habitat quality)
8. Frequency of meeting instream water rights

Terrestrial Ecosystems

9. Area, distribution, configuration, and types of cover for established ecological classes
10. **Change in land use and land cover**

Estuarine Ecosystems

11. Area, distribution, type, and change in area of tidal and submerged wetlands
12. Index of Biotic Integrity for estuaries

Ecosystem Biodiversity

13. Number of native plant and animal species and distribution over time (departure from potential)
14. At-risk species (aquatic, estuarine, and terrestrial; plant and animal)
15. Percent of nonnative invasive species (focus on subset of known species)

Integrated Study Design

The INR worked with the Oregon Department of Environmental Quality, the Oregon Department of Fish and Wildlife, and the federal Environmental Protection Agency to propose an integrated study design for collecting data on Native Fish, Indexes of Biotic Integrity and Water Quality, and Riparian Area Condition and Function. Estimated costs are provided at various scales.

The reporting time frame will depend on the indicator and the sample design. A reporting time frame of 5–10 years would allow ecosystems to respond perceptibly to both natural disturbances and management activities and policies. Shorter reporting periods are likely to reveal very little change and yet increase costs.

Next Steps

1. The INR recommends that OWEB begin to build understanding, acceptance of, and support for the proposed indicators and priorities from state, federal, and local governments and nongovernmental organizations.
2. The proposal to integrate monitoring programs at the data collection level presents several organizational and budgetary challenges that will require strong partnerships. OWEB should determine how much support for integrated monitoring is available from state, federal, and local partners.
3. The proposed study design, while building on current Oregon Plan monitoring approaches, will need further refinement. Before state-wide integrated data collection begins, a pilot study to identify areas for improvement and increase the likelihood for longer term success would be valuable.
4. OWEB should work with partners to further refine and define study designs and associated costs for collecting data on the indicators not addressed in the paper's study design section.

Introduction

The Oregon Plan for Salmon and Watersheds (Oregon Plan), initiated in 1997, is a state-led effort to restore watersheds and recover fish populations to productive and sustainable levels while providing substantial environmental, cultural, and economic benefits (CSRI 1997; Governor's Executive Order EO99-01 1999). Many fish populations became listed as threatened species during the late 1990s and early 2000s. The original plan focused on anadromous fish in the Coast Range, but the current Oregon Plan expands the focus to recovery and conservation of all native fish and watershed health throughout Oregon. The strategy depends on landowner and community support and volunteer actions, regulatory programs, and monitoring and research to achieve its goals for watershed and native fish conditions.

Our ability to evaluate sustainability depends on the availability of sound social, economic, and environmental indicators. This report focuses on environmental indicators because there currently are no data or agreed-on indicators to characterize ecological conditions at meaningful scales. Conversely, social and economic indicators are generally agreed on, and available data allow reporting at meaningful scales. A process to describe existing social and economic indicators within the same hierarchical scheme proposed for ecosystem conditions in this document has been initiated by the Oregon Progress Board. Social, economic, and environmental indicators thus will be linked in a framework that can be used to assess whether we are achieving the goal of sustainable communities and watersheds.

The Oregon Watershed Enhancement Board (OWEB) has several key statutory responsibilities regarding implementation of the Oregon Plan, including a requirement to report to the Governor and the Legislative Assembly biennially on environmental trends. Although a huge volume of environmental data is available, much of it is so site-specific that it cannot be used collectively to assess the condition of broad geographic regions. In order to assess the success of Oregon's collective restoration investments (state, federal, and private dollars), OWEB is leading an effort to develop and institutionalize a small set of environmental indicators to be tracked and reported at a basin scale throughout Oregon. Once defined and agreed on, these indicators will allow Oregonians to answer the questions *What are the environmental conditions of Oregon's basins? Are they stable, declining, or improving over time?* Ultimately, indicators of environmental condition should support resource management policies and management programs that will lead to more effective use, protection, and restoration of Oregon's natural resources.

Purpose of This Project

The OWEB commissioned the Institute for Natural Resources (INR) to specify a small set of environmental indicators and their measurement methodology that can quantitatively and consistently measure trends in environmental conditions. Ideally, the environmental indicators will be used to evaluate 15 Oregon Plan "basins" throughout the state (Figure 1) and will

- *detect status and trends* in environmental resources over time
- *be meaningful* at the *basin scale*
- *be sensitive to management actions*
- *inform policy and land management decision makers* (e.g., boards and commissions, agency staff, legislature) regarding resource-related investments, rules, regulations, and management actions

This project introduces a framework for organizing a broad set of sustainability indicators. We then focus on a subset of four environmental components: Aquatic and Riparian Ecosystems, Terrestrial Ecosystems, Estuarine Ecosystems, and Biodiversity. We also draft a study approach for a subset of indicators.

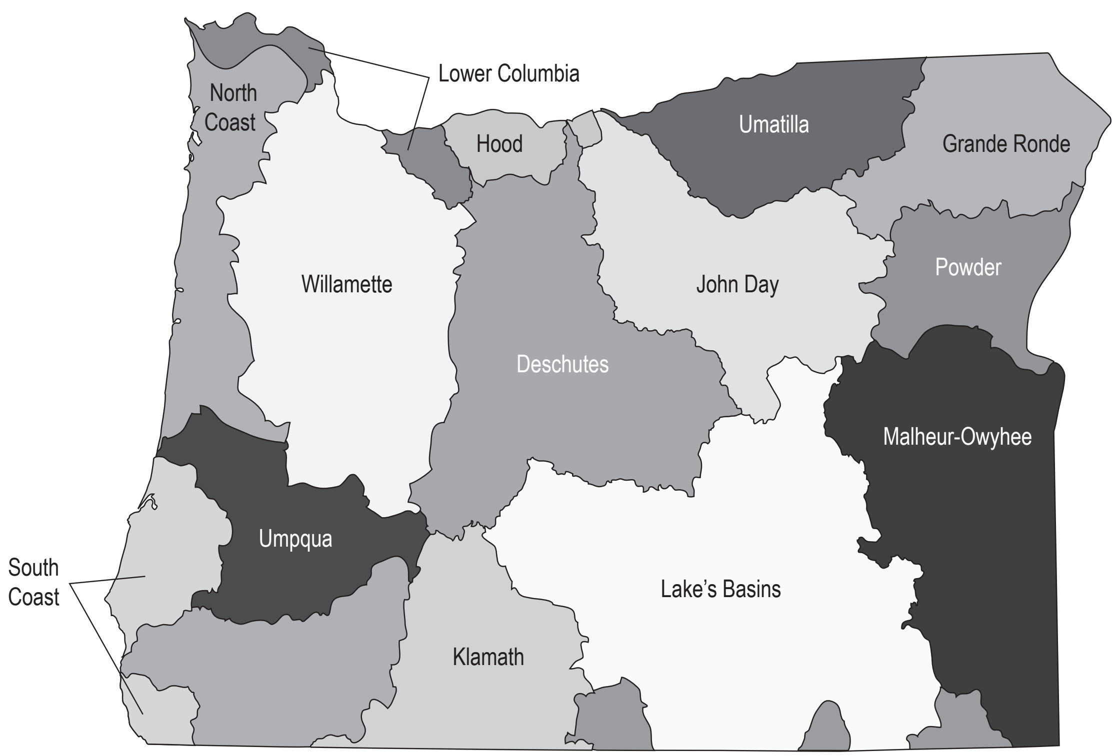

Figure 1. Fifteen Oregon Plan Basins. The basins are based on 3rd-field hydrologic unit classifications (HUC), modified to provide more familiar names and to better represent physical and biological diversity in southwest Oregon. Note that some HUCs cross drainage boundaries (e.g., North and South Coast HUCs).

Evaluating the Oregon Plan at Multiple Scales

Establishing what indicator monitoring can and cannot provide to decision makers is important. Monitoring the proposed indicators at a basin scale provides a measure of the status or condition of given values and, when implemented over time, can measure changes or trends in those conditions. This is different from establishing that a given action (e.g., the Oregon Plan or riparian restoration) *caused* a given condition. To answer the question *Do our actions cause improved environmental conditions?,* we must successfully establish cause-and-effect relationships. This requires a different scale than does broad-scale indicator monitoring. Therefore, the state should invest in nested reach- and small-watershed-scale effectiveness studies to evaluate if restoration and management practices are contributing to desired watershed conditions. In concert, indicator monitoring at the larger basin scale, as discussed in this paper, and effectiveness studies at smaller reach and watershed scales would provide a complete picture of environmental conditions and indicate whether our actions are having the desired results.

Background

Basin Condition

For the purpose of this project, *basin* is defined as the land area, biological communities, and water bodies contained within a 3rd-field hydrologic unit classification (HUC) as designated by the United States Geologic Survey (Seaber et al. 1987) Although this paper refers to these as "basins", they actually represent an aggregation of watersheds that may not drain to a common water body. Within a 3rd-field HUC there may be a mixture of land (terrestrial) habitats, such as forested mountains and grassy plains. There may also be a combination of aquatic habitats, such as streams, lakes, reservoirs, freshwater wetlands, and estuarine wetlands. Vegetated transitional (riparian areas) habitats between terrestrial and aquatic habitats provide unique habitats that may include meadows, low-growing shrubs, hardwoods, or conifers. Basin condition therefore is defined as the status of these terrestrial, aquatic, and riparian habitats and the biological communities they support within the boundaries of a 3rd-field HUC.

Oregon ecosystems support a wide range of aquatic and terrestrial communities that both shape and depend on basin characteristics to support their life histories. Hydrologic, geologic, and soil processes, frequency and intensity of natural disturbance, and the climatic and vegetative characteristics of a basin affect the character, quality, and quantity of terrestrial and aquatic habitats. The State of the Environment Report (SOER Science Panel 2000a) stated that the extent to which these processes and characteristics reflect natural ranges is considered the best long-term indicator of basin and aquatic ecosystem "health". This approach can be problematic and raises several challenges, such as defining the temporal and spatial scales within which the range is considered, defining "natural", and determining the human role within "natural". Natural is commonly defined as conditions before settlement by European-Americans, a yardstick that represents ecological conditions before industrial human population. Within this definition, the temporal and spatial scales of processes used to define "natural" should incorporate a range of rates and extents of disturbances such as fire, flood, and debris flows characteristic of particular ecoregions or HUCs.

Indicators

Indicator, parameter, and attribute often are used interchangeably. The differences are important. For the purposes of this project, an indicator provides an overarching quantifiable description; the data parameters or attributes describe specific data collected and used to support or calculate the value of the indicator. We employ the definition of indicator articulated by Cairns et al (1993): "An indicator is a characteristic of the environment that, when measured, quantifies the magnitude of stress, habitat characteristics, degree of exposure to the stressor, or degree of ecological response to the exposure."

Why Establish Indicators?

The fundamental and common driver among the various processes for establishing indicators is to inform decision makers (Montreal 1999, National Research Council 2000, Heinz 2002, Whitman and Hagan 2003). Whitman and Hagan eloquently describe the utility of indicators in the following excerpt:

> *Good indicators will inform us about whether things we value are being maintained (or sustained), and warn us of an impending breach in a value or a group of values. Typically, the values we wish to maintain are highly complex (e.g., the economy, biodiversity) and we cannot afford to measure all the possible components of the system of concern. Indicators are specific components of these complex systems, that, when measured, tell us a great deal about the present or future condition of the large system.*

Valuable thinking about and implementation of environmental, social, and economic indicators have been abundant at the basin, state, regional, national, and international scales, particularly in recent years (Green Mountain 1998, Montreal Process 1999, National Research Council 2000, Heinz Center 2002, Salwasser and Fritzell 2002, EPA 2003, Hillman 2003, NRTEE & TRNEE 2003, SOER Science Panel 2000a). All these efforts share a common goal and face similar challenges:

- a *goal* to establish an accounting system to track the assets that sustain our social, economic, and environmental values
- an *obligation* to bridge the gap between policy and science by informing decision-making processes with scientifically credible information
- a *need* to represent highly complex and interconnected environmental, social, and economic systems with simple, intuitively meaningful indicators
- a *constraint* to obtain useful decision-making information based on scientifically defensible data for the least cost

Indicator Development: Criteria and Framework

The process used to establish indicators can profoundly affect the likelihood that the proposed indicators will shed light on the questions; will be supported by the collectors, users, and stewards of the data; and will successfully inform decision makers. If the process bridges the gaps among scientific, social, and political stakeholders, it is more likely to be successful. The integrity of the bridges depends on establishing clear goals, identifying the social values that form the basis of the goal, and seeking and implementing input into the process from representatives of the stakeholder communities in a way that focuses on the values and goals of the project.

There are long-established "frameworks" or approaches designed to guide indicator development. Most efforts have established principles or qualities of an ideal indicator (Cairns et al. 1993, National Research Council 2000, Heinz Center 2002, Salwasser and Fritzell 2002, Whitman and Hagan 2003). Authors commonly recommend using these principles to screen candidate indicators and move towards a less biased, more scientifically rigorous set of indicators. The lists can be quite long (35 criteria), but for this project we have focused on six characteristics:

- ▼ **Quantifiable**: The indicator can be described numerically and objectively.
- ▼ **Relevant**: The indicator will be biologically and socially germane to the questions being asked.
- ▼ **Responsive**: The indicator will be sensitive to the stressors of concern.
- ▼ **Understandable**: The indicator can be summarized so as to be intuitively meaningful to a wide range of audiences and pertinent for decision makers.
- ▼ **Reliable**: The indicators will be supported by science. Statistical properties will be well understood and have acceptable levels of accuracy, sensitivity, precision, and robustness.
- ▼ **Accessible**: Data are available or collection of necessary data is feasible in terms of cost, time, and skills.

Whitman and Hagan (2003) went beyond a list of criteria and adapted a long-standing conceptual framework based on four types of indicators.

- ✓ **Pressure** indicators represent the level of stress related to human activity that affects a value of interest (e.g., area of timber harvest/yr).
- ✓ **Condition** indicators describe the current condition or status of a resource.
- ✓ **Impact** indicators signify the change in a value of interest as a result of a pressure.
- ✓ **Policy Response** indicators show the level of action taken to reduce the pressure on a value of interest.

The Pressure-Condition-Impact-Response framework offers a hierarchy by which to link indicators with values and goals. This framework acknowledges that our goals are, by definition, value driven. The inclusion of four types of indicators is compelling in that it provides different types of information on which to base decisions. Once established, the process by which we evaluate if these goals are being met can be based on scientific monitoring. We have adapted the Whitman and Hagan framework to this Oregon Plan Indicators Project.

In the case of the Oregon Plan, the overall goal is to achieve basin and native fish sustainability (Figures 2–5). Social, environmental, and economic components are associated with this sustainability goal (discussed further in this paper under "Monitoring Sustainability"). Each component, in turn, has a set of associated values described as "ecosystem categories". For example, we define the Oregon Plan environmental component with the set of four environmental categories, which will provide a complete framework for addressing basin and native fish sustainability. Our ecological understanding of basin sustainability is supported by what is learned from trends in ecological indicators.

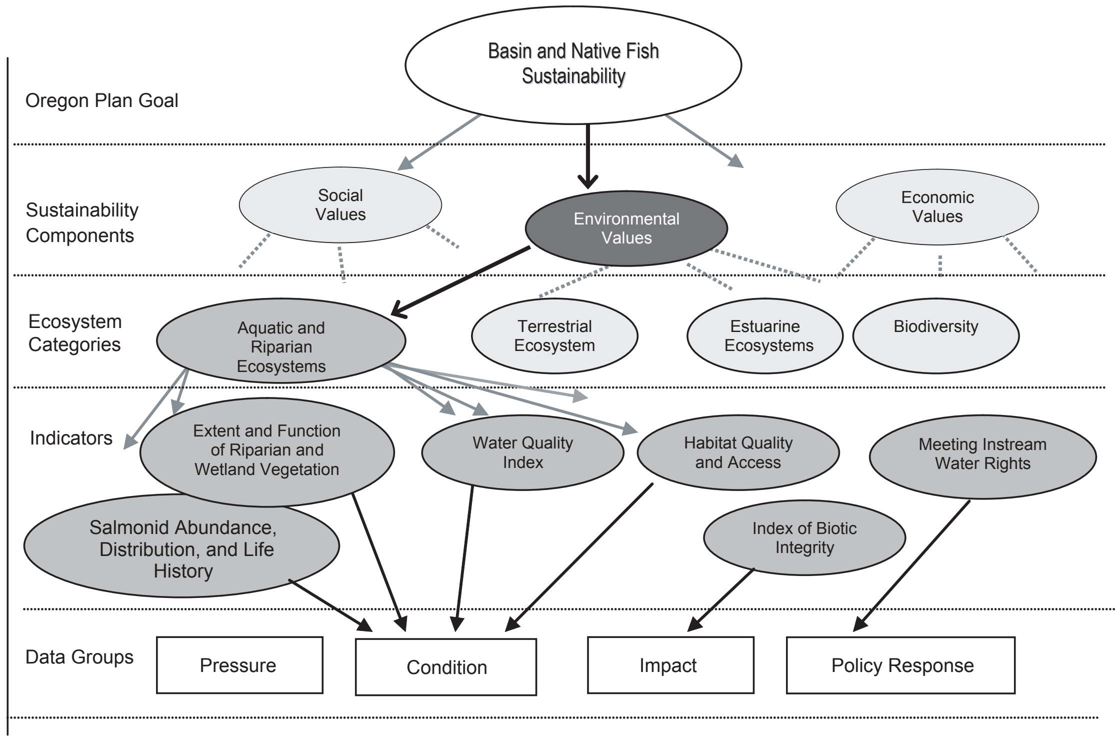

Figure 2. Schematic of how indicators of aquatic and riparian ecosystem conditions support an understanding of sustainable basins and native fish (adapted with permission from Whitman and Hagan 2003).

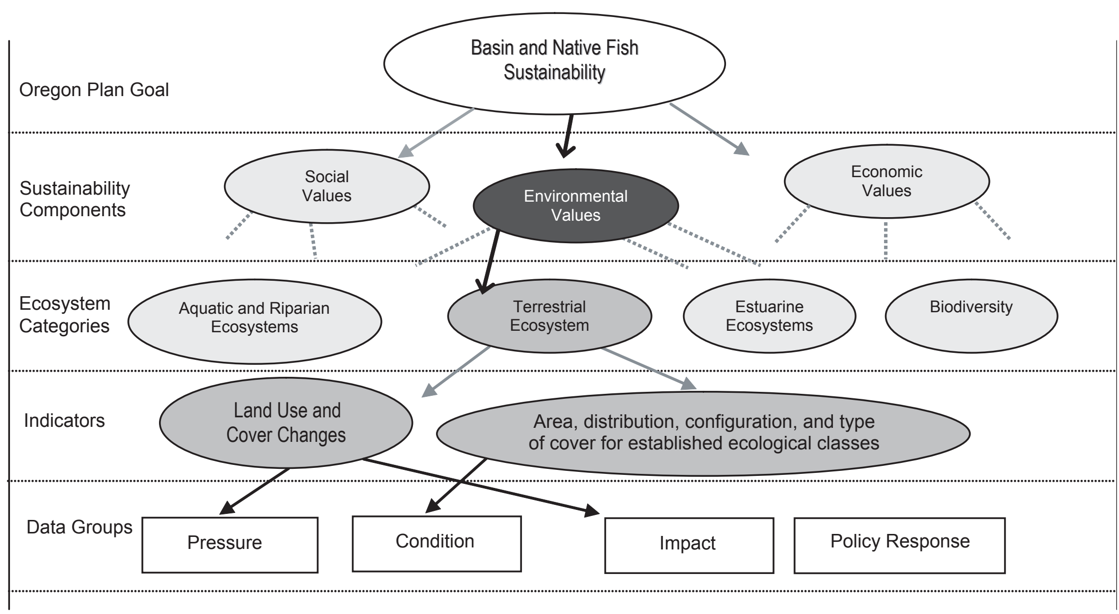

Figure 3. Schematic of how indicators of terrestrial ecosystem conditions support an understanding of sustainable basins and native fish (adapted with permission from Whitman and Hagan 2003.)

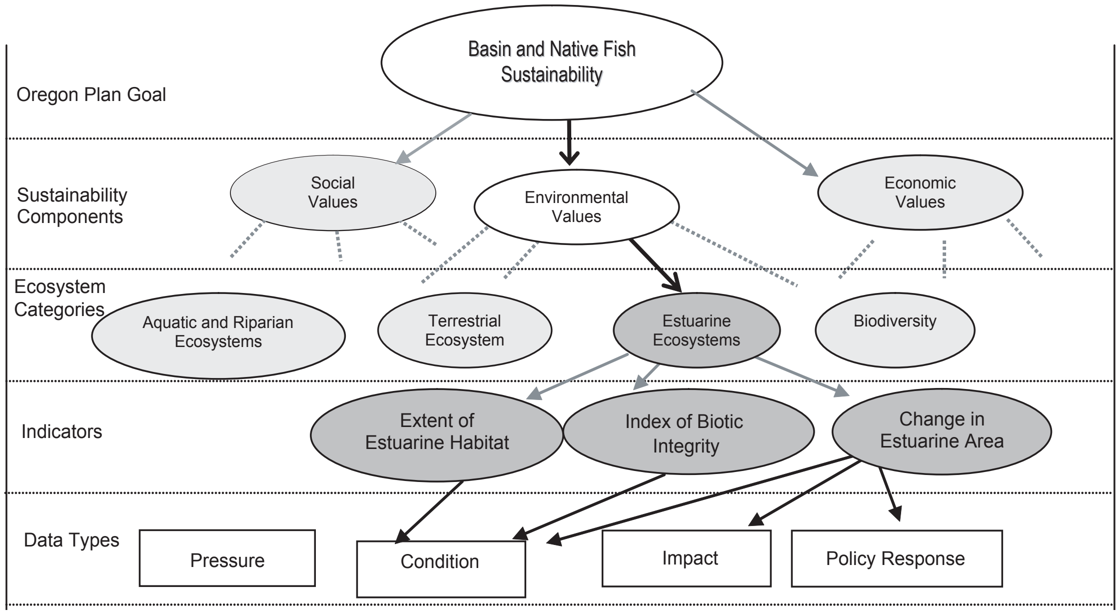

Figure 4. Schematic of how indicators of estuarine ecosystem conditions support an understanding of sustainable basins and native fish (adapted with permission from Whitman and Hagan 2003).

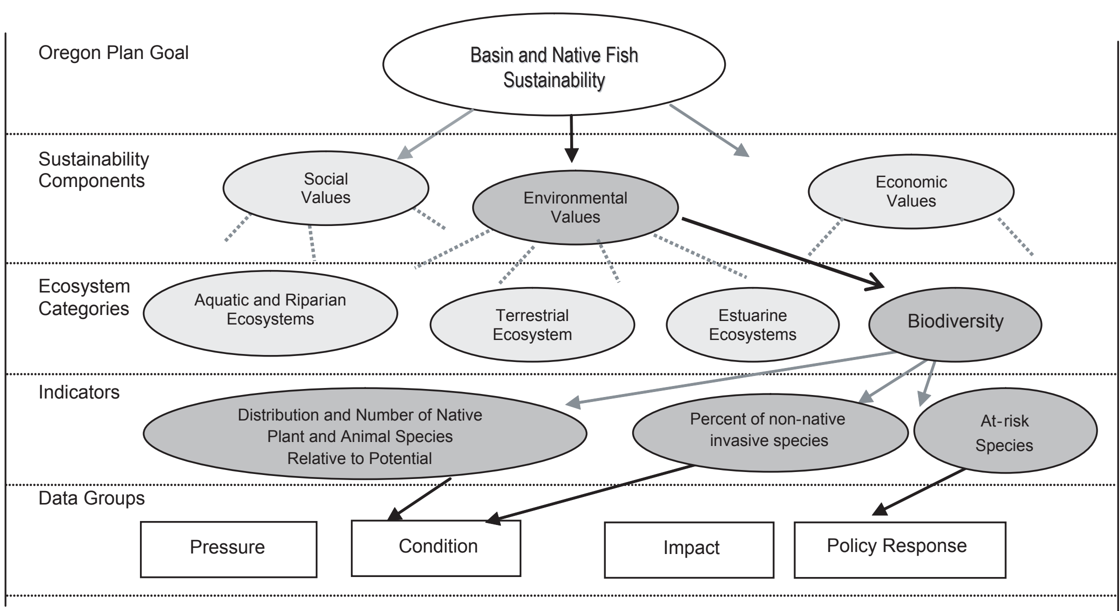

Figure 5. Schematic of how indicators of biodiversity support an understanding of sustainable basins and native fish (adapted with permission from Whitman and Hagan 2003).

Relationship of Oregon Plan Indicators to Other Efforts

Our strategy for organizing the environmental indicators into four environmental categories differs somewhat from current or historic efforts, but there is significant overlap and opportunity for collaboration. For example, in the Oregon State of the Environment Report (SOER Science Panel 2000a), the authors evaluated environmental conditions for "key natural resource systems", which included water quantity; water quality; marine, estuarine, and freshwater wetlands; and riparian ecosystems. They further reported findings and recommendations by land use (forest and rangeland, agricultural, and urban ecosystems), biological diversity, and ecosystem.

The State of the Nation's Ecosystems Report (Heinz Center 2002) researched 10 "core national indicators" and 93 ecosystem-specific indicators. The indicators were grouped into four categories: System Dimensions, Chemical and Physical Conditions, Biological Components, and Human Uses. Indicators for each of these categories were reported for six "ecosystem" categories: coasts and oceans, farmlands, forests, fresh waters, grasslands/shrublands, and urban/suburban. The core national indicators are referenced in Appendix A. The Environmental Protection Agency (EPA 2003) used a hierarchical system as well, starting with six categories: Clean Air, Purer Water, Better Protected Land, Human Health, Ecological Condition, and Working Together for Environmental Results. The EPA further organized ecosystem condition indicators into six categories: Landscape Condition, Biotic Condition, Ecological Process, Chemical and Physical Characteristics, Hydrology and Geomorphology, and Natural Disturbance. Indicators for each of these categories were in turn reported for each of the six Heinz report ecosystems.

The 1992 Earth Summit called on all nations to ensure sustainable development, including the management of all types of forests. Following the summit, Canada convened an International Seminar of Experts on Sustainable Development of Boreal and Temperate Forests. This seminar, held in Montréal in 1993, focused specifically on criteria and indicators for boreal and temperate forests and how they can help define and measure progress towards conservation and sustainable development. Ten countries participated (with the addition of two more in 1995), representing over 90% of the world's temperate and boreal forests. In 1995, from Santiago, Chile, the original 10 countries issued the 'Santiago Declaration', which identified 7 criteria and 67 indicators. Rather than comparing all 67 indicators to the proposed Oregon Plan Indicators, this report focuses on those that have been considered for use in Oregon by the Oregon Department of Forestry (ODF) and evaluated by Salwasser and Fritzell (2002).

Relationships between proposed Oregon Plan indicators and those used for other state, regional, and national projects are illustrated in Appendix A. In this report, we organize existing indicators for Oregon and the nation in a hierarchical framework, which links environmental benchmarks with those addressing the broader topic of sustainability. Taking a subset, we then propose a method for collaborative data collection and reporting.

Monitoring Sustainability

"To sustain" literally means "to keep going, or keep in effect as an action or process". Through the Oregon Plan, Oregonians have established that we value environmental quality, not only for the natural resources vital to the state's economy and social values, but also for ecological sustainability. There are many practical definitions of sustainability, most of which project a state of well-being into the future, maintained by a self-perpetuating process. Oregon's Independent Multidisciplinary Science Team described the recovery of endangered or threatened salmon as the process by which "the decline of an endangered or threatened species is arrested or reversed, and threats to its survival are neutralized, so that its long-term survival in nature can be ensured" (IMST 1999). The US Fish and Wildlife Service (USF & WS) defined the goal of the recovery process as the maintenance of secure, self-sustaining wild populations achieved with the minimum necessary investment of resources (IMST 1999). The OWEB strategy for achieving healthy watersheds (OWEB 2001b) links healthy watersheds with thriving communities in the vision to "help create and maintain healthy watersheds and natural habitats that support thriving communities and strong economies".

Effective indicators of sustainability provide a balanced view of environmental, social, and economic conditions at the scale of interest (community, ecoregion, basin, county, etc.). This is particularly attractive when considering Oregon because of our social and economic success that stems from fertile agricultural valleys and productive forests, abundant fishery resources, and a diverse array of recreational opportunities. The three sustainability components and examples of related values are listed below:

- Environmental Values
  - Aquatic Communities
  - Aquatic and Riparian Ecosystems
  - Terrestrial Ecosystems
  - Estuarine Ecosystems
  - Biodiversity
- Social Values
  - Land Stewardship
  - Land Management and Policies
  - Fish Management: Harvest and Hatcheries
  - Education
- Economic Values
  - Sustainable Economies
  - Poverty and Employment Rates

The Oregon Progress Board has developed a strategy for monitoring sustainability in Oregon "based on the assumption that the social and economic well being of Oregonians depends on the inter-connectedness of quality of jobs, a sustainable environment, and caring communities" (Oregon Progress Board 2003). This approach emphasizes the three components of sustainability (social, environmental, and economic) and recognizes that the three components must be considered simultaneously in order to monitor sustainability effectively. As noted earlier, the remainder of this paper focuses on the environmental component, where the need is greatest because of a lack of agreed-on indicators and supporting data.

Proposing Environmental Indicators for the Oregon Plan

The environmental indicators presented in this paper relate particularly to a subset (75–89) of the environmental benchmarks described in the Oregon Progress Board's Benchmark Performance Report (Oregon Progress Board 2003). The benchmarks have been significantly reviewed and revised; the current versions are described on the Oregon Progress Board Web site (http://www.econ.state.or.us/opb/0305obms/Environ.pdf). The relationship between the Oregon Plan Indicators and Progress Board Benchmarks are summarized in the Appendix, along with other environmental indicators specified in regional and national reports.

The INR hosted a workshop in November 2003 for technical staff from state and federal agencies, local governments, and nongovernmental organizations. The participants designated 15 environmental indicators (Table 1), identifying five as an immediate priority. The proposed indicators have been ranked against the six principles of a suitable indicator discussed earlier. Each of the proposed indicators ranked well against this small set of principles, but none was without limitations or challenges (Table 2).

The reporting time frame will depend on the indicator and the sample design. Five to 10 years would allow ecosystems to evolve and change in response to both management activities and policies and natural disturbances. Shorter reporting periods are likely to reveal very little change and yet increase costs.

Table 1. Proposed environmental indicators of basin condition. Indicators in boldface type were ranked as of immediate priority in the November 2003 workshop.

Aquatic and Riparian Ecosystems

1. **Anadromous fish abundance, distribution, and life histories**
2. **Coldwater Index of Biotic Integrity (IBI) for fish and for macroinvertebrates** (With the same data we can report native and nonnative species numbers and distributions for Indicator 15.)
3. **Water Quality Index (WQI)** (miles or percent of streams with rating of poor, fair, or good WQI)
4. **Area, distribution, and types of riparian and wetland vegetation**
5. Riparian function index based on vegetation and site capability (e.g., large wood recruitment, shade, and nutrient input) and wetland function index based on hydrogeomorphic (HGM) typing
6. Condition of physical aquatic habitat and estuarine habitat
7. Access to freshwater and estuarine habitat (miles of habitat accessible or limited; further analyze by habitat quality)
8. Frequency with which instream water rights are being met

Terrestrial Ecosystems

9. Area, distribution, configuration, and types of cover for established ecological classes
10. **Change in land use and land cover**

Estuarine Ecosystems

11. Area, distribution, type, and change in area of tidal and submerged wetlands
12. Index of Biotic Integrity for estuaries

Ecosystem Biodiversity

13. Number of native plant and animal species and distribution over time (departure from potential)
14. At-risk species (aquatic, estuarine, and terrestrial; plant and animal)
15. Percent of nonnative invasive species (focus on subset of known species)

Table 2. Aquatic and Riparian, Terrestrial, Estuarine, and Biodiversity indicators, assessed according to the indicator criteria discussed on p. 15. Indicators have been preliminarily ranked on a scale from 1–3 on likelihood to meet the criteria. 1 = likely to meet, 2 = likely to meet with the specified challenges, 3 = unknown certainty or unlikely to meet the criteria. Indicators identified as an immediate priority at the November 2003 workshop are in bold.

Indicator	1. Quantifiable	2. Relevant	3. Responsive	4. Understandable	5. Reliable	6.[1] Accessible	Total (6 = best; 18 = worst)
			Aquatic and Riparian				
1. Anadromous fish abundance, distribution and life histories	1	1	2: Responsive to multiple stressors	1	2: Challenges with precision for trend detection due to natural variability	1	8
2. Coldwater Index of Biotic Integrity for fish and for macroinvertebrates (With these data, we also can report native and nonnative species numbers and distributions for Indicator 15.)	1	1	1	2: Requires some technical explanation	1	1	7
3. Water Quality Index (WQI) (miles or % of streams with rating of poor, fair, or good WQI)	1	1	1	1	2: Challenges with seasonal variability not being captured	1	7
4. Area, distribution, and types of riparian and wetland vegetation	1	1	1	1	1	3: Remote data are of limited value	8
5. Riparian function based on vegetation and site capability (e.g., large wood recruitment, shade, and nutrient input) and wetland function based on HGM typing	2: Need agreed-on index of "function"	1	1	2: Depends on index of function	1	3: Remote data are of limited value	10
6. Condition of physical aquatic habitat and estuarine habitat	1	1	2: Response may be overshadowed by large disturbance events	1	2: Natural variability may dampen precision	1	8
7. Access to freshwater and estuarine habitat (miles of habitat accessible or limited; further analyze by habitat quality)	1	1	1	1	1	2: Challenge to obtain complete census	7

continued

Table 2. continued

Indicator	1. Quantifiable	2. Relevant	3. Responsive	4. Understandable	5. Reliable	6.[1] Accessible	Total (6 = best; 18 = worst)
8. Frequency with which instream water rights are being met	1	2: Depends on how the rights were established	2: Response may be over-shadowed by natural variability in flow and complex hydrologic processes	1	2: Reliability may be limi-ted by natu-ral variability in flow and complex hydro-logic processes	1: Modeled approach currently being used for 2003–2004 Oregon Plan Assessment.	9
Terrestrial							
9. Area, distribution, configuration, and types of cover for established ecological classes	1	1	1	1	2: Challenges with precision to evaluate trends	1	7
10. Change in land use and land cover	1	1	1	1	2: same as above	1	7
Estuarine							
11. Area, distribution, type, and change in area of tidal and submerged wetlands	2: Challenges with establishing baseline	1	1	1	1	1	7
12. Index of Biotic Integrity for estuaries	2: IBI not established yet	1	1	2: Requires some technical explanation	1	3: Need to develop IBI	10
Biodiversity							
13. Number of native plant and animal species and distribution over time (departure from potential)	2: Challenges with establishing potential	1	1	1	2: Challenges with precision to evaluate trends	1	8
14. At-risk species (aquatic, estuarine, and terrestrial; plant and animal)	1	1	1: Although may also simply reflect policy shifts	1	1	1	6
15. Percent of nonnative invasive species (focus on subset of known species)	2: Need manageable subset of species to focus on	1	1	1	1	2: No systematic evaluation	8

[1]Data needed for most of these indicators are not currently available statewide. A rating of "1" therefore reflects an assessment of the ability to acquire data, given collection costs and available technology.

Priority Environmental Indicators

Eventually, tracking a component of each environmental indicator group and combining the findings from environmental, social, and economic indicators to provide a balanced picture of environmental trends and sustainability in Oregon will be important. The state is unlikely, however, to be able to pursue all the proposed environmental indicators simultaneously. The following discussion evaluates the immediate priority indicators identified during the workshop in more detail.

Aquatic and Riparian Ecosystems

Status and trends in aquatic and riparian conditions comprise eight indicators, all of which concern condition (Table 1). The four indicators identified as a high priority are discussed below. Examples of available data are provided in Table 3.

Table 3. Summary of priority aquatic and riparian ecosystem indicators, data needs, and sample design, with examples of currently available data.

Indicator	Aquatic Biota Data Needs	Sample Design	Currently Available Data	Scale of Available Data
Native fish abundance, distribution, and life histories	• Native fish adult abundance	Spatially balanced random sampling	• Coastal streams since 1998 • John Day • Lower Columbia River tributaries, 2003 • ODF&W started in early 1990s using stratified random sampling	4th-field HUC
	• Juvenile abundance: Fish/m² and pool occupancy	Spatially balanced random sampling	Coastal streams since 1998	3rd-field HUC
	•Coho smolt abundance: total number of migrants	Life cycle basins[1]	Various streams & start/end dates	Small scattered streams
	•Dam counts		• Winchester Dam: N. Umpqua • Columbia • Willamette Falls	
Coldwater Index of Biotic Integrity	• Species richness & relative abuncance of fish & other aquatic organisms, & health of the organisms •Need to develop index based on reference conditions for some HUCs	Spatially balanced random sampling; reference sites	• Coastal streams since 1998 • Willamette, John Day & Deschutes	3rd-field HUC

continued

Table 3. continued

Indicator	Aquatic Biota Data Needs	Sample Design	Currently Available Data	Scale of Available Data
Water Quality Index	• Temperature • Dissolved oxygen • Bacteria • Turbidity • pH • Phosphorus • Nitrogen, nitrate, & ammonium nitrate • Macroinvertebrates • BOD • Total solids	Spatially balanced random sampling	Coastal streams since 1998; ambient sites statewide since 1960	• 3rd-field HUC • Subwatersheds for ambient data
Area, distribution, and types of riparian and freshwater wetland vegetation	• Acreage/miles of stream with vegetative cover in one of the following categories: hardwood, softwood, hardwood/softwood mix, shrub, grassland, shrub/grassland mix, row crops, pasture, impervious area, bare ground • Acreage & location of wetlands by HGM type	• Field: Spatially balanced random, and/or augment current FIA plots for value at the 3rd field HUC • Remote: Use 1:100K hydro layer as a guide to select scenes, then use Gradient and Nearest Neighbor • 35 m remote sensed • 5 m remote sensed • 0.5 m aerial photos	• Field: FIA plots, state • AREMP • Remote: Low-level air photos (DOA), certain watersheds; DEQ-TMDL data satellite: field plot comparisons for select watersheds • CLAMS • EPA, USF&WS, DSL and OWEB: Change in wetland acreage below 100 m. Time frame, between 1984 and 1999; available in 2004	• FIA: State • Remote: Select watersheds • Ground-based plots: reach • Interagency Workplan: Combine all at 3rd- to 4th-field HUC

[1]These sites could be considered for watershed scale effectiveness studies, and possibilities to replicate the approach to other basins should be evaluated. May need to place adult traps where the smolt traps are located. Look for opportunities to link with or build on other watershed scale studies in the region.

Anadromous fish abundance, distribution, and life histories

Indicators of abundance and distribution of native anadromous fish are singled out from those for other species because the focus of the Oregon Plan historically has been on recovery of threatened fish populations. Therefore, the Oregon Plan goal for sustainable fish populations can only be monitored if we track the numbers and distribution of threatened fish species. Life history trends (i.e., size, age, and weight, combined with migration timing) in native fish are also critical to understanding how management decisions may be influencing population vigor. Because monitoring life history trends is challenging, we typically retreat to reliance on fish numbers to inform our management decisions, but such an approach is incomplete. In a few cases, life history studies provide some data to allow examination of run timings, sizes, weights, and ages of fish and answer questions such as *Are fish maturing faster and coming back smaller?* Although life-history monitoring was identified as a high priority, we limit discussion in this report because Oregon Department of Fish And Wildlife (ODF&W) is formulating species conservation plans as directed by its Native Fish Conservation Policy. These plans will contain information on life history monitoring needs.

Index of Biotic Integrity

Anadromous fish indicators focus on a small component of aquatic communities and respond to multiple pressures and conditions that challenge interpretations. Therefore, we recommend using an IBI to broaden our understanding of aquatic ecosystems. The use of an IBI provides a more comprehensive index of aquatic organisms, including native fish, and incorporates reference conditions as a measure of the relative "health" of the aquatic environment. An IBI combines measures of multiple biological indicators, such as species richness, relative abundance of specific organisms, and health of the organisms, to rate the condition of the system (Hughes et al. 1998, Mebane et al. 2003, Hughes et al. 2004). The data also can be used to evaluate pressures from introduced species.

Water Quality Index

Trends in water quality conditions are proposed as an indicator because of the relative sensitivity to management, the availability of data, and the importance of water quality to native fish. Multiple parameters (Table 3) are tracked and used to calculate one WQI.

Area, Distribution, and Types of Riparian and Wetland Vegetation

Undoubtedly one of the greatest needs is to understand riparian conditions in the state at broad landscape scales (SOER Science Panel 2000a). This need has been articulated by the IMST, the Core Team for the Oregon Plan, multiple natural resource agencies, nongovernmental organizations, and researchers. The value of riparian data for Oregon Plan indicators is in the sensitivity of riparian vegetation to management and its linkages with water quality and aquatic and terrestrial habitat and communities. Protection, maintenance, and improvement of riparian areas also represent key management approaches to conservation of aquatic species currently considered at risk. Therefore, improving the ability to report on riparian conditions could vastly improve the likelihood of understanding environmental changes over time that are sensitive to management and restoration investments and have well-understood linkages to the health of basins and native fish.

In March 2003, an interagency team wrote a work plan for developing riparian landscape condition assessments (State Interagency Work Group 2003). The report established the need for interagency efforts to collect riparian data at multiple scales, using three types of data (satellite imagery, aerial photography, and field plots), and a structure for implementing the work. If implemented, this work plan would provide basic information on the area, distribution, and types of riparian vegetation. The indicators recommended in this paper could be acquired in a subset of basins by implementing the pilot study described in the interagency work plan.

Freshwater wetlands provide unique and diverse functions with regard to aquatic and basin health. These functions vary by ecosystem (e.g., Klamath Basin versus Cascades or Willamette Valley) but commonly include water storage to delay flood runoff, fish and wildlife habitat, and improved water quality. Indicators are proposed that are significant to ecological condition and sensitive to change. Wetland data are currently being collected by the EPA, USF&WS, the Oregon Department of State Lands (DSL), and OWEB and will be available in 2005.

Terrestrial Ecosystems

Status and trends in terrestrial conditions are addressed by Indicators 9 and 10 (Table 4). Both Indicators 9 and 10 are relevant and sensitive to management. They can be used to quantify pressure and conditions. Indicator 10, Land Use and Land Cover Changes, was identified as an immediate priority at the workshop.

Land use change analyses are currently available from 1973 to 2001 for nonfederal lands in Oregon (Lettman et al. 1999, Lettman et al. 2004). The data were compiled from aerial photographs and US Forest Service (USFS) Forest Inventory and Analysis (FIA) plot data. Land cover change analyses will require further refinement of cover classifications for terrestrial ecosystems.

Estuarine Ecosystems

Estuaries are important both for our social and economic needs and from an ecological perspective. Oregon's 22 estuaries provide unique ecological functions because they are transition zones that integrate the basins they drain with the marine environment. Estuaries are ecological "hot spots' boasting exceptionally high biological productivity and providing habitat that serves critical life stages of a wide variety of marine and anadromous species *(*SOER 2000b, Chapter III*)*. The proposed indicators were selected because of their ecological importance and sensitivity to environmental change. While the estuarine indicators were not identified as an immediate priority and will not be discussed further in this paper, data are available that can provide a synoptic report on various estuarine qualities (EPA 1999). A cooperative effort among the EPA, the USF&WS, the DSL, and OWEB will generate wetland change data for all of Oregon coastal wetlands below 100 m elevation. This data will be available for the change between 1984–1999 for the entire coast in 2005.

Table 4. Summary of terrestrial ecosystem indicators, data needs, sample design, and currently available data.

Terrestrial Indicators	Terrestrial Data Needs*	Sample Design	Currently Available Data	
			Type and source	Scale
Area, distribution, configuration, and type of cover for established ecosystem and cover classes	Need an agreed-on classification system. Could include those used by the USGS in the NLCD layer grouped to align with broad land-use categories: *Water* Open water Perennial ice/snow *Urban* Low-intensity residential High-intensity residential Commercial/Industrial/ Transportation *Bare/Mining* Bare Rock/Sand/Clay Quarries/Strip mines/Gravel pits *Forest* Transitional Deciduous forest Evergreen forest Mixed forest *Shrubland* Shrubland *Farmland and Grazing* Orchards/Vineyards/Other Grasslands/Herbaceous Pasture/Hay Row crops Small grains Fallow Urban/recreational grasses *Wetlands* Woody wetlands Emergent herbaceous wetlands Other potential indicators include impervious area and road density separately from the Urban Class. Subclasses might include total density density within 100 ft of streams, and density on steep slopes	Combination of plot data and remote sensing data Statewide Report every 10 years	USGS National Land Cover data; most recent is 1990. **Forest Condition Analyses** *Forest Type(C)* by structural stage: FIA plots combined with satellite imagery *Fire Condition Class (C):* USFS (Missoula) and FIA or satellite *Forest Management Trends (P):* Land use boundaries within various management classes *The Nature Conservancy (TNC)*: Remote, Cascades not complete yet, also part of ODF&W Conservation Plan **Farmland and Grazing Data** *NRCS-NRI*: Soil and vegetation condition compared to potential natural community, plot data *TNC*: Remote, Cascades not complete yet, also part of ODF&W Conservation Plan **Available Urban** *Sprawl*: Northwest Environmental Watch *Portland Metro*: Area providing intact riparian areas	Statewide Statewide; EO is a mix of years and sources Statewide and national; current Statewide; 1960–current Statewide, by ecoregion, every 10 years Statewide-every 5 years until 2004, then every year. Doesn't revisit sites. Statewide by ecoregion, report every 10 years Portland area Portland metro has riparian data
Land use and land cover changes	Conversions from farming or forestry or grasslands to urban or rural residential and back again Conversions to conservation use Urban sprawl	Air photos and FIA plot data	ODF and TNC studies	1973–2000, statewide

*C = condition data, P = pressure data, PR = policy response data

Ecosystem Biodiversity

The need to understand the biodiversity of ecosystems is common to the other four environmental values identified in the framework—aquatic and riparian, terrestrial, and estuarine ecosystems. Biodiversity has been described as the variety and variability of living organisms. It includes the diversity of ecosystems, as well as the diversity between and within species. Protecting, maintaining, and restoring native biological diversity at both local and landscape scales is important for sustaining the biological systems humans depend on—their web of life and the ecological processes that all species need to survive (Salwasser and Fritzell 2002). Indicators 13, 14, and 15 (Table 1) are recommended for tracking the biodiversity of ecosystems. Although the biodiversity indicators were not identified as an immediate priority for this project and will not be discussed further in this paper, available data can provide a synoptic report on various biodiversity qualities. It is also important to note that the state of Oregon is undertaking a statewide conservation plan and biodiversity assessment. The final Oregon Plan indicators should be synonymous with those identified in the statewide conservation plan and assessment.

Data Management and Information Systems

Selecting an appropriate data management tool that facilitates the sharing of data among partners will be critical. This is especially important because it is likely that the information will be collected by multiple sources. An interagency project, funded by OWEB, initiated a data library in 2003. This system provides a data clearinghouse for the Oregon Plan Assessment, also initiated in 2003. Eventually, the data library may be used for both housing and distributing natural resource data.

Draft Study Approach for a Subset of Indicators: Fish Distribution & Abundance, Index of Biotic Integrity, Water Quality Index, and Riparian Condition

The overarching questions articulated in the Introduction—*What are the conditions in Oregon's basins? Are they stable, declining, or improving over time? Do our actions cause improved environmental conditions?*—are combined into one general question for this study design:

Are restoration projects and land management practices protecting and/or improving aquatic communities, aquatic ecosystems, and riparian ecosystems?

We propose collecting data for Fish Abundance & Distribution, an IBI, a WQI, and Riparian Characteristics within the same sampling scheme (e.g., at the same places and with the same strata or classes). Some of the challenges to this approach include the need to visit some of the sites several times in 1 year in order to measure water quality accurately. Also, capturing accurate measures of fish distribution and abundance may require an increased density of sites in areas populated by specific species of interest. The approach we propose, however, can answer some specific questions (Table 5).

Table 5. Monitoring questions and indicators that can be used to answer specific questions. The questions are posed to address conditions at the "basin" scale, in this case the 3rd-field HUC. The sample design can be adapted to other scales, for example, "provinces" or ecoregions, in which case basin would be replaced with "province" or ecoregion.

Monitoring Questions[1]	Indicators
What fish and amphibians occur most commonly?	IBI
What aquatic and riparian nonnative invasive species occur most commonly?	IBI; Riparian Area, Distribution, & Cover (also develop riparian index)
What percent of stream miles are in good, fair, and poor condition for aquatic biota, water quality, and riparian condition?	IBI; WQI; Riparian Area, Distribution, & Cover (also develop riparian index)

continued

Table 5 continued

What streamside vegetation occurs most commonly?	Riparian Area, Distribution, & Cover (also develop riparian index)
What parameters represent the main stressors (e.g., sediment, temperature, nutrients) to aquatic biota?	IBI; WQI; Riparian Area, Distribution, & Cover (also develop riparian index)
What is the salmonid abundance?	Fish Abundance & Distribution *plus* spawner surveys
What is the salmonid distribution ?	Fish Distribution & Abundance, Habitat Quality
What targets or benchmarks represent attainment of biotic, water quality, and riparian condition or function?	IBI, WQI, Riparian Area, Distribution, & Cover (also develop riparian index), Habitat Quality

[1] All monitoring questions except the last are considered with respect to two subquestions: *How is this changing over time?* and *How does this vary within land classifications of interest (stream size, land use, etc.)?*

Indicator Definitions and Parameters

Indicator	Definition	Parameters
Fish Distribution and Abundance	Numbers and distributions of salmonids. This grouping includes "canary-in-the-coalmine" species, as well as fish that are listed or vulnerable to listing. It also tracks the numbers and distribution of species throughout the measurement unit. The species conservation plans being formulated by the ODF&W will include life history monitoring needs.	Species, age, count (snorkeling and electrofishing). Adults will have to be monitored with a separate sample.
Index of Biotic Integrity (IBI)	Observations are compared with those in reference reaches. Separate indices will be established for invertebrates and vertebrates. RIVPACS (a multivariate model) will be used to evaluate invertebrates. A vertebrate multimetric model will be used to evaluate fish and aquatic amphibians. RIVPACS and vertebrate models have been developed (Hughes et al. 1998, 2004) and are available for use. (The current RIVPACS model applies to Western Oregon only.) Periphyton should	*Invertebrate IBI:* Species and abundances *Vertebrate IBI (fish and aquatic amphibians):* Species, abundances, size, anomalies (diseases, deformities, tumors, lesions)

	also be considered as an indicator because it is relatively inexpensive to collect and analyze and is not constrained by a permitting process, as fish sampling is. It is also sensitive to management and can be used to detect various anthropogenic disturbances and stresses.	
Water Quality Index (WQI)	The parameters listed are compared with values established by the Oregon Department of Environmental Quality (DEQ) from reference conditions or standards. Multiple parameters are combined into one index.	Temperature, pH, bacteria, phosphorus, nitrate, nitrogen, ammonium nitrate, dissolved oxygen, biological oxygen demand (BOD), total solids (Revisiting a subset will be necessary to determine seasonal trends.)
Riparian Condition	Measures of streamside vegetation and land-use characteristics. Species, size, cover, and distribution; land use categories; and cover over the stream are measured. An index for riparian condition still needs to be developed or agreed on. EPA's EMAP has developed a riparian disturbance index that incorporates these variables. We may also consider using site capability as described by the Oregon Department of Agriculture (ODA) and used in collaboration with some total maximum daily loads (TMDLs). Functional aspects that vary by ecosystem (e.g., meadow, shrub, forest) and goals may also be incorporated. The precision, accuracy, and responsiveness of these alternatives need to be evaluated.	To be determined by existing methods [e.g., AREMP, DEQ, EMAP, FIA, Greenline, ODA, ODF, ODF&W, PIBO (Windward 2000)]. Data parameters typically include but are not limited to, understory and overstory vegetative species; size (diameter and/or height); cover over the stream and within the riparian area; distribution relative to the stream of trees, snags, shrubs, and herbs; dominant land use categories (forestry, agriculture, range, urban, rural residential, open space); stubble height; vegetative buffer width.

Sampling Design

Random probabilistic: We propose an EMAP (random probabilistic) sampling design with a 5-year rotating panel. A similar design has been implemented in the state for various projects, including EMAP and Oregon Plan monitoring by EPA, DEQ, and ODF&W.

Table 6. Indicator and expected precision with 50 sites per classification unit (basin, province, etc.).

Indicator	Precision (%)
IBI	12–15
WQI	12–15
Riparian characteristics	5–40 (depends on indicator)
Fish abundance and distribution	20–40

Sample size and precision: We propose 50 sites per classification unit (e.g., 3rd-field HUC, province, or ecoregion) plus 50 additional reference sites. This equals 300 sites for 5 provinces or 800 sites for 15 basins. In general, as sample size increases and variability decreases, the precision in estimating conditions increases. The expected precision of an estimate of the average "condition" for a given sample size is provided for each parameter in Table 6.

Five-year rotating panel: This approach involves visiting a subset of sites each year until the desired sample size is attained after 5 years. For example, visit 60 sites a year for 5 years (300 sites) for province-level sampling, or visit 160 a year for 5 years (800 sites) at the basin scale. It will be necessary to return to a subset of sites every year, as well as a subset of sites several times a year, in order to characterize some WQI components adequately.

This approach presents three advantages:

- Sample size increases after the first 5 years, because we would start a new set of 300 (five provinces) or 800 (15 basins) sites.
- We can report a preliminary statewide picture every year with increasing precision over time.
- After the first 5 years, we can report on the classification unit of interest (e.g., provinces or 3rd-field HUC), and every year after that begin reporting on trends.

Sampling Frame: The sampling frame currently available is the 1:100,000-stream layer. The 1:24,000 stream layer will provide a superior sampling frame if it is available when this project is implemented.

Classifications: The goal of this project was to describe indicators that could describe ecological conditions for 15 3rd-field HUCs throughout Oregon. An additional goal was to propose a cost-effective study design for collecting data on those indicators. The necessary sample size for acceptable precision (<15–20%) increases with increasing number of classifications (e.g., 5 provinces versus 15 basins). Therefore, we offer alternatives to the 15 Oregon Plan Basins and associated budget estimates.

1. Landscape classes. The greatest limitations to implementation of this program are costs. Creating fewer classifications reduces costs. Each of the following classifications is desirable for the reasons described.

- *15 Oregon Plan Basins*: OWEB has defined 15 3rd-field HUC reporting basins (Figure 1). Sampling schemes will allow inferences for each of the 15 basins.
- *5 DEQ Provinces (Draft)*: DEQ is considering 5 provinces that would meet the agencies' programmatic needs (statewide monitoring that addresses TMDLs and permitting programs) and be cost effective to implement. Use of provinces would increase collaborative and cost-reduction opportunities.
- *9 Ecoregions, Level III*: Ecoregions stratify the environment into areas with generally similar type, quality, and quantity of environmental resources. EPA Ecoregions were specifically designed through an interagency effort to develop a common framework on which to base ecological research and monitoring (EPA 2003). A hierarchical scheme, designated by roman numerals, has been adopted for different levels of ecological regions. The EPA has defined 9 level III and 65 level IV ecoregions within Oregon. This project can be designed to characterize the environment for Level III Ecoregions.
- *7 ODF Georegions*: Oregon Department of Forestry rules vary regionally and scale down the ecoregions into 7 georegions. Results would align with ODF policy and program questions.
- *8 Fishery Basins*: The above delineations may not align with fish populations and distributions. The following combinations may provide better strata when considering fish abundance and distribution:

    Umatilla, Grand Ronde and John Day
    Lake Owyhee and Powder
    Hood and Lower Columbia and Willamette
    North Coast, Umpqua, South Coast to Cape Blanco
    South Coast
    Rogue
    Deschutes
    Klamath

2. Stream size. An additional stream size subclass should be considered for each landscape class as defined by stream order: Headwater (1st order), Wadeable (2nd–4th order), and Boatable (>4th order). If stream flow is modeled and mapped for the whole state at the time this project is implemented, the use of stream flow would be a superior sampling subclass to stream order.

Post-stratification: Intrinsic characteristics of the environment will influence the observed spatial and temporal trends of indicators such as water quality, IBI, and vegetation. The data will be "post-stratified" so that indicators can be reported in the context of this natural variability. Possible strata include

- Geology: geology can be considered categorically.
- Gradient: gradient can be considered on a continuum or categorically.
- Landform: landform can be considered categorically.
- Valley width: valley width can be considered categorically.
- Stream size: stream size can be considered categorically. If it is not a sample classification, it should be addressed with post-stratification.
- Elevation: elevation can be considered on a continuum or categorically.

- Natural disturbance and cycles: natural disturbances and cycles that have broad influence on the priority indicators will be accounted for in the analyses. These include fires, floods, droughts, windstorms, and ocean conditions.
- Land-use classes: It will be useful to describe the results for various political and land-use boundaries when making management and policy decisions. These may include land-use classes such as urban, rural residential, agriculture, range, and forestry.
- Ecoregion: if ecoregion isn't used for the initial landscape class, it should be used as a pre- or poststratification.

Assessing Trends

The indicators are designed to provide a measure of condition, but when tracked over time they can also provide an index of change over time. To answer the question *Is there a difference between years?*, we will use a step-trend (box-and-whisker plot) analysis. To answer the question *Is the trend improving, degrading, or staying the same?*, we will use a monotonic (regression) analysis. Trend analyses can be reported every year, with increasing certainty over time.

Estimated Costs

Establishment of a statewide coordinated effort may be able to leverage other funds, especially if it is linked to programmatic interests and national efforts such as the EPA EMAP program. There may also be opportunities to build on existing state and federal programs and program budgets.

The estimated cost for collecting, processing, managing, and analyzing data is about $8,126/site with a design of 50 sites for 5 provinces plus 50 reference sites. Tables 7–9 summarize and break down costs. The costs/site vary, depending on the design, because some expenditures do not change with increasing sample size. For example, two data managers and analysts are recommended, regardless of sample size (Tables 8 and 9). Total costs over 5 years are estimated at $5.8 million to report on 15 Oregon Plan Basins. Costs range from $2.5 million to $12.9 million, depending on study design decisions.

Table 7. Number of samples and total estimated costs for the various classification systems.

Classification System (number)	Number of Trend and Reference Sites over 5 Years (and per Year)	Estimated Annual Costs ($)	Estimated Rotating Panel Costs over 5 Years ($)
DEQ provinces (5)	300 (60)	487,564	2.5 million
Fishery basins (8)	450 (90)	693,346	3.5 million
OWEB basins (15)	800 (160)	1,154,192	5.8 million
*DEQ provinces (5), 3 subclasses	900 (180)	1,265,724	6.3 million
*Fishery basins (8), 3 subclasses	1350 (270)	1,570,038	7.9 million
*OWEB basins (15), 3 subclasses	2400 (480)	2,574,512	12.9 million

*150 reference sites rather than 50, due to 3 subclasses within each landscape class.

Table 8. Estimated annual and 5-year costs for five provinces without subclasses. The calculations assume 60 sites/year for a total of 50 sites per province and 50 reference sites after 5 years.

Expenditure	Annual Costs ($) for 60 Sites	Estimated Costs ($) over 5 Years for 300 Sites
2 crews of 3 @$5000/mo for 4 months to do 60 sites	120,000	600,000
Travel ($85/night-commercial) 5 nights for 3 months for 6 people	24,480	122,400
Project Coordinator	110,000	550,000
Data Manager and Analyzer (@$95K/year) step 3	95,000	475,000
Data Manager and Analyzer (@$105K/year) step 4	105,000	525,000
Vehicles-2 @$1000/mo for 3 months with travel plus 9 months "parked"	12,000	60,000
Overtime (10 hours/week) @$22/hour	1,584	7,920
WQ Data/lab processing @$125/site	7,500	37,500
I-IBI Data/lab processing @$150/site	9,000	45,000
V-IBI Data/lab processing @$50/site	3,000	15,000
TOTAL	**487,564**	**2,437,820**
Per-site estimate	**8,126**	

Table 9. Annual costs ($) for various classification schemes.

	Classification System				
	8 fisheries basins	15 OWEB basins	5 DEQ provinces, 3 subclasses	8 fisheries basins, 3 subclasses	15 OWEB basins, 3 subclasses
5-year Sample Size	**Number of Reaches**				
50/unit plus 50 reference reaches (no subclass) or 150/unit plus 150 reference reaches (3 subclasses)	450	800	900	1350	2400
	Number of Crews and Expenditures ($)				
Explanation of Costs	**3**	**6**	**7**	**9**	**16**
3 people/crew @5000/mo, including OPE, for 4 months to do 30 sites	180,000	360,000	420,000	540,000	960,000
Travel ($85/night-commercial) 5 nights for 3 months for each crew member	36,720	73,440	85,680	110,160	195,840
Project Coordinator: (1 for 2–3 crews, 2 for 6–9 crews, 3 for 16 crews), including OPE	110,000	220,000	220,000	220,000	330,000

continued

Table 9. continued

	Classification System				
	8 fisheries basins	15 OWEB basins	5 DEQ provinces, 3 subclasses	8 fisheries basins, 3 subclasses	15 OWEB basins, 3 subclasses
Data Manager and Analyst[1] (@95K/year including OPE) step 3	95,000	95,000	95,000	95,000	95,000
Data Manager and Analyst[1] (@105K/year including OPE) step 4	105,000	105,000	105,000	105,000	105,000
Vehicles: 2@$1000/mo: 3 months with travel, 9 months “parked”	18,000	36,000	42,000	54,000	96,000
Overtime (10 hours/week), $22/hour	2,376	4,752	5,544	7,128	12,672
WQ Data/lab processing @125/site	56,250	100,000	112,500	168,750	300,000
I-IBI Data/lab processing @150/site	67,500	120,000	135,000	202,500	360,000
V-IBI Data/lab processing @ 50/site	22,500	$40,000	45,000	67,500	120,000
Annual total:	**693,346**	**1,154,192**	**1,265,724**	**1,570,038**	**2,574,512**
5-year total:	**3,466,730**	**5,770,960**	**6,328,620**	**7,850,190**	**12,872,560**

[1]Cost is the same regardless of sample size

NEXT STEPS

1. The INR recommends that OWEB begin to build understanding, acceptance of, and support for the proposed indicators and priorities from state, federal, and local governments and nongovernmental organizations.
2. The proposal to integrate monitoring programs at the level of data collection presents several organizational and budgetary challenges that will require strong partnerships. OWEB should assess how much support for integrated monitoring is available from state, federal, and local partners.
3. Although the proposed study design builds on current Oregon Plan monitoring approaches, it will need further refinement to ensure that it is adapted to partner programs such as state conservation plans. Before state-wide integrated data collection begins, a pilot study to identify areas for improvement and increase the likelihood for longer term success would be valuable.
4. OWEB should work with partners to further refine and define study designs and associated costs for collecting data on the indicators not addressed in the study design section of this paper.

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Appendix A: Summary Table of Indicators for the State and Nation in Comparison to Proposed Oregon Plan Environmental Indicators

Table A-1. Comparison of various program indicators, parameters, and attributes to the proposed Oregon Plan Indicators (OPIs).

Source	Riparian and Aquatic Ecosystems								Terrestrial Ecosystems		Estuarine Ecosystems		Biodiversity		
Proposed Oregon Plan Watershed Indicators (this document)	**1. Anadromous fish**	**2. Cold-water Index of Biotic Integrity**	**3. Water Quality Index**	**4. Riparian & wetland vegetation**	5. Riparian function	6. Condition of physical aquatic, estuarine habitat	7. Access to freshwater, estuarine habitat	8. Frequency of meeting instream water rights	9. Area, distribution, and types of cover	**10. Change in land use & land cover**	11. Tidal & submerged wetlands	12. IBI and WQI for estuaries	13. Native plant & animal species	14. At-risk species	15. Percent of nonnative invasive species
Oregon Progress Board Benchmarks *(Oregon Progress Board 2003)*	*Overlap*: Benchmark 87 (see OPI 15)	Not addressed	*Same:* Benchmark 78: Percent of streams with (a) increasing and (b) decreasing water quality trends, and (c) good to excellent condition	*Same:* Benchmark 77: Freshwater wetland acreage change/year	----------Not addressed----------			Benchmark 79: Percent of key streams meeting minimum flow rights (a) 9 or months out of the year and (b) 12 months out of the year	See OPI 10	*Same:* Benchmark 80: Percent of agricultural land in 1982 not converted to urban or rural development Benchmark 81: Forest land preserved for forest use	*Same:* with additional detail on type of estuarine wetland Benchmark77: Freshwater wetland acreage change per year	-------Not addressed-------		*Same:* Benchmarks 85 & 87: Percent of monitored freshwater and terrestrial species not at risk (state or federal listing)	*Overlap*: Benchmark 89: Number of most threatening invasive species not successfully excluded or contained since 2000
Pacfish/Infish Biological Opinion Monitoring Team (PIBO) *(Kershner et al. 2004)*	*Overlap:* Biological parameters are collected	*Overlap*: Invertebrate community structure	*Overlap:* Water quality Temperature	*Overlap*: Effective ground cover	*Overlap*: Fragmentation of riparian vegetation Seral stage/ structural complexity of riparian vegetation	*Overlap*: Floodplain interactions connectivity Distribution of large wood Cross section mapping Width to depth ratio Longitudinal profiles, residual pool depth, bank angles, percent undercut bank, substrate, bank stability	*Overlap*: Number of culverts and stream crossings	Not addressed	Harvest history	*Overlap*: Equivalent road acres Road density hydrologically connected Number of culverts and stream crossings Culvert failure rate Mining history Fire frequency Landslide frequency, size, location Livestock management	----------Not addressed----------				
Pacific Northwest Aquatic Monitoring Partnership *(PNAMP 2004)*	*Overlap*: Adults: escapement, age structure, size, sex ratio, origin,genetics, and fecundity Number and distribution of redds Parr/juvenile: abundance, distribution, and size Smolts: number, size, genetics	*Overlap*: Macroinvertebrates transport and composition	----------Under development----------						Under development: current focus is on consistent roads layer and landslide modeling		-------Not addressed-------			Not addressed. Focus is on aquatic species	

Source	Riparian and Aquatic Ecosystems								Terrestrial Ecosystems		Estuarine Ecosystems		Biodiversity		
Proposed Oregon Plan Watershed Indicators (this document)	**1. Anadromous fish**	**2. Cold-water Index of Biotic Integrity**	**3. Water Quality Index**	**4. Riparian & wetland vegetation**	5. Riparian function	6. Condition of physical aquatic, estuarine habitat	7. Access to freshwater, estuarine habitat	8. Frequency of meeting instream water rights	9. Area, distribution, and types of cover	**10. Change in land use & land cover**	11. Tidal & submerged wetlands	12. IBI and WQI for estuaries	13. Native plant & animal species	14. At-risk species	15. Percent of nonnative invasive species
EPA's DRAFT Report on the Environment[1] *(EPA 2003)*	Addressed if considered an "at risk species" and as part of an IBI	*Overlap*: Benthic Community Index	*Overlap*: Nitrate levels in streams Total nitrate load (ecological process) Additional parameters (e.g., phosphorus, sediment, pesticides, chemical contamination)	*Overlap*: Wetland extent and change and sources of change	*Overlap*: Percent of riparian areas in urban and agricultural lands	Parameters are more typical of those reported under OPI 3: Temperature Nitrate levels in streams Report notes the need to relate these qualities to status of aquatic species	Not addressed	*Overlap*: Change in timing, magnitude of stream flows	*Overlap*: Extent of 6 "ecosystem types" identified by Heinz Center (2002)	*Same*: Extent of developed, urban and suburban, agricultural, grasslands and shrublands, and forested lands Forest ownership and management Soil erosion Forest disturbance: fire, insect, and disease	*Overlap*: See OPI 4	*Same*: Benthic Community Index for Coastal Waters Multiple water-quality parameters (e.g., nitrogen, phosphorus, sediment, pesticides, chemical contamination)	*Overlap*: Trends in Invasive and native noninvasive bird species	*Same*	*Overlap*: Trends in invasive and native noninvasive bird species
Upper Columbia Basin Oregon Plan Monitoring Strategy *(Hillman 2003)*	*Overlap*: Adults, redds, parr/juvenile, smolts	*Overlap*: Macroinvertebrates	*Overlap*: Data used for WQI are same	*Overlap*: Structure, disturbance, cover	*Overlap*: Structure	*Overlap*	*Overlap* or *Same*	Change in peak, base, and timing of flows	None—although may overlap with watershed disturbance	None—although may overlap with watershed disturbance, road, and railroad density	----------Not addressed----------				
Environmental Attributes for Ecosystem Diagnostic Treatments (EDTs) (*Mobrand Biometrics, Inc. 2003*)	*Overlap*: Fish community richness, pathogens, nonnatives, hatchery, predation, salmon carcass	*Overlap*: Macroinvertebrate diversity and production	*Overlap*: Chemistry and temperature	Not addressed	*Overlap*: Riparian function, wood	*Overlap*: Embeddedness, fine sediment, turbidity, scour, habitat type, confinement, morphology	Not addressed	*Overlap*: Water withdrawals, flow variation, hydrologic regime	----------Not addressed: focus on fish and streams----------						Not addressed, outside of focus on nonnative fish
Environment and Sustainable Development Indicators for Canada *(NRTEE & TRNEE 2003)*	-----------Not addressed----------		*Overlap*: Water quality indicator: scope, frequency and amplitude of problem	*Overlap*: Extent of wetlands	----------Not addressed----------				*Overlap*: Changes in forest cover—12 ecotones	---------- Not addressed ----------					

Source	Riparian and Aquatic Ecosystems								Terrestrial Ecosystems		Estuarine Ecosystems		Biodiversity		
Proposed Oregon Plan Watershed Indicators (this document)	**1. Anadromous fish**	**2. Cold-water Index of Biotic Integrity**	**3. Water Quality Index**	**4. Riparian & wetland vegetation**	5. Riparian function	6. Condition of physical aquatic, estuarine habitat	7. Access to freshwater, estuarine habitat	8. Frequency of meeting instream water rights	9. Area, distribution, and types of cover	**10. Change in land use & land cover**	11. Tidal & submerged wetlands	12. IBI and WQI for estuaries	13. Native plant & animal species	14. At-risk species	15. Percent of nonnative invasive species
Oregon Department of Forestry—Core indicators from Montreal Process[2] *(ODF 2003)*	*Same/ Overlap*: Soil and Water (S&W) Resources 23: % water bodies in forest areas outside range of historic variability in biological diversity		*Overlap*: S&W Resources 24: Water-quality limited streams S&W Resources 18 Erosion	*Overlap*: Techniques for evaluating riparian forests are addressed in the sustainability plan	See OPI 4	-----------------------Not addressed-----------------------			*Same:* Biodiversity 1: Area by forest type Biodiversity 2: Area by successional stage Biodiversity 3 Area by forest type in protected categories Productive Capacity 10, 11, 13, and 14	*Overlap:* Ecosystem Health 15: Area affected by processes or agents beyond range of historic condition. Global Carbon Cycle 27: Contribution from Oregon' forests	----------Not addressed-------		*Overlap*: Biodiversity 9 Population levels of representative species	*Same:* Biodiversity 7- Status: rare, threatened, endangered	See OPI 11
Biodiversity and Land Use Indicators– Washington, DC 2000 Workshop *(Institute for Environmental Research and Education et al., draft 6-11-02)*	----------Not addressed-----------		*Overlap:* Assimilation of toxins by land and water	*Overlap*: Area of physically or legally protected riparian vegetation	----------------------Not addressed--------------------			Modification of natural hydrologic function Depletion of surface and ground water	*Overlap*: Distribution of native managed versus total managed and size of managed versus average field size Connectivity of native habitat with managed and natural habitat	Protection indicators described under OPI 1 Road density Number of biodiversity-linked BMPs Soils: Organic carbon Protection of priority habitats and species	---------Not addressed------		*Overlap* Percent area dominated by native vegetation Restoration of native vegetation in previous year	Not addressed	*Overlap*: Coverage of nonnative species within protected areas
The State of the Nations Ecosystems *(Heinz Center 2002)*	Not addressed	Status of fish and bottom-dwelling animals in urban and suburban streams	Nitrogen movement Chemical contamination	Extent, fragmentation, and pattern of 6 major ecosystems (overlaps with OPIs 9 and 12)	*Overlap*: Riparian condition for grasslands and shrublands Streamside vegetation for urban areas	Nitrogen movement Chemical contamination Stream habitat quality Phosphorus in lakes, reservoirs, large rivers	Not addressed	Changing streamflows Water withdrawals	*Same:* Extent, fragmentation, and pattern of 6 major ecosystems (overlaps with OPIs 4 and 12) *Overlap*: Forest age Forest and grassland/ shrubland carbon storage	*Same:* Reported over time with extent Public or private ownership of forests Forest community types Impervious area for urban areas *Overlap*: Condition of plant and animal communities Plant Growth Index by ecosystem Cropland soil erosion, organic matter, salinity	*Same:* Extent, fragmentation, and pattern of 6 major ecosystems (overlaps with OPIs 4 and 9)	Nitrogen movement Chemical contamination	*Overlap*: Native vegetation for cropland Nonnative for forest land, grasslands and shrublands	*Same:* At -risk native species	*Overlap*: Reported for 6 ecosystems Population trends in invasive and noninvasive birds for grasslands and shrublands

Source	Riparian and Aquatic Ecosystems								Terrestrial Ecosystems		Estuarine Ecosystems		Biodiversity		
Proposed Oregon Plan Watershed Indicators (this document)	**1. Anadromous fish**	**2. Cold-water Index of Biotic Integrity**	**3. Water Quality Index**	**4. Riparian & wetland vegetation**	5. Riparian function	6. Condition of physical aquatic, estuarine habitat	7. Access to freshwater, estuarine habitat	8. Frequency of meeting instream water rights	9. Area, distribution, and types of cover	**10. Change in land use & land cover**	11. Tidal & submerged wetlands	12. IBI and WQI for estuaries	13. Native plant & animal species	14. At-risk species	15. Percent of nonnative invasive species
Pacific Coast Salmon Recovery Fund 2002 Workshop: (Breakout group to discuss indicators for restoration projects)	*Overlap*: Fish abundance	*Overlap*: Primary productivity, macroinvertebrates	*Overlap*: Temperature and sediment	*Overlap*: -----Vegetation measures-----		*Overlap*: Large woody debris loading	*Overlap*: Barriers, fish presence or absence	*Overlap*: Hydrology	Not addressed: focus on fish and streams with minimal overlap, such as decommissioning roads				Addressed only with respect to fish, other aquatic organisms		*Overlap*: Invasive riparian plants
Measuring Success: Biodiversity and Habitat Indicators at Multiple scales. Workshop *(Institute for Natural Resources et al. 2002)*	Not addressed except as under OPI 2	*Overlap*: Index of "aquatic integrity", including biological factors	Addressed under OPI 2	*Same*: Amount and distribution of riparian vegetation	Not addressed	Addressed under OPI 2	Not addressed	*Same*: Amount available for ecological needs	*Same*: Ecosystem extent: distribution of native habitats relative to modified ones *Overlap:* Fragmentation of native habitats	Addressed under OPI 9 when tracked over time *Overlap*: Conditions relative to historic range of variability Soil organic matter (although no consistent metric)	Not addressed	Not addressed explicitly for estuaries; may be covered under OPI 2	*Overlap*: Terrestrial invertebrates (although no consistent metric)	*Same*: Number or proportion of at-risk species	*Same*: Distribution and extent of invasive species
Evaluation of Montreal Process Indicators for Sustainable Forest Management *(Salwasser and Fritzell 2002, shown in parentheses*)	(Consider number of species occupying a small portion of their former range)	------------Not addressed------------							*Overlap* for forests: Area by type, age classes, successional stages Fragmentation Area in protected categories (protection needs to be defined through policy, improved utility when arrayed by age class or successional stage)	Area in protected categories (See OPI 9)	---------Not addressed-------		Number of forest – dependent species (more useful if arrayed by forest type and structural stage) and Occupying a small portion of their former range Population levels from diverse habitats	Rare, threatened, endangered, or extinct forest species (not useful if habitat data are lacking)	Not addressed
Willamette Initiative *(OWEB 2001a and b)*	Percent classified as healthy	*Same:* For invertebrates	*Same*	*Overlap* Wetland area compared to historic	*Same:* Amount of intact or functional riparian area, compared with 1990	Focuses on IBI, water quality, upland conditions	Not addressed	*Same*: Instream water right being met Consumption in priority watersheds during Aug-Sept	See description under OPIs 10 and 11	Trends in soil quality and erosion rates Timber harvest relative to sustainable levels	---------Not addressed---------		*Same*	*Overlap*: Percent protected in conservation areas	*Same*

Source	Riparian and Aquatic Ecosystems								Terrestrial Ecosystems		Estuarine Ecosystems		Biodiversity		
Proposed Oregon Plan Watershed Indicators (this document)	**1. Anadromous fish**	**2. Cold-water Index of Biotic Integrity**	**3. Water Quality Index**	**4. Riparian & wetland vegetation**	5. Riparian function	6. Condition of physical aquatic, estuarine habitat	7. Access to freshwater, estuarine habitat	8. Frequency of meeting instream water rights	9. Area, distribution, and types of cover	**10. Change in land use & land cover**	11. Tidal & submerged wetlands	12. IBI and WQI for estuaries	13. Native plant & animal species	14. At-risk species	15. Percent of nonnative invasive species
Aquatic and Riparian Effectiveness Monitoring Program *(Reeves et al. 2001)*	*Overlap/Same*: Biotic integrity: amphibians and fish; macroinvertebrates, community, multimetric indices		*Overlap*: Water temperature Nitrate, phosphorus, etc.	*Overlap*: Riparian vegetation— seral stage and association		*Overlap*: Channel connectivity with floodplain in unconstrained reaches Channel cross-section, sinuosity, pools, complexity Substrate composition Off-channel habitat	*Overlap*: Density of crossings	*Overlap*: Water quantity (alteration of flow regime)	See OPI 10	*Overlap*: Seral stage and series Road density Landslides	---------Not addressed---------		Not addressed in AREMP, but may be in other portions of the Northwest Forest Plan		
Ecological Indicators for the Nation *(National Research Council (2000)*	---------------Not addressed----------		*Overlap*: Nutrient runoff Lake trophic status Stream oxygen May be able to apply production capacity (see OPI 11)	---------Not addressed--------		May be able to apply production capacity (see OPI 11)	-------------Not addressed-------------		*Overlap*: Extent and status of land use and land cover	*Overlap*: Soil organic matter Carbon storage Production capacity Nutrient use efficiency Nutrient balance (ecological function)	May be able to apply production capacity (see OPI 11)	Not addressed	*Overlap*: Total species diversity, native species diversity Net primary productivity (ecological function)		
Oregon State of the Environment Report *(SOER Panel 2000a,b)*	*Overlap* Percent of native fish classified as healthy Population level of commercial and sport fishing harvest	Relates to that listed under OPI 1	*Same:* WQI: trends and percentage of streams in good to excellent Plus WQI for estuaries	*Same:* *Plus* change in wetland diversity and distribution Connectivity with other aquatic resources Hydrologic characteristics	*Overlap* Riparian function (miles consistent with functional plant communities) Invertebrate index of riparian health Urban riparian area intact and/or providing hydrological and biological services	*Overlap*: Habitat quality of urban streams, lakes and rivers	Not addressed	*Overlap*: Allocation during low flow	*Overlap*: Acres of forest structural stage compared with historic landscape pattern *Plus* Rangelands—vegetation patterns compared with natural range with fire regime	*Overlap:* Forest land conversion Forest management activity Urban land conversion to other uses/covers **Forests** Sustainable timber harvest Large conifers Annual tree growth **Rangelands** Plant species that influence ecological processes Ecological condition of degraded areas Soil erosion Sustainable livestock production **Ag lands** Adoption of sustainable practices Soil erosion rates	*Same:* *Plus* habitat in protected areas, freshwater inflow	*Same*: WQI	*Same*: Forests Species diversity All Change in native vegetation types Native habitat distribution	*Same:* Percent protected in conservation areas At risk stocks of marine fish, shellfish Trends in extinctions or endangered fish communities (these can be tracked with IBI as well)	*Same*

Source	Riparian and Aquatic Ecosystems								Terrestrial Ecosystems		Estuarine Ecosystems		Biodiversity		
Proposed Oregon Plan Watershed Indicators (this document)	**1. Anadromous fish**	**2. Cold-water Index of Biotic Integrity**	**3. Water Quality Index**	**4. Riparian & wetland vegetation**	5. Riparian function	6. Condition of physical aquatic, estuarine habitat	7. Access to freshwater, estuarine habitat	8. Frequency of meeting instream water rights	9. Area, distribution, and types of cover	**10. Change in land use & land cover**	11. Tidal & submerged wetlands	12. IBI and WQI for estuaries	13. Native plant & animal species	14. At-risk species	15. Percent of nonnative invasive species
Pacific Northwest Salmon Habitat Work Group *(Green Mountain Institute for Environmental Democracy 1998)*	*Same*: Fish abundance Spawning area	*Same*: IBI, may be using different model?	*Overlap*: Temperature Chemical WQI, multi-parameter	*Overlap*: Extent of riparian, off-channel, wetland habitat	*Overlap*: Value of riparian and wetland habitat to salmonid life cycle	*Overlap*: Large woody debris Stream depth Sediment Spawning area (also OPI 1)	*Same*: Number of locations where salmon are impeded, by type, and the amount, by type, of historical habitat inaccessible	*Same*: Plus seasonal flow required by salmonids and/or sufficient to allow salmonid access	Not addressed	*Same*: Land use and land cover: % converted between various land uses with emphasis on floodplain and riparian areas Impervious surface *Overlap*: Transportation impacts	*Overlap*: Value wetland habitat to salmonid life cycle	*Overlap*: Extent of estuarine habitat and value to salmonid life cycle	---Not addressed---		
Northwest Environment Watch *(2002)*	---Not addressed---									*Same*: Urban sprawl			Not addressed		

[1]Each indicator is reported for the 6 ecosystem types identified by Heinz Center 2002.
[2]Nine socioeconomic and legal and institutional framework indicators were not included in this table.

NOTE: Other efforts in Oregon currently underway that may influence the selection of indicators include the Oregon Technical Recovery Team, development of a Statewide Conservation Plan (ODF&W), and state agency sustainability plans.