Identifying Ecological Indicators of Climate Change and Land Us Impacts to a Coastal Watershed

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Executive Summary

Climate change and land use impacts are growing concerns for communities, policy-makers, scientists and land managers around the world. Coastal communities are increasingly faced with the effects of climate change and land use impacts as sea levels rise, weather patterns change while development and population growth increases pressure on those coastal ecosystems.

The Coos Watershed Association (Coos WA) and the South Slough National Estuarine Research Reserve (SSNERR) are located in the Coos Watershed on the southern coast of Oregon. Coos WA and SSNERR formed the Partnership for Coastal Watersheds (The Partnership) to address the growing pressures of climate and land use changes. A grant from the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) and the Norton Family Foundation ă dzLJLJ 2 NJ ű ă ű K Ŝ t l· NJ ű ƴ Ŝ NJ objectives, which are:

1) To monitor the long-term impacts of climate and land use changes to the Coos Watershed through the development of an ecological indicators program.
2) To evaluate the effectiveness of management and restoration efforts through an adaptive management process informed by an ecological indicators program.

Within the larger Coos Watershed, the Partnership identified the South Slough Coastal Frontal Watershed as the pilot study area for the initial development of indicators program because the area has not yet been assessed by the Coos WA and it is the location of the SSNERR, which maintains long-term environmental data about the watershed. The Partnership aims to use the pilot study area to demonstrate the Coastal Watersheds Ecosystem Management Process, an integrated ecosystem decision-support process. The process brings together scientists, resource managers, and community members to respond to local problems associated with climate change and changing land use patterns. This partnership will build on current local and regional ecosystem management efforts to demonstrate a decision-support process focused on adaptively managing the effects of land use and climate change in the South Slough and Coastal Frontal watersheds (Coos WA and SSNERR 2009).

The Partnership identified the Pressure-State-Response (PSR) framework as the structure within which to develop their indicators program. The PSR framework, developed by the Organisation for Economic Co-operation and Development, is widely used because its premise is easily understood by stakeholders including, scientists, managers, citizens and policymakers. This framework is based on the idea that human activities can change the state of an ecosystem and its individual components. When those changes are undesirable to society, this can prompt action to mitigate the effects of those human activities through policies and actual changes to the environment, such as restoration efforts.

To assist with the initial stages of the indicator development process, the Partnership collaborated with the Field Naturalist Program at the University of Vermont. The goals of this project were

1) To apply the PSR ŀ NJ l· Ÿ Ŝ ǿ 2 NJ ȴ ű 2 ű K Ŝ t l· NJ ű ƴ Ŝ NJ ă K ƛ LJ Ω ă LJ ƛ ƒ 2 ű ă ű
2) To identify applicable ecological indicators already in use through a review of literature and existing indicator programs.

3) To use stream temperature as an example indicator by taking it through the PSR framework.

The goal of this report is to provide a resource for managers, citizens and policymakers to use as a reference for understanding the development process for ű K Ŝ t ŀ NJ ecological indicators pilot program This reports steps through the process of using the Pressure State Response framework. It then uses stream temperature as an example potential indicator by taking it through the PSR framework for the Coos Watershed Indicators Program.

Finally, overall recommendations are focused on data collection, Quality Assurance-Quality Control (QAQC) protocols, and on communicating indicators to the public. It is recommended that The Partnership develop QAQC protocols for data collection. The recommendations for stream temperature data collection are to reduce the number of stream stations to 4 key locations, while ensuring that the data from those stations are consistent in quality. To help ensure quality data collection, it would be helpful to place two temperature units at each location, which would allow the manager to check the accuracy of the units while also assuring data collection should a unit fail or become lost.

Lastly, indicator programs that plan to report on the status and trends of an ecosystem, such as the Coos Watershed, should be linked to public values and should involve the public in the development of those indicators. Therefore, it is recommended that The Partnership hold multiple Coffee Klatches throughout the indicator development process to assess stakeholder values, refine indicator selection and to create a common language for communicating indicator information.

As pressures from climate and land use changes increase coastal communities, the importance of understanding how these changes are impacting human and natural communities also grows. The Partnership must have the support and trust of the Coos Watershed community in their efforts to track ŀ ƴ Ř ŀ Ř ŀ LJ ű ƛ Ǿ Ŝ ƒ ѐ Ƴ ŀ ƴ ŀ ∃ Ŝ ű Ƙ Ŝ / ƻ ƻ ă ² ŀ ű Ŝ NJ ă -based effort Ŏ Ƙ ŀ ƴ ∃ ƛ ű ƻ ō dz ƛ ƒ Ř ű Ƙ Ŝ / ƻ ƻ ă ² ŀ ű Ŝ NJ ă Ƙ Ŝ Ř Ω ă NJ Ŝ ă ƛ ƒ ƛ Ŝ ƴ Ŏ Ŝ ŀ ƴ Ř ŀ Ř ŀ LJ change pose now and in the future.

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Abbreviations

Abbreviation	Definition
7dAM	7 day average maximum; moving average
CICEET	The Cooperative Institute for Coastal and Estuarine Environmental Technology
Coos WA	Coos Watershed Association
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
EPA	Environmental Protection Agency
EPIC	Environmental Protection Indicators for California
HUC	Hydrologic Unit Code
NERRS	National Estuarine Research Reserve System
ODF	Oregon Department of Forestry
ODFW	Oregon Department of Fish and Wildlife
OECD	Organisation for Economic Co-operation and Development
OIMB	Oregon Institute of Marine Biology
OWEB	Oregon Watershed Enhancement Board
PNW	Pacific Northwest
PSR	Pressure-State-Response framework
SSNERR	South Slough National Estuarine Research Reserve
SWMP	System Wide Monitoring Program
TAG	Technical Advisory Group

Image Credits

Cover: Author, June 28, 2009.

Page 5: Author, July 2009

Page 7: Daniel Draper, Coos Watershed Association

Pages 3, 25, 29, 36, 37, 39, and 40: University of Oregon 1930 photo Archives

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Introduction

Located on the southern coast of Oregon, the Coos Watershed is a coastal watershed where communities face increasing pressures from climate and land use changes. The Coos Watershed Association and the South Slough National Estuarine Research Reserve are partnered to develop an ecological indicators program to track the condition of the Coos Watershed and to evaluate the effectiveness of their management actions.

Indicators are common in our everyday lives. They are meant to inform us quickly and easily about the condition of something of value to the society. For example, we follow unemployment rates among other economic measures to get an understanding of the state of the economy. Likewise with human health, blood pressure is measured and tracked to provide a quick assessment of the state of our health. An indicator is a measure of some characteristic, which is used to represent a host of other characteristics as a whole; these other
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measured and may never be measured.

Indicators are meant to inform us quickly and easily about something of interest. They communicate how the condition of a specific measure is changing over time and any
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not possible to measure everything ű (National Research Council, 2000)

The information we receive from monitoring unemployment rates or our blood pressure might cause government officials to propose new legislation, while a result of high blood pressure might cause an individual to change their eating or exercise habits. We continue to follow unemployment rates or our blood pressure to evaluate whether our responses are changing those previous undesirable conditions.

Similarly, ecological indicators are used to give us a picture of an ecosystem Ω ă Ŏ ƨ ƴ and to Ř ű ƛ ƨ ƴ Σ help guide our management decisions and actions. Ecological indicators are used to establish the condition of an ecosystem by using a few, specific measures that indicate the larger picture τ ű Ƙ Ŝ Ŝ Ŏ ƨ ă è ă ű Ŝ Ƴ Ω ă Ŏ relative to what is accepted according to ă Ŏ ƛ Ŝ ƴ ű ƛ ă ű Ω ă ˄ ƴ ƨ ǿ f Ŝ Ř ∃ Ŝ ŀ ƴ Ř

The use of indicators in environmental management is growing, especially in response to climate change and land use impacts to communities and their surrounding environments. Increasingly, scientists, public officials and citizens want to know how to identify signals of climate change and how to address the associated impacts to the environment and human communities. Land managers also want to understand more about how to manage for ecosystem resilience in the face of climate and land use changes.
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Indicators of climate and land use impacts are especially important in coastal watersheds, where communities are concerned about rising sea levels, the impacts of a warming climate couple with the increased pressures from land use changes on the ecosystems that comprise and sustain coastal economies.

Audience

This document is intended specifically for the Coos Watershed Association (Coos WA) and the South Slough National Estuarine Research Reserve (SSNERR) for their use in the development of ecological indicators of the impacts of climate and land use changes to the Coos Watershed. It is also for use by natural resource professionals and citizens beyond the

Coos Watershed, looking for a resource about the development of ecological indicators of climate and land use changes in a coastal watershed using the Pressure-State-Response framework.

Purpose

The purpose of this project was to assist the Partnership with the initial stages of the indicator development process. The objectives for the project were:

1) To apply the PSR framework to the t l NJ ű y Ŝ NJ ă K ʎ LJ Ω ă LJ ʎ f ‑ ű
2) To identify applicable ecological indicators already in use through a review of literature and existing indicator programs
3) To use stream temperature as an example indicator by taking it through the PSR framework.

The purpose of this document is to provide the Partnership with a reference that provides background, resources, and recommendations for the indicator development process.

Structure

This document is constructed in four main parts:

Chapter 1 briefly profiles the study area, reviews ecological indicators, and examines land use and climate changes locally.

Chapter 2 reviews ecological indicators and their use in environmental monitoring.

Chapter 3 introduces the PSR framework for developing ecological indicators and applies it to the pilot study area, identifying potential indicators.

Chapter 4 uses stream water temperature as an example indicator taken through the Pressure-State-Response framework.

Chapter 5 offers overall recommendations for the t l NJ ű y Ŝ NJ pilot indicators program. Appendices follow the recommendations, providing additional resources.

Content and Definitions

This document is a synthesis of a fraction of an extremely large body of scientific and social literature about the development and use of ecological indicators to measure, monitor, predict and address human-induced environmental change.

The terms environmental and ecological indicators are often used synonymously (Niemi 2004). Environmental indicators are those measures that represent all the parts of a chain linking human activities to environmental impacts, and ă ‑ Ŏ ʎ Ŝ responses to those impacts (Smeets & Wetering 1999). Thus, environmental indicators are conceptually very broad, encompassing any physical characteristic within an environment.

Ecological indicators are a more specific subset of environmental indicators that apply to ecological processes, are most often biological and respond to chemical, physical and other biological processes (US EPA 2002b). Ecological indicators are derived from the measurement of ecosystem processes in the field and are often combined into ă dz Ɣ Ɣ l NJ ѐ Ǿ l f dz Ŝ ă Σ ă dz Index of Biotic Integrity (IBI) used by the EPA. The most important function of ecological indicators is to measure the response of an ecosystem to anthropogenic disturbance (Niemi 2004, US EPA 2002b).

Indicator programs should be developed within a framework to provide conceptual structure for how to address the environmental questions. The lack of a framework can result in an ineffective program: one in which the objectives are not clear or the indicators do not provide the desired information.

Oregon State University Archives

Document Overview:

Chapter 1 briefly profiles the study area and examines land use and climate changes regionally and locally.

Chapter 2 reviews ecological indicators and their use in environmental monitoring.

Chapter 3 introduces the PSR framework for developing ecological indicators, applies it to the study area, identifying potential indicators

Chapter 4 uses stream water temperature as an example indicator taken through the PSR framework.

Chapter 5 offers overall recommendations for the development of the t ŀNJű ƴŜNJă Ʀ ƛLJΩă program.

Chapter 1: The Coos Watershed & Climate Change

The Coos Watershed

The Coos Watershed is a coastal watershed drained by the Coos River, which enters the Pacific Ocean along the southern coast of Oregon. Tucked into the biologically rich temperate rainforest, the watershed comprises 390,000 acres, of which roughly 85% is privately owned (Coos Watershed Association). Estuaries, upland forests, riverine ecosystems and increasing urban development broadly characterize the landscape of the Coos Watershed.

Through the Oregon Watershed Enhancement Board (OWEB) and external grant funding, the Coos Watershed Association (Coos WA), a 501(c)(3) non-profit, works collaboratively with local landowners and other environmental organizations to test and implement science-based management practices that support the ecological and economic integrity of the Coos Watershed (Coos Watershed Association).

South Slough National Estuarine Research Reserve is a 4,800-acre natural area located in the Coos estuary on the south coast of Oregon. Designated in 1974 as the first reserve of the National Estuarine Research Reserve System (NERRS), established by Congress as part of the Coastal Zone Management Act (CZMA). NERRS is a network of estuarine habitats protected and managed for research, education and coastal stewardship. The NERRS also has the System-Wide Monitoring Program (SWMP). Initiated in 1995 to provide standardized data on national estuarine environmental trends, SWMP also allows each reserve to use the data collected to address specific coastal management issues of regional or local concern.

Climate Change

The difference between weather and climate can be confusing. They are defined differently, but are directly related, differing in time scale. Weather describes short term atmospheric conditions, while climate is the long term pattern of weather in an area, which is simply the nature of the weather over a relatively long period of time (NOAA, February 2005)

How is climate change defined? The Intergovernmental Panel on Climate Change defines climate change as a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. The United Nations Framework Convention on Climate Change (UNFCCC) makes a distinction between natural climate variability and a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere, and which is in addition to natural climate variability observed over comparable time periods (IPCC 2007).

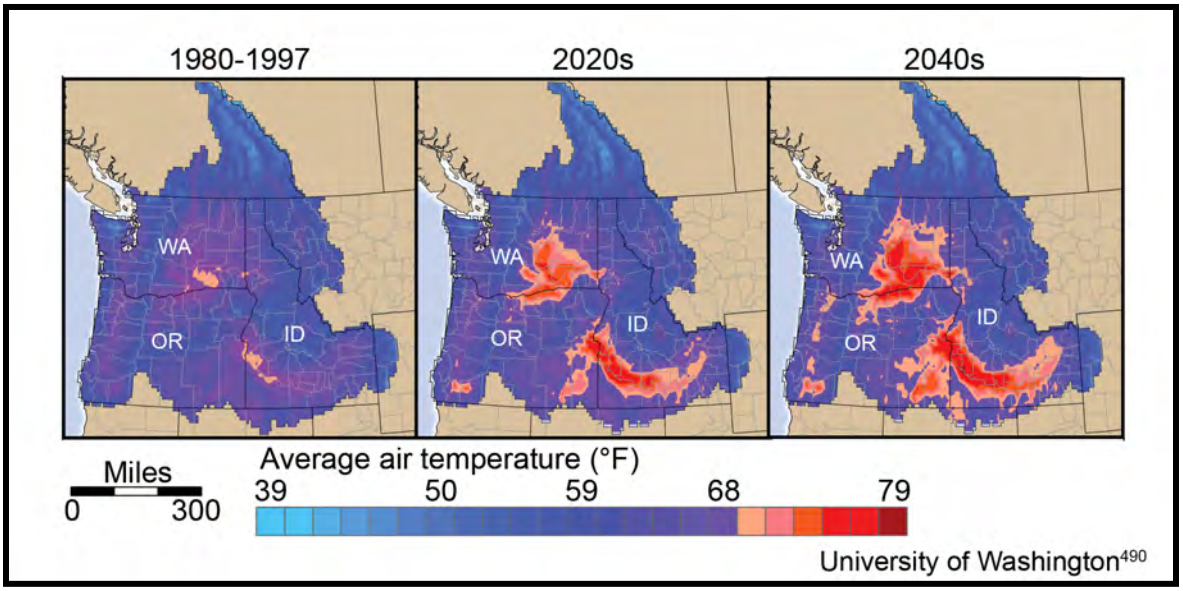

Figure 1: Historical and projected average air temperature change for the PNW. ***U.S. Global Change Program***

Climate Change Models

Most climate change models are global climate models (GCMs), and regional climate models (RCMs) are extrapolated from larger global climate models and modified to account for complex topographical features and land cover heterogeneity (IPCC 2007). While RCMs continue to improve their statistical accuracy at finer spatial scales, they are limited because they do not account for feedback loops between global and regional climate models. RCMs are also limited because the temporal scale at which GCMs are established does not match the finer scale data needed for regional models (IPCC 2007).

Thus climate changes at the local scale, such as the Coos Watershed, cannot be easily extrapolated from the larger global and regional climate models because of local differences in topography, land use, vegetation, weather patterns and overall general climate variations. It may be more useful for local environmental managers to identify specific, sensitive indicators of climate change through which impacts can be observed, allowing local management actions to be focused on ecological climate preparedness and resilience, which does not exclude humans in that system

Expected Regional and Local Climate Changes

For this project, local air temperature, precipitation, and wind data from the North Bend Regional Airport NOAA weather station were analyzed and compared to regional trends (see Appendices E-G). Another source fo regional data and local climate modeling is the Climate Leadership Initiative (CLI), which is a research collaborative between the Resource Innovation Group and the University of hNJŜ∃ƻ ƴΩă Lƴăű ƛűdzűŜ Ŧ ƻNJ Environment. CLI provides technical assistance to an array of organizations to help develop solutions to the complex problems global climate change presents for communities.

According to the Regional Climate Impacts Report published by the U.S. Global Change Research Program (USGCRP), the northwest is already experiencing the effects of climate change. Average annual air temperature has increased by 2 degrees in the past century, with some locations experiencing a 4-degree increase.

The U.S. Global Change Program predicts several factors will affect communities on the Pacific coast. Among the impacts identified are sea-level rise; increased spring run-off and increased summer drought; higher water temperatures; ocean acidification and changing ocean currents. Each is projected to impact the NortĶ ǿŜăűΩă ǿŜŀűĶŜNJ coastal LJŀ űŜNJǻăΣ ecosystems and fisheries (U.S. Global Change 2009).

In a consensus report on the potential impacts of climate change in the Pacific Northwest, 67 scientists agreed on the likely impacts to the major ecosystem processes: temperature, precipitation, sea level, snowpack, marine ecosystems and terrestrial ecosystems.

Temperature

The U.S. Global Change Research Program reports annual average temperature has increased 1.4° F over most of the PNW region in the last century. It is predicted that in the next 10-50 years, temperatures will increase 2.7° F (1.5° C) by 2030 and 5.4° F (3° C) by the 2050s (U.S. Global Change Research Program, 2009) Scientists believe these changes may result in increase elevation of the upper tree line and change vegetation zones, which are trends that would happen over a long period of time. Changes that might occur in a shorter period of time is an increase in the growing season; increased fire season duration; earlier breeding by animals and plants; and longer, more intense allergy seasons because some allergenic plants, which typically flourish in warmer temperatures with increased levels of CO_2 (Ziska, et al., 2003).

Precipitation

There are conflicting reports about precipitation, as climate scientists continue to examine climate change models, and precipitation can be rather difficult weather pattern to analyze and predict, especially at the regional and local scales. Scientists in Oregon report that there is not yet a consistent precipitation signal in the Western states, however from 1916 to 1997 scientists have concluded that there was a moderate increase in precipitation (Water Resources Breakout Group, 2004). Since the beginning of the 20th Century however, the USGCRP reports that precipitation has increased across the PNW region by an average of 10 percent.

The IPCC climate models suggest the PNW will see increases in winter precipitation and winter storm severity, while summer precipitation will decrease. Increasing air temperatures will likely translate to earlier snowmelt, which when coupled with drier summers could have a number of impacts. Potential impacts agreed upon by scientists in the PNW are:

- Increased water demand due to population growth and development with decreased streamflow, which could result in water shortages and a decrease in the ability to meet instream flow targets.
- Greater stress on fish populations such as salmon because of decreased streamflows and increased air temperatures, creating decreased fish habitat; salinity and pollutant concentration could also become greater threats to fish and shellfish populations, as stream flow decreases and sea level rises

Sea Level

Land on the southern Oregon coast between Florence and Coos Bay has been rising faster than worldwide increases in sea level by roughly 1 mm per year (Abbott, 2004), however land to the north is being submerged by rising sea level at 1.5-2 mm per year. Although the southern Oregon Coast is rising, the Charleston, NOAA station has recorded an increase in sea level.

Sea levels will continue to rise as global temperatures increase, however the impact of sea level rise on the Oregon will vary due to tectonic processes occurring in the Pacific Northwest. It is expected that the Coos Bay area will rise faster than the increased sea level, but the increase in shoreline movement and maximum wave heights from storm surges will still have an impact on near shore and estuarine ecosystems, and in the long term tectonic uplift will not counteract sea level rise (Allan, 2009).

Snowpack

Mote (2003) describes the foremost impact from climate change in the PNW will be reduction in regional snowpack. Between 1950 and 2000, the April 1 snowpack has declined and timing of peak snowpack has changed, so that March streamflows have increased while June streamflows have decreased. Climate scientists report that snowpack at low- to mid-elevations are the most sensitive to warming temperatures (*The Scientific Consensus Statement on the Likely Impacts of Climate Change on the Pacific Northwest*, 2004). Projections suggest the April 1 snowpack will continue to decline with an earlier peak in streamflow.

Marine Ecosystems

In response to changing ocean-atmospheric processes, ocean circulation is predicted to keep changing, although specifically how it will change is unclear. Scientists suggest an increase in the magnitude and duration of seasonal upwelling, as well as an increase in storm severity and surges. The changes in upwelling may increase the severity and duration of hypoxic events off the coast of Oregon like those that occurred in 2002 and 2004 (*The Scientific Consensus Statement on the Likely Impacts of Climate Change on the Pacific Northwest*, 2004)

Terrestrial Ecosystems

It is unclear exactly how terrestrial ecosystems will respond to changing climate patterns, however scientists agree that warming temperatures and decreasing summer precipitation will cause drought stress in forests and increase vulnerability to fire, disease, insects and invasive species (*The Scientific*

Consensus Statement on the Likely Impacts of Climate Change on the Pacific Northwest, 2004) Predictions suggest that species composition in the landscape will shift and the growing season will lengthen.

Land Use and Climate Change

The Pacific Northwest has experienced several decades of population and economic growth at nearly twice the national rate, with the population almost doubling since 1970. Many people are attracted to the region by the temperate climate and outdoor recreation opportunities. Of course, the same environmental qualities that attract newcomers are also stressed by increased development and use (U.S. Global Change Research Program). According to the U.S. Census, the Coos Bay area is the largest urban center directly on the Oregon coast with 30,000 people. The population is projected to increase to 90,000 by 2018.

Urbanization, rural residential development and increased recreational development can alter stream channels and landscape drainage patterns; contribute to nutrient, pesticide and sediment loads in waterways; and, increase bacterial loads and the introduction of invasive, non-native plants and animals (Coos WA, SSNERR 2009).

Scientists suggest climate change will only exacerbate land use impacts to the local environment. Uncertainty exists about how marine and terrestrial ecosystems will change. Scientists suggest changes in land use and other human activities will be convolved with changes in the natural environment, which will have a greater impact on ecosystems (*The Scientific Consensus Statement on the Likely Impacts of Climate Change on the Pacific Northwest*, 2004)

Adaptive Capacity & Climate Change Resilience

The rising pressures faced by coastal communities from climate change and land use impacts have caused scientists and land managers to place a greater focus on adaptive capacity and resilience of both natural and anthropogenic systems (Gibbs, 2009). The scale of global climate change is so large that managers are not able to take actions or create policies at the local scale, which can have a direct and measurable impact on climate change. Instead, managers are focusing on mitigation of the impacts being felt by communities, and management strategies that will increase human and natural Ŏ ƶ Ƴ Ƴ dz ƴ ƛ ű ƛ Ŝ ă adaptive capacity and resilience to climate change pressures.

Resilience is commonly thought of the ability of something to withstand or resist perturbation and still function in the capacity intended (Gibbs, 2009). It is seen as the ability of something to return to a state of equilibrium after a disturbance. This view is largely developed from an engineering viewpoint, which focuses on the design of structures and their resilience to outside forces. Structures can reach a point beyond which their ability to function is destroyed.

When applied to ecosystems, resilience is the ability to maintain core functions, such as nutrient cycling and to maintain flexibility in response to rapidly changing conditions, so that the structure and physical appearance of the system may change, but that the essential functions and services are maintained.

There are many types of ecological indicators. These may offer one way to track an Ŝ Ŏ ƶ ă è ă ű Ŝ Ƴ Ω ă NJ Ŝ ă ƛ ƭ ƛ Ŝ ƴ Ŏ Ŝ ŀ ƴ Ř pressures from climate and land use changes

Chapter 2: Defining Ecological Indicators

Although ecological indicators have not been considered as powerful as the most influential economic indicators because of the complexity of environmental systems, they are gaining importance. Indicators, such as global mean temperature, sea surface temperature and atmospheric carbon dioxide concentrations have gained considerable clout in the last decade as climate changes have become more apparent (National Resource Council 2000). The rate of increase of mean surface temperature in the last 50 years has been +0.13 C per decade, which is nearly double the rate of the last one hundred years. Sea surface temperature has a similar story. The rate of increase in sea surface temperature has been greatest in the last 30-40 years, increasing roughly 0.13 C per decade globally (Solomon, et al., 2007).

These are examples of ecological indicators developed at the global scale, however developing indicators at the local and regional scale of comparable influence ecologically can be challenging for scientists and land managers due to data and resource constraints. Their development however will direct attention to environmental conditions in our communities and can help to shape policy at the local level. Ecological indicators can also help us to measure and evaluate the performance of those public and land management policies (Natural Resource Council 2000).

Types of Indicators

Effective indicators 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 in the system of concern. Indicators are specific components of these complex ecosystems that, when measured, can tell us a great deal about the present or future condition of the large ă è ă ű Ŝ Ƴ ¢ ǎ (Dent, Salwasser, & Achterman, 2005)

Due to the variety and complexity of environmental issues and data, and the pressing need for effective management decisions, many types of indicators have been developed for an array of purposes. These different types can reflect physical, chemical and biological aspects of an ecosystem and have been used to characterize status, track or predict change, identify stressors or stressed systems, assess risk, and influence management actions (Kurtz, Jackson, & Fisher, 2001)

Indicator literature emphasizes that an effective ecological indicators program should incorporate different types of indicators (Kelly and Harwell 1990, Hughes et al. 1992, Water Quality Guidelines Task Group 1996). Table 1 identifies many types of indicators based on what they measure in the ecosystem. The term ά λ ƴ Ř λ Ŏ ŀ ű ϩ NJ ε λ ă ϩ Ŧ ű Ŝ ƨ NJ Ŝ Ř Ŝ Ŧ use, however ecological indicators are intended to describe and evaluate the state and function of an ecosystem (Hughes et al. 1992, Landres 1992, Watzin et al. 2005), as well as the Ŝ Ŏ ϩ ă è ă ű Ŝ Ƴ Ω ă NJ Ŝ ă Lt. 1 according ű ϩ Ƴ (Watzin et al. 2005).

Table 1: **Adapted from Watzin 2005, Kelly and Harwell 1990, Council of Great Lakes Research Managers 1991, Landres 1992, Karr 1992, Rapport 1992, OECD 1993, Nip and Uno de Haes 1995, Niemi 2004, Water Quality Guidelines Task Group 1996, Harwell, et al. 1999.**

Indicator Type	Description
Pressure	Measures the direct and indirect impacts from human activities.
State/Condition	Measures current environmental condition.
Response	Measures societal or management response to the state of environment.
Structural/Environmental	Measures biotic and abiotic components of an ecosystem.
Process/Function	Measures the rate or extent of changes in ecosystems processes.
Disturbance	Measures disturbance regimes that maintain ecosystem structure.
Compliance/Management	Evaluates effectiveness of management actions toward achieving goa and objectives.
Diagnostic/Sensitive	Provides information as to cause of ecosystem changes.
Early Warning	An indicator that quickly signals ecosystem changes before signif degradation occurs.
Long Term	Detects ecosystem changes over a long time.
Index	Combines multiple environmental characteristics into a single mea of ecological condition.
Ecological	Measurable characteristics of the structure, composition, and func of ecological systems.

Chapter 3: Steps for Establishing an Indicators Program for the Coos Watershed

Step 1: Scale and Objectives for Coos Watershed

The first step in an indicators program is to establish the scale and objectives for which ecological indicators will be developed. The Partnership focused their efforts on a pilot study area, the South Slough and Coastal Frontal Watershed, with a larger goal being to establish a program for the entire Coos Watershed. Coos WA works across the entire watershed, while SSNERR is focused on the South Slough and Coastal Frontal watershed. The organizations partnered to create an indicators program to track the condition of the pilot study area and to evaluate the impacts of climate and land use changes.

To establish an ecological indicators program the most important first step is to define the objectives, then identify public values and concerns, as well as understand current, relevant regulations, and then frame the objectives within the context of that information (U.S. EPA 2008).

The Partnership identified two main objectives for the development of ecological indicators under their CICEET proposal:

1. Monitor the long-term impacts of climate and land use changes to a coastal watershed, the Coos Watershed.

2. Evaluate the effectiveness of management and restoration efforts through use of indicators.

Step 2: Set the Framework: Pressure-State-Response

A conceptual framework is used to outline a preferred approach to an idea or problem. There are a number of frameworks available for developing indicators, and a common challenge to establishing an indicators program is choosing the best framework by which to conceptualize potential indicators. Choosing a
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scale and objectives can often lead to indicators that are not clearly linked to ű K Ŝ LJNJ ƻ ∃ NJ ŀ Ÿ Ω purpose, as well as public values or management actions, resulting in a lack of importance to the public and potentially ineffective management policies and programs (Watzin, et al., 2005).

The Partnership chose the Pressure-State-Response Framework because of its simplicity and because of its wide use by other organizations, such as the EPA and the National Park Service. The Pressure-State-Response framework is used by organizations around the world, including entities such as the U.S. EPA. The PSR framework is so widely accepted because of its ease of interpretation by the public. It clearly shows the relationship between human activities that act on the condition of an ecosystem, and the management responses and policies that are meant to reduce the impact of those pressures.
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happening in the environment? Why is it happening? What are we doing about it? (Hammond, Adriaanse, Rodenburg, Bryant, & Woodward, 1995)

The PSR framework (Figure 2) organizes indicators into three categories: pressure, state and response indicators. Pressure indicators measure the extent to which human pressures are acting on an ecosystem, while state indicators describe the condition of the ecosystem. Response indicators describe the management actions that seek to address the pressures placed upon the ecosystem by human activities.

This framework is based upon the idea that human activities exert pressure on the environment that result in changes in the state of the environment as a whole, as well as its individual parts. These changes often cause a societal response, which results in changing environmental policies or implementing management actions (OECD 1993). The central

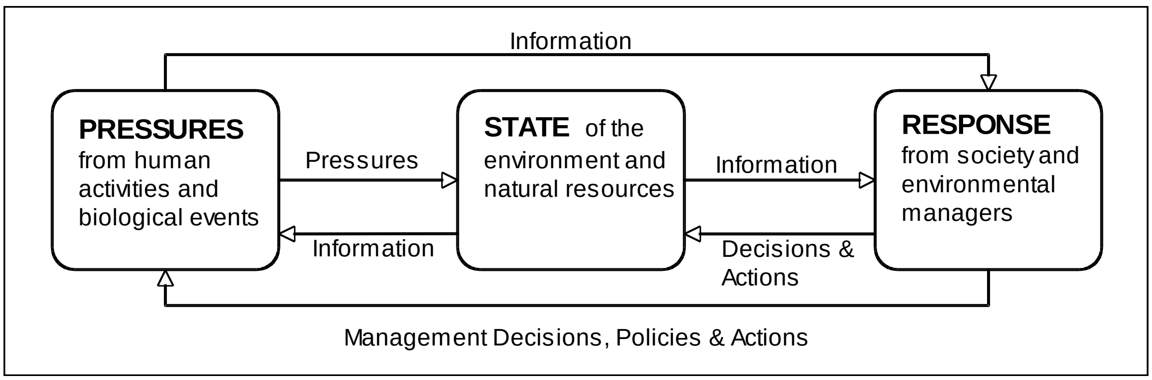

Figure 2: Pressure-State-Response Framework adapted from the OECD (1993).

ideal is that societal responses affect the pressures by causing changes in the human activities that initially caused the environmental degradation, or even by direct changes to the degraded environment (OECD 1993). Response indicators have not been in use for as long as pressure and state indicators. Data availability and our limited understanding of potential and actual management outcomes often constrain the development of response indicators (OECD 1993, Watzin et al. 2005).

While tK Ŝ t { w ŦNJŀ Y Ŝ ǿ ƻNJŀş Ω ă ƒ ƛ ỿ easy to understand, many feel it is limited ō Ŝ Ŏ ŀ dz ă Ŝ ƛ ű ƻ Ǿ ŜNJ ă ƛ YLJ ƒ ƛ Ŧ ƛ Ŝ ă characteristics and processes, and can be narrow in its evaluation scope (Bowen & Riley, 2003).

Climate Change and Land Use Impacts: Coos Watershed PSR

A coastal watershed, like the Coos, is a uniquely complex ecosystem because it encompasses a transition from freshwater and upland terrestrial ecosystems, to a mosaic of terrestrial, emergent wetland and tidal ecosystems, to coastal nearshore marine ecosystems. In order to identify potential indicators the Coos pilot study area was conceptually broken down into smaller landscape classes (Dent, et al., 2005). The classes are: 1) Freshwater Aquatic & Riparian 2) Terrestrial 3) Estuarine Aquatic and 4) Near shore Marine.

The development of ecological indicators requires the interacting factors within ecosystem be conceptually modeled. The PSR concept model for an ecosystem can be very simple, focusing on the primary or secondary interactions, or the models can be quite complex, incorporating many of the factors that are either impacting the system or being impacted within that ecosystem. The goal is to identify the environmental components, which are of greatest importance, both socially and scientifically, as integral drivers of the

Concept models must be easily understood by scientists and land managers, and incorporate enough information to facilitate the effective selection of the appropriate indicators for the ecosystem (United States Environmental Protection Agency (USEPA), 2008)

Figure 3: Climate Change and Land Use PSR diagram for Coos Watershed

Ŝ Ŏ ƌ ă ề ă ű Ŝ Ƴ Ω ă Ŧ dz ƴ Ŏ (United States Environmental Protection Agency (USEPA), 2008). The PSR framework is often criticized for oversimplification of ecosystem complexity, as crucial factors can be overlooked or underestimated as to their influence or pressure on the system.

An overall PSR concept model was developed for the Coos Watershed (Figure 3) to broadly and simply depict the relationship between the ecosystem and the drivers of greatest concern to the Coos WA and SSNERR. In the Coos Watershed PSR model, the pressures are those forces related to climate change and human