Assessing Ecological Integrity Across Jurisdictions and Scales

THIS PAPER IS THE PRODUCT OF A SERIES OF WORKSHOPS that occurred between 2011 and 2014. They were hosted by the Institute for Natural Resources - Oregon Biodiversity Information Center, U.S. Geological Survey, Defenders of Wildlife, and NatureServe, and attended by a wide variety of staff from resource agencies, non-profit organizations, universities and the private sector. Many of the participants reviewed and/or contributed to the content of the paper. Final editing decisions were made by the primary authors and do not necessarily reflect unanimous agreement from all parties. See page 38 for a partial list of participants and contributors.

Special thanks to the Bullitt Foundation for providing financial support for the ongoing process to develop a more consistent and effective way to measure biodiversity and ecological integrity.

Primary Authors:
Sara Vickerman
James S. Kagan

Designer:
Kassandra Kelly

Copies of this report can be downloaded from these links:
http://www.defenders.org/publication/eco-integrity-measures-across-jurisdictions-and-scales
http://oregonstate.edu/inr/eco-integrity
http://hdl.handle.net/1957/54180

2014

Cover images, clockwise from the top: Refuge visitor taking photographs at the Edwin B. Forsythe National Wildlife Refuge, by Ryan Hagerty, courtesy USFWS; Greater sage-grouse in Modoc County, California, by Dave Menke, courtesy USFWS; Black-footed ferret by Ryan Hagerty, courtesy USFWS.

Assessing Ecological Integrity Across Jurisdictions and Scales

December 2014

Table of Contents

Showers over Abert Rim in eastern Oregon. Photo by Bruce Taylor, Oregon Habitat Joint Venture.

Executive Summary

This paper offers a framework for use by public and private entities who manage natural resources. It focuses on the maintenance and restoration of ecological integrity to help ensure that natural systems continue to provide intrinsic value and benefits to human communities. The ecological integrity measures assess four different attributes of natural systems: landscape features, habitat characteristics, representative and at risk species. Intact natural systems generally support a broader range of benefits to people than altered systems.

This integrated, accessible, and transparent framework will be used by agencies and private partners to collect, store, and share spatial data relating to the distribution, condition, and changes to the status of terrestrial, aquatic and estuarine, plants, animals, habitat, landscapes and ecological processes across the United States. These data are organized to inform allocation of resources and management decisions at project, landscape, and regional scales, to support comprehensive assessments of the full spectrum of nature's benefits, and inform determinations of management effectiveness.

The need for an improved system to assess and monitor the condition of ecosystems has never been greater. Credible, accessible scientific information is essential for making sound decisions about natural resource management. Response to problems involving land and water management must focus on the appropriate geographic scale, while taking political and jurisdictional boundaries into account. Climate change, invasive species, massive wildfires and droughts, intensive development pressure, and shifting patterns of vegetation and species highlight the need for a coordinated multi-scale and multi-party approach.

A range of existing policies is already in place to facilitate the level of cooperation necessary to build and implement an ecological monitoring system that works across jurisdictions and scales. Such a system can improve efficiency, lower costs, reduce redundancy, provide information to report on outcomes as well as outputs, improve transparency and credibility with the public, and help inform planning and management decisions from the project level to landscape scale.

The ecological integrity assessment framework is being applied in several locations across the United States: in the Rogue Basin of Southern Oregon by the Institute for Natural Resources; by the Bureau of Land Management for several Regional Ecosystem Assessments; by the National Park Service; and the Washington Department of Fish and Wildlife in cooperation with NatureServe.

Recommendations for adopting ecological integrity measures presented in this paper were derived from multiple workshops over several years and in different locations across the country. They involved scientists and practitioners, state and federal resource specialists, and representatives from private conservation organizations. Key recommendations include prioritizing nationally consistent spatial databases for human infrastructure, plant and animal species distributions, soils, rivers and streams, wetlands and vegetation communities along with, improved national data standards, stronger leadership, and incentives for agency staff to work together. Also proposed are coordinated and enhanced citizen science programs to maximize social and ecological benefits available from environmental monitoring.

Introduction

Biodiversity refers to the variety of life and its processes. Genetic, species, ecosystem, and landscape diversity all contribute to the maintenance of life on earth, including the support of human communities. This support comes from wild plants and animals consumed by humans, services that pollinate crops, filter and help purify water, reduce flood damage, and help control erosion. Biodiversity also provides aesthetic, scientific and cultural values to human communities. Many people believe that biodiversity (or nature) has intrinsic value.

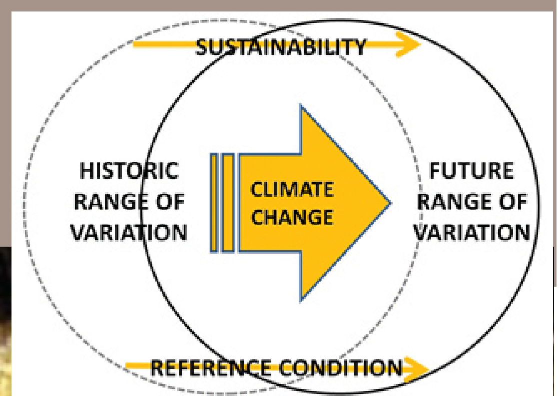
Biodiversity underpins the proper functioning of ecosystems and ensures the delivery of ecosystem services (World Economic Forum, 2010). Ecological integrity of a landscape refers to the ability of an ecosystem to support and maintain a community of organisms that naturally occur in that landscape. The composition, structure, function and natural range of variation may reflect conditions that have been irreversibly altered by climate change, exotic species, or other stressors or disturbance. There are numerous definitions of ecological integrity, but the Forest Service defines it as within the range of natural variation. This range should be sufficiently long to include the full range of variation produced by dominant natural disturbance regimes such as fire and flooding, and should also include short-term variation and cycles in climate (USDA Forest Service, 2013). Measuring ecological integrity in a consistent way will establish current baseline conditions and identify what types of changes are occurring where.

Natural resource attributes of ecological integrity are measured in a variety of ways: by public, private, and academic interests, for different purposes, at different scales, across various time horizons and at widely different degrees of accuracy and reliability. These data are often hard to access, protected for economic, privacy or other reasons, and sometimes technically difficult to integrate.

In the face of myriad impacts, including changes in climate, it is challenging to communicate to the public and policy makers the status of ecosystems. However, with significant technical innovations, an increasing concern about the long-term sustainability of the earth's natural resources, and a growing recognition that managing ecosystems requires a landscape-scale approach that transcends the legal and geographic reach of existing jurisdictions and institutions (Turner, 2005; McKinney et al., 2010), the time has come for the widespread adoption of a more integrated and comprehensive approach to assessing ecological integrity at multiple scales. The goal of this effort is to provide for a meaningful and repeatable snapshot of the status of biodiversity across the United States. Over time, this information can reveal trends, conservation successes and failures, and conservation needs. Implementation of the proposed framework can focus public funding on improving data quality and consistency across the country.

VISION STATEMENT

An integrated, accessible, and transparent system is in place and used by agencies and private partners to collect, store, and share spatial data relating to the distribution, condition and changes to the status of terrestrial, aquatic and estuarine, plants, animals, habitat, landscapes and ecological processes across the United States. These data are organized to inform allocation of resources and management decisions at project, landscape, and regional scale, support comprehensive assessments of the full spectrum of nature's benefits, and to be useful for determining management effectiveness.



Nature's ecosystem engineer, a beaver, near Tower Falls area, Yellowstone Park. Photo by R. Robinson, courtesy of the National Park Service.

AUDIENCE, NEED, SCOPE, AND SCALE

Credible, accessible scientific information is essential for managers to make sound decisions about natural resources. It is increasingly apparent that our response to problems involving land and water management must focus on the appropriate geographic scale, while taking political, ownership and jurisdictional boundaries into account. When decisions are focused on single projects or single sites managed by a single agency or owner, a fragmented, disparate information system may be sufficient. However, climate change, invasive species, massive wildfires and droughts, intensive development pressure, and shifting patterns of vegetation and species highlight the need for a multi-scale and multi-party approach. Without considering landscape-scale impacts, lands and waters will continue to suffer 'death by a thousand cuts', and may become so fragmented that long term viability of the ecosystems upon which people depend may be at risk.

> *Collect data once, use it multiple times.*
>
> -Gordon Toevs
> Bureau of Land Management

The vision statement and specific recommendations that follow reflect extensive discussions among practitioners at workshops held in different sections of the country and involving a variety of federal, state, and private natural resource specialists between 2011 and 2014. (See partial list of participants and contributors on page 38.) Initially, the discussion focused on site-scale metrics for market-based transactions and incentive payments for biodiversity conservation (Willamette Partnership, 2011). The conversation expanded to address the need for a more holistic, multi-scale system to support coarse and fine-filter approaches to conservation. It also expanded to address a growing interest and need by agencies and the private sector to address ecosystem services, or the benefits that nature provides. Although this report focuses more on the measurement of the biophysical attributes of different landscapes, it acknowledges the importance of addressing the expectations and values that communities have for natural lands and waters in the nature's benefits column of the framework described later in this report. (See page 12.)

Landowner working with National Resource Conservation Service staff. Photo courtesy NRCS.

This paper is written for resource professionals, policy makers, citizen scientists and anyone else who is interested in supporting and/or participating in a more efficient, effective, and comprehensive natural resource information collection and management system. It is based on the belief that collaboration among agencies, local governments, landowners, academics, businesses, and citizens will all play an important part in its implementation. The scope includes terrestrial, aquatic, and estuarine resources within the United States, ideally in a manner consistent with U.S. commitments to contribute information to global programs. It does not include marine resources as they may require a different approach. Ultimately however, monitoring lands and waters should be connected more effectively. The assessments should address both public and private lands, although the private land information concerns will require more complex agreements and reporting. What is presented here is not a mandate that commits the authors and contributors to redirect current programs and resources. The intention is to illustrate a path forward toward building an assessment framework that fosters cooperation among natural resource professionals and that can be used to support effective resource management decisions at multiple scales.

The framework offered here is intended to be a broad overview, not a detailed prescription for implementation by specific agencies or organizations. It offers a set of indicators that can be addressed in a way that is locally appropriate, given a wide variety of ecological systems and different management objectives. Further work is needed to determine how best to apply the framework on-the-ground. The quality and extent of data that are available to assess the ecological attributes vary across ownerships and regions, and will improve over time.

Pronghorn antelope. Photo courtesy of the Washington Department of Fish and Wildlife.

Policy Direction

While there are considerable obstacles to the implementation of compatible ecological monitoring systems working across jurisdictions and at multiple scales, there are numerous policy statements directing or encouraging such an approach. A few examples follow:

> *Federal agencies have been directed to develop a more integrated, comprehensive approach to monitoring biodiversity, and to do it together.*
>
> *-Woody Turner*
> *National Aeronautics and Space Administration*

Report to the President — Sustaining Environmental Capital: Protecting Society and the Economy

In 2011, the President's Council of Advisors on Science and Technology (PCAST) issued a report calling for the encouragement and coordination of cross-scale and cross-agency collaboration in monitoring biodiversity and ecosystems (PCAST, 2011). The report noted that while a variety of organizations gather ecological data, these data are not readily available or aggregated across sectors, agencies, or regions, nor are they integrated in ways that provide information on the condition and sustainability of the nation's biodiversity and ecosystems. Given the pace and scope of environmental change, biodiversity monitoring and other ecological parameters must be frequent and comprehensive, spanning spatial scales from local to global. U.S. capacity is substantial, though it is limited by budget cuts and distributed among agencies to an extent that limits its overall effectiveness. The report also identified a need for improved information to help guide government investments in biodiversity and ecosystem sustainability to yield maximum benefits per dollar.

The PCAST report is a watershed document, urging U.S. Government agencies to better understand their biodiversity monitoring efforts across agencies, identify gaps in these efforts, and work under the leadership of the White House to fill them. The report encourages the White House to coordinate cross-scale and cross-agency collaboration in monitoring. This is to be done within a coordinated informatics framework that allows integration of biodiversity data with geophysical, earth observation, and socio-economic data. This work is to be the basis for regular assessment of the condition of U.S. ecosystems. Federal agencies are still identifying their monitoring efforts and defining the components of a regular biodiversity assessment. Defining common measures for assessing elements of biodiversity at local to national scales is a necessary first step. This is a job for relevant federal agencies to undertake with partners in academia and the non-profit and commercial sectors. It is also a time-sensitive job as biodiversity changes rapidly.

National Fish, Wildlife and Plants Climate Adaptation Strategy

The 2012 National Fish, Wildlife and Plants Climate Adaptation Strategy (NFWPCAS), developed by over 100 federal and state agencies and tribal entities, defines and articulates a number of goals. For example, Goal 4, Strategy 4.1 states: "Support, coordinate, and where necessary develop distributed but integrated inventory, monitoring, observation and information systems at multiple scales to detect and describe climate impacts on fish, wildlife, plants, and ecosystems" (NFWPCAS, 2012). The strategy also called for the formation of a coordinating body, and the Joint Implementation Working Group was formed in the fall of 2013 to promote and evaluate progress on implementation of the strategy and support transparency and engagement. Many federal agencies, states and tribes have started to incorporate recommendations outlined in the strategy into their planning and implement key actions across the country (NFWPCAS, 2014).

Enhancing the Climate Resilience of America's Natural Resources

In the October 2014 report, *Enhancing the Climate Resilience of America's Natural Resources*, the Council on Climate Preparedness and Resilience directed agencies to design an ecosystem resilience index. Resilience refers to the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions, including those caused by humans (Executive Order 13653, 2013). In 2015, federal agencies, including the Department of the Interior, National Oceanic and Atmospheric Administration, Federal Emergency Management Agency, Army Corps of Engineers, and the Department of Transportation will design a framework for a decision-support tool that will provide baseline resilience data and measure the progress of restoration, conservation, and other resilience-enhancing management approaches. Experts will work toward developing common metrics, monitoring protocols, modeling approaches, and valuation methodologies to establish baseline conditions and provide measures of increased ecosystem resilience from restoration. This work is to be coordinated with other federal projects, including emerging efforts to develop indicators through the *National Climate Assessment* by the U.S. Global Change Research Program (2014).

The ecological integrity assessment framework described in this paper can inform the development of these indicators, and the indicators should be coordinated with the application of the framework to maximize efficiency.

Pacific tree frog, near Olympia, Washington. Photo by Lauriel Amoroso, courtesy Defenders of Wildlife.

Forest Service

The 2012 Forest Planning Rule provides for the maintenance or restoration of the ecological integrity of terrestrial and aquatic ecosystems and watersheds within forest planning areas. It also requires complementary ecosystem and species-specific approaches to provide for the diversity of plant and animal communities . The rule addresses the need for landscape-scale assessments as a context for management, and provides a platform for the agency to work with the public and across boundaries with other land managers, taking an 'all-lands approach.' (USDA Forest Service, 2012).

In 2013, Chief Thomas Tidwell issued a memorandum to Forest Service staff, noting there is no reliable infrastructure for the agency and partners with shared business priorities to maximize opportunities to align and integrate inventory, monitoring, and assessment activities, and that the lack of consistent corporate standards and protocols has resulted in redundant, inefficient, and expensive efforts that produce data with limited applicability. The memo outlines an inventory, monitoring and assessment strategy that puts the agency on a course for a systematic approach, working across boundaries and with partners and stakeholders to generate and maintain the information for land management decisions (Tidwell, 2013).

Bureau of Land Management

The Bureau of Land Management recently adopted an assessment, inventory and monitoring strategy. The goal of the strategy is to reach across programs, jurisdictions, stakeholders, and agencies to provide key information for decision makers that can be collected once and used many times. By using standardized monitoring indicators and methods for collecting this data, land managers have a basis from which to (1) adaptively manage resources, (2) improve understanding of the ecosystem, and (3) adjust monitoring efforts as necessary using a well-documented and consistent approach (BLM, 2011).

Tongass National Forest. Photo courtesy of USDA Forest Service.

Project Description and Goals

This project proposes a system of core measures for ecological integrity that can be applied across jurisdictions and scales, and repeated to reveal changes in ecological condition.

> ***Challenge:*** *Find the simplest combination of measures that reveal the current land / water condition and can demonstrate positive or negative change over time.*
>
> *-Workshop participants, 2014*

Although there are multiple sources of data that may be core measures, they may not be readily available, consistent, or easily aggregated. A system is needed to improve the coordination and consistency in collection, storage and application of this core set of measures.

ESSENTIAL CHARACTERISTICS FOR A SYSTEM TO MEASURE ECOLOGICAL INTEGRITY

Characteristics should include:

- Essential ecological attributes for revealing trends and detecting change, including aquatic and terrestrial resources;
- Previous work and existing inventories and data where possible — integrated with similar, ongoing inventory and data collection efforts;
- Examination of inefficiencies and duplication in existing systems that lead to cost-savings or better use of existing resources; and
- Measures that capture information about the dynamics of ecosystems.

System should be:

- Applicable at multiple geographic and temporal scales;
- Used by different jurisdictions, at different organizational levels, by managers and policy makers;
- Straightforward to implement and explain to technical and non-technical audiences;
- Updatable, cost-effective and transparent;
- Credible to scientists, decision-makers and stakeholders;
- Inclusive of data collected by scientists, managers, citizens, and students, including imagery and observational data;
- Appropriate to variable land uses and intensity of management, from undeveloped to developed.

SEPARATING ECOLOGICAL INDICATORS FROM SOCIAL/POLITICAL VALUES

Natural resource management decisions are influenced by a variety of factors. This report focuses on the need for more comprehensive and integrated information about the condition of plants, animals, water, ecological processes, and other elements of nature. Ideally, this information is complete, objective, and accurate. But resource management decisions — especially controversial ones — are not driven entirely or even primarily by scientific data. The proposed approach focuses on the assessment of ecological attributes, including, but not limited to those with economic value. Information on the condition of an ecosystem, now and into the future, is needed to determine what kind of services or benefits it can provide. There will be tradeoffs, as it is rarely possible to maximize all services in a location, but having a robust underlying science basis is essential.

BENEFITS OF APPLYING AN ECOLOGICAL INTEGRITY MEASUREMENT FRAMEWORK

The application of a system of ecological integrity measures would provide a number of benefits:

1. A system in which multiple agencies and organizations in a given location collect information on a core set of ecological measures can improve the efficiency and lower the cost of data collection by reducing redundancy and sharing costs among agencies.

2. Many current reporting systems focus on outputs rather than outcomes. Acres treated, miles of fence installed, number of trees planted, etc. report activity without revealing whether an ecological outcome is achieved or a change occurs. Ecological integrity can be measured in several ways that are sensitive enough to detect improvement or degradation over a period of several years (depending on the attribute) to provide important feedback for adaptive management and effectiveness monitoring.

3. A collaborative, cross-boundary ecological monitoring system can improve the transparency of management effects and enhance credibility with stakeholders. Sometimes called "all party monitoring", a participatory process that is well-designed and offers accessible results would improve stakeholder relations.

4. A process that offers comprehensive information on ecological integrity in a given place may lead to more effective interdisciplinary planning. A more integrated process that allows for cross-sector approaches would incorporate a wider range of community values than a traditional process.

5. A broad-scale ecological integrity assessment that includes various jurisdictions is vital for landscape and ecoregional scale planning and management. Many ecological processes occur at a scale that extends well beyond individual projects or management units, e.g., water flows, fire, species ranges, and insect and disease infestations. Cross-jurisdictional assessments can inform site or project-scale plans or management decisions, and assist in mitigation processes.

6. A regional ecological integrity assessment will identify the places where ecosystems are relatively intact, and where extensive disturbance has occurred. This will help inform many kinds of decisions regarding appropriate areas for managing particular ecosystem services. Mitigation programs can be more strategic, and therefore more effective and easier to implement. Future development planners can minimize degradation of ecological integrity by staying close to existing development and away from areas of high integrity. (This approach may be preferable in most cases, but not in all. If the trade-off involves an important corridor that has so-so

integrity, it may still be more important to the overall ecological integrity of the landscape than a different site that is relatively ecologically intact.) Regardless, the data is the fundamental currency of good decision-making, the importance of understanding the landscape cannot be overstated.

7. An important application of ecological integrity assessments may be to detect ecological change. This requires that the monitoring be designed to be repeatable, and that the measurements are repeated at useful intervals. Keeping track of ecosystem changes can help inform future decisions. Equally important is determining whether restoration efforts have produced the desired results.

8. Including a citizen science component in ecological integrity framework can help engage citizens, improve their ecological literacy, and build a larger, better informed constituency for conservation and management. It can also provide useful, cost effective, and more comprehensive data on selected ecological attributes, since researchers and agencies lack the capacity and resources to collect data on many important ecological elements.

   Citizens can also validate and ground-truth remotely gathered and processed data (such as landcover classification from satellite imagery), making data sets more robust. Just as with the Mars Rover data, data sets can be open to the public for crowd-sourced analysis, which gains its strength from highly repeated assessments converging on conclusions. Methodologies to maximize scientific rigor of citizen-based science observation are on the rise (Bowser and Shanley, 2013).

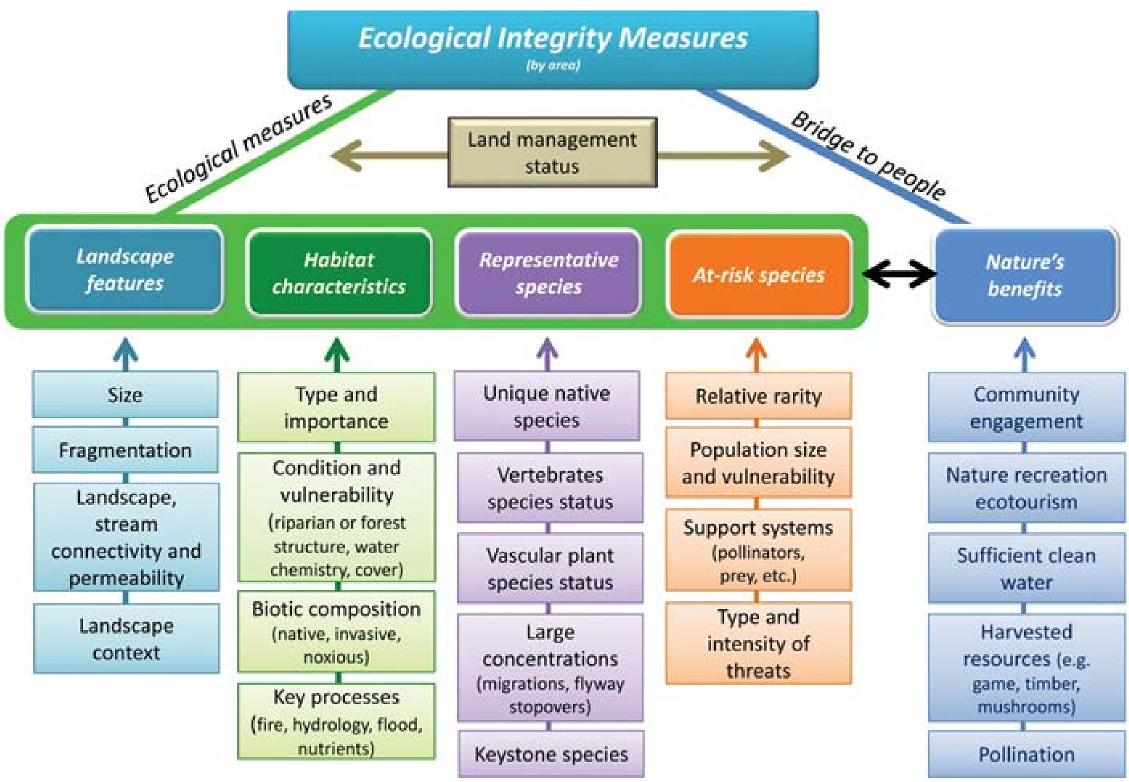
9. The proposed system explicitly connects to ecosystem services for human communities. To be fully implemented, land management planning must address scale-appropriate biodiversity potential, climate change, and potential human uses and impacts to ecosystems.

10. Ecological integrity assessments can help prioritize restoration opportunities by selecting those areas that may be degraded but maintain some viable elements of biodiversity.

11. Integrating and displaying the results of a cross-jurisdictional assessment of a natural resource issue may encourage policy makers to allocate funds strategically to address the problem. An example is the mapping of threats to forests caused by insects and disease, for which Congress has authorized substantial funding.

An Approach to Measuring Ecological Integrity Across Jurisdictions and Scales

The framework below is one approach for measuring ecological integrity at different spatial scales. The original version was developed in a workshop hosted by the National Center for Ecological Analysis and Synthesis in response to the need for a more consistent way to measure biodiversity and ecological integrity in an ecosystem services assessment. It was modified during several workshops and consultations with practitioners to make it more accessible and to clearly separate the ecological indicators from social and economic ones. In this framework, ecological assessments come first, although some prefer that people's demands on the ecosystem should drive the ecological analysis. Either way, an iterative process is useful in making transparent and well-informed decisions about resource management and allocation. This framework is best suited for application at a broad scale, although if fine-scaled data are available, it is also applicable to smaller areas.



Source: Collaboration involving Oregon Biodiversity Information Center, NatureServe, Defenders of Wildlife, U.S. Geological Survey, and The New Nature of Business.

BACKGROUND FOR THE FRAMEWORK

The biodiversity exhibited by a site, landscape or region is linked to its natural potential, including its inherent disturbance regime, and the degree to which it has been altered by human-mediated perturbations. The intrinsic biodiversity of natural systems, absent human influence, varies a great deal across climate, soils, elevation, topography, geology, latitude and other influences. While biodiversity potential informs ecological integrity, it would be misleading to compare biodiversity characteristics among sites with different potentials. Therefore, an approach that focuses on the integrity of natural systems, or the extent to which they reflect their biodiversity potential, provides a consistent approach to supporting sound management of natural communities and the ecosystem services they provide.

Such a system will be useful for identifying areas in which development is not appropriate, in selecting places to invest in conservation, in setting goals and tracking progress toward those goals. It will also be helpful in providing a way for agencies, nonprofit groups, and businesses to report on the decline or improvement in the status of biodiversity. If the measures are applied periodically using a consistent approach, trends will be evident.

ASSUMPTIONS LEADING TO THE PROPOSED MODEL FOR ECOLOGICAL INTEGRITY MEASURES

1. This framework is a tool to characterize the integrity of ecosystems at different scales. Given access to fairly complete and reliable information on natural resources and relevant technical expertise, most of the attributes in the framework can be quantified, leading to a score for each column. However, it is also useful as a conceptual model that allows users with less complete data and limited resources to consider more general assessment designations, such as assigning high, medium and low as values.

2. More complete data are generally available for vertebrates and vascular plants than for invertebrates, non-vascular plants and fungi, with some notable exceptions. Butterflies, valued pollinators, insect pests, freshwater mollusks and other aquatic organisms may be well surveyed and can be included in the assessments.

3. The values within each box or within each column could be weighted to assign higher priority to certain attributes.

4. If different agencies and organizations measure core ecological attributes using the same methods, it will facilitate assessment of ecological integrity across ownerships and jurisdictional boundaries and at different scales.

5. The model builds on the "coarse-filter, fine-filter approach." A "coarse-filter" of characteristic ecosystem types in an area is an efficient way to represent predominant ecological processes that support most species. A complimentary "fine-filter" addresses species of concern in that same area whose habitat requirements demand individual attention in conservation assessment, planning, management, and monitoring (Noss, 1987; Hunter, 1990). However with the increasing sophistication and accessibility of spatial models, remote sensing and other quantitative tools, the notion of coarse and fine grain may be less useful than it once was.

6. The framework is open-source, allowing its adaptation and application to different situations. Consideration of all or most of the attributes in the boxes will help people working at various scales to understand the ecological (and possibly social) context in

which they are working, and to make better resource decisions. Applying this framework offers greater transparency than is often available to support resource management decisions, since it offers specific ecological elements to be considered.

7. Imbedded in the logic behind the framework is the belief that a naturally functioning ecosystem with native plant and animal species is more valuable for biodiversity conservation than human dominated systems. Many human systems have been altered to meet human needs (e.g. cities) or to maximize productivity of ecosystem outputs (e.g., food production), and this involves tradeoffs that result in reductions in native biodiversity. Measurements using this framework therefore aim to make the results more transparent.

8. A parallel framework could be developed to apply to systems such as agricultural and commercial forestry operations that retain elements of native biodiversity. In these cases, the measurements aim to characterize the biodiversity and ecosystem service production of sustainably managed farms, rangelands, or forests.

9. Terrestrial, freshwater aquatic, and estuarine elements should be included in a suite of ecological integrity measures, but a significantly different framework is probably needed for marine systems.

10. Measuring ecological attributes should be independent of utilitarian purposes.

11. The column listing nature's benefits does not represent a comprehensive list of "ecosystem services." Rather, it provides a list of examples of benefits that are most directly connected to biodiversity.

DESCRIPTION OF BOXES IN THE FRAMEWORK

Ecological integrity measures (by area) The framework offers four types of measures for the biophysical properties in an ecosystem. Two relate to habitat, the others relate to species. The fifth theme shows examples of benefits that people derive from ecosystems.

Management and management designation refers to the guidelines that define current management of any area. These are often synonymous with the legal designation of that area. This would include whether the land is in public or private ownership, the degree and duration of protection, as in designation as wilderness, wildlife refuge, nature preserve, conservation easement, management agreements, etc. Existing systems for documenting conservation management of lands and waters include standards developed by the IUCN (Global Protected Areas Program) and those established by the USGS Gap Analysis Program (Gergely and McKerrow 2013). When evaluating the overall quality and potential for an area to maintain its ecological integrity, the management designation is critical.

Landscape features apply to large areas of land and include the extent and intensity of the human footprint on the land.

<u>Size refers to the size of vegetation patches.</u> Ideal patch size will vary according to the ecosystem type, the natural disturbances associated with the ecosystem, and other factors. An ideal patch size for a typical wetland restoration project in a developed landscape would be smaller than patch needed to support old growth forest obligates such as the spotted owl.

<u>Anthropogenic fragmentation</u> refers to the extent of human activities on the landscape that present barriers to the movement of fish, wildlife, plants, insects, and natural processes.

Roads, buildings, intensive agriculture or forestry, industrial and residential developments, stream culverts, dams, dikes, large invasive species outbreaks, and other barriers all fragment natural landscapes. Some landscapes are more naturally fragmented than others, and addressing variable patch sizes requires care in this analysis.

Landscape, stream connectivity, and permeability measurements capture the degree to which vegetation, rivers and streams, corridors and buffers provide opportunities for animals and plants to move from one location to another. These features are especially important in assessing the resilience of landscapes to changing climate and other stressors.

Landscape context refers to the placement of a certain parcel of land within a larger landscape, and considering surrounding land cover and land uses. All things being equal, a parcel imbedded within other lands that are similar and represent larger contiguous blocks is generally more valuable for biodiversity conservation than an isolated parcel. This measure may also refer to alignment with broader landscape protection strategies. If small parcels provide “stepping stones”, as for butterflies, they may be ranked highly even if they are small and occur within a human-dominated landscape. Spatial scale will vary depending on the scope and purpose of the assessment.

Habitat characteristics measures focus on areas smaller than landscape integrity measures. Some habitats are more important than others from a biodiversity perspective, based on risk and vulnerability to different stressors.

Type and importance refers to the vegetation or aquatic habitat type and its importance for conservation. Importance can be determined by the habitat that remains intact or the degree to which it supports species at risk. Regional conservation plans generally identify high priority habitats. Evaluating the type and importance is not a critical part of the assessment, but can help if prioritization is an objective.

Condition and vulnerability applies to both aquatic and terrestrial habitats. The condition is based on habitat structure and composition relative to its ability to support biodiversity and ecosystem services, not necessarily pre-settlement condition. Measures of terrestrial or riparian vegetation may include the width, height, and density of trees and shrubs, amount of shade, number of snags, cavities for nesting animals, degree and condition of cover. Condition of aquatic habitat includes measures such as water temperature, nutrients, sediment, and toxic substances. Vulnerability refers to the degree of threat to the maintenance of biodiversity and ecosystem services.

Biotic composition measures deal with the relative distribution of native plants and animals as well as the number and extent of non-native, invasive and noxious plants, animals, pathogens, etc.

Key processes vary across systems. The ones to measure are those that shape and maintain integrity of the system. Periodic fire and flooding are essential to some systems. The hydrology of the system determines the timing and amount of water. Nutrient cycling, pollination, and predator-prey relationships all contribute to a process measure.

Representative species measures reflect the need to understand the status, condition, and relationships among species that may not be considered at risk, but are important to the overall function of the ecosystem. Since complete biological inventories are not practical across large areas at frequent intervals, it is necessary to select a subset of species to monitor. Species or species groups can be weighted, if appropriate. The boxes below provide examples of species that might be used for this purpose.

Unique native species including endemic species, may warrant special consideration since they are not widely distributed or likely to be found in large numbers elsewhere, although if they are at risk they would be considered elsewhere.

Vertebrate species status could be the native species richness, percentage of native vertebrate species occurring historically, that remain.

Vascular plant status, as above, could be the presence and distribution of vascular plants relative to those that might have occurred prior to settlement.

Large concentrations of animals may be important to some systems. Examples include species of large ungulate herds, flyways and migration routes for birds, important stopover sites, etc.

Keystone species — umbrella, focal, indicator, or surrogates —, are species believed to exert a disproportionate amount of influence over habitat that affects other species. Sometimes these are large apex predators like wolves, ecosystem engineers like beavers, or wide-ranging animals that require habitat supporting many other species. The term 'focal species" is used in bird conservation plans; by managing for a suite of species representative of important habitat components in a functioning ecosystem other species and elements of biodiversity will be conserved. Focal species are selected by their degree of association with important habitat attributes (Altman & Alexander 2012).

At-risk species measures are necessary for compliance with laws and policies that seek to prevent those species from being adversely affected and/or to address recovery needs. These include formally listed species along with those having other designations such as sensitive or rare. In these measures, individual species can be weighted depending on the degree of risk or other factors.

Relative rarity refers to the number of at-risk species and populations present in the area relative to other sites.

Population size and vulnerability measures require more intensive field studies than other measures, and more frequent monitoring.

Support system refers to the specific needs of the rare species. This could include amount and timing of stream flow, availability of pollinators to assist with plant reproduction, presence of predators, etc.

Type and intensity of threats requires an inventory of threats to the rare species and determination on the severity of those threats.

Nature's benefits or ecosystem services is the final column in the framework, and provides a bridge to connect ecosystem with people and their needs. The boxes provide examples of some direct benefits of ecosystems with an emphasis on biodiversity, and are not intended to be a comprehensive list. The services will vary from place to place depending on the capacity of the system to provide them, and the communities' expectations.

Community engagement. Many people derive pleasure from interacting directly with nature by volunteering in conservation projects, raising money to purchase sensitive lands, participating in citizen science efforts, and other activities that provide positive social benefits for families and communities.

Nature recreation is appealing to many people and includes a vast array of activities from ecotourism, wildlife viewing and photography, hiking, camping, river rafting, boating, bird watching and feeding, and others. These activities have significant economic and social benefits for certain businesses and communities.

Sufficient clean water includes both water quality, quantity, and timing of delivery to meet ecological, recreational, municipal, industrial, agricultural, and other needs.

Harvested resources include a broad range of plants and animals harvested for sport, building materials, food, and other purposes.

Pollination is especially significant to agriculture, providing billions of dollars in support services to farmers who depend on them to pollinate crops. In addition, birds pollinate plants, disperse native seeds, consume insects, and contribute to the maintenance and resiliency of ecosystems.

CONNECTION TO NATURE'S BENEFITS

The ecological integrity framework includes nature's benefits, but the process for addressing human preferences for the services provided by nature is widely debated. There are complex models designed to help managers weigh tradeoffs and sort competing demands from stakeholders, such as the multi-criteria decision framework offered by Duke University (Olander, 2014). Other, less resource intensive approaches use qualitative data derived from interviews, focus groups or surveys to determine people's management preferences.

It is important for discussions of nature's benefits to be based on an understanding of the condition of a particular landscape and its subsequent capacity to sustainably provide a unique set of ecosystem services while maintaining ecological integrity. Plant communities and vegetation structures follow geological, climatic and soil characteristics with varying abilities to provide ecosystem services including forest and agricultural products, wildlife habitat, recreation opportunities, carbon sequestration, regulation of water flow and more. Hydrologic properties (e.g. whether a system is rain or snow dominated, groundwater or surface water fed) influence flow regimes, water supplies, aquatic habitats, and recreation opportunities. Identification of key services provided by a landscape involves an iterative exchange of knowledge among resource specialists and the public so stakeholders receive background information on how ecological conditions determine public benefits, and managers can incorporate public values in decision making (Nikola Smith, personal communication, 2014).

COASTAL PROTECTION EXAMPLE

Ecosystem processes and functions relate explicitly to the delivery of ecosystem services. For any ecosystem service, a subset of ecological processes or functions will be most relevant to the provisioning of the service. One of the ecosystem services that coastal wetlands such as salt marsh and mangroves provide to communities is coastal protection, specifically wave reduction and soil erosion protection. Ecological factors that influence coastal protection such ecosystems provide include vegetation structure (including stiffness and density of individuals), plant biomass, species composition, and area of continuous, uninterrupted habitat. These factors are important ecological values for predicting coastal protection benefits; these may or may not be the same factors important in the provisioning of other benefits such as nursery habitat, carbon sequestration and storage, or water quality improvements. It is important to recognize that different subsets of ecological information are likely to be needed when examining the relationship between ecosystem processes and functions and the provisioning of ecosystem services. And sometimes, we may not yet fully understand which ecological processes and functions are most important for provisioning an ecosystem service. This is true for, though not limited to, cultural services (Ariana Sutton-Grier, personal communication 2014).

CHALLENGES IN IMPLEMENTING ECOLOGICAL INTEGRITY MEASURES

There are challenges in implementing the proposed framework for measuring ecological integrity. Examples to consider include:

1. Ecological processes and jurisdictional boundaries (local, state, federal, private, etc.) do not align well. This issue can be addressed by considering ecological conditions first, and adding jurisdictional boundaries at the end of the process. The exception may be for private property, which needs to be recognized early in the analysis.

2. Agencies, organizations, academic institutions and Congress all work under various missions, objectives and capacities. The National Research Council describes this fragmentation of authority as *the stovepipe effect*, in which each agency focuses on its own statutory mandate. Although there are good reasons for concentrated expertise and narrowly focused missions, this approach can undermine effective collaboration. The National Research Council suggests that agencies legitimize and reward individuals at the staff and leadership level who engage in initiatives that 'cross silos' in the interest of sustainability (NRC, 2013).

3. Even when reliable, integrated, broad-scale information is available, it may not be immediately seen as useful to managers making project or site-scale decisions. The flow of work within agencies — granting permits, building roads, authorizing timber sales, even restoring degraded lands — do not rely on broad scale ecological data.

4. Another challenge is gaining access to data that responds to specific needs. As needs change, existing monitoring systems may no longer relate to emerging issues or different conditions.

5. Data quality, quantity, and accessibility vary widely across the United States. They are more complete in areas with vast public lands, and maybe less complete (or less available) in areas dominated by private lands.Ecological baselines also vary widely. Lands dominated by urban and agricultural activities will score lower for ecological integrity, but can be improved with management. Implementation of this framework can focus public funding on improving the quality and consistency of data across the country.

6. Regardless of the ecological integrity score or the quality of the data, many decisions are driven by other social, political, or economic factors. Having complete information on these attributes in addition to the ecological data may lead to more informed decisions (Ervin et al., 2014).

ECOLOGICAL INTEGRITY ASSESSMENT IN SOUTHWEST OREGON'S ROGUE BASIN

THE ROGUE BASIN OF OREGON is well known for its exceptional biodiversity, beautiful and varied landscapes, and world-class outdoor recreational opportunities. Because of the high numbers of endemic species and the increases in fire frequencies predicted by all the climate models, the biodiversity in the Rogue Basin is likely to experience more severe impacts from climate change than other areas of the state. The frequency and severity of wildland fires and potential for them to be even more intense when the climate gets warmer has residents on edge and agencies scrambling for the resources to address the risk, primarily by thinning overstocked forest stands where fire has been suppressed historically.

The Rogue Basin also has the benefit of many groups of engaged citizens, and a wealth of natural resources information collected by federal, state and local, agencies, non-profit organizations, and Oregon's universities. The Oregon Biodiversity Information Center, which is part of the Oregon Institute for Natural Resources (Oregon State and Portland State Universities) is doing a basin-wide ecological integrity assessment, funded largely by grants from the U.S. Geological Survey's Climate Change Science Center and the U.S. Forest Service. The assessment uses spatial data at a 30 meter pixel scale for each of the themes in the ecological integrity framework. For each theme (landscape, habitat, characteristic species, and rare species) a score will be calculated to indicate the relative integrity (health or intactness) of each pixel. The process can be repeated in several years to detect changes in the ecosystem, either negative impacts of various stressors or positive changes attributable to successful restoration efforts.

This information will be combined with other relevant data to develop a comprehensive basin-wide strategy that prioritizes the restoration of terrestrial and aquatic habitats to generate the greatest benefits at the lowest cost. The data and ecological integrity assessment can populate models to help managers predict how certain actions will affect the system, and what ecosystem services the ecosystem can generate. The project also involves social and economic assessments that will help decision makers determine which of these services or benefits are most important to the people of the basin and all people across the country who appreciate its special character and resources.


Oregon's Rogue River Canyon. Photo by Ruth Jacobs, courtesy U.S. Geological Survey.

MONITORING ECOLOGICAL INTEGRITY ON WILDLIFE AREAS IN WASHINGTON STATE

WASHINGTON DEPARTMENT OF FISH AND WILDLIFE is undertaking a collaborative effort to use citizen science to monitor changes in ecological integrity on the one million acres of land it owns or manages. This Ecological Integrity Monitoring strategy supports the efforts of the agency to manage and restore ecosystems and to provide the monitoring and evaluation data needed to inform conservation plans. This effort is based on the work of Washington Department of Natural Resources Natural Heritage ecologists and NatureServe's Ecological Integrity Assessment framework.

All of Washington State is mapped at the ecosystem level by the Gap Analysis Program. The names of the ecological systems used in the assessment are defined by NatureServe. A fundamental component of the strategy is the comparison of an ecosystem to its characteristics when operating within the natural range of variation. Ecological integrity is evaluated against a scorecard that describes the condition of several integrity indicators along a gradient from excellent condition (Rank A) to poor condition (Rank D). The method provides this information at three scales:

Level 1 - Large scale remote sensing indicator assessment

Wildlife agency staff is conducting remote sensing assessment to determine ecological integrity condition at the landscape scale.

Level 2 - Field-based rapid qualitative indicator assessment

Citizen science will be used in two ways:

1. Conduct rapid on-the-ground assessment using a simplified 'ecological integrity scorecard,' ranking each site across several indicator metrics;
2. Periodically visit permanent photo reference points on each site to photographically monitor features of the landscape. Staff can examine the images and analyze the biological data to evaluate wildlife sites and trends in ecological integrity (Hall, 2002).

All level 2 data is submitted to the wildlife agency's cloud-based geo-database from mobile devices or a desktop application.

Level 3 - Quantitative field plot measurements of ecological indicators

Level 3 data collection will monitor and evaluate:

1. Response to alteration of livestock grazing;
2. Calibration and verification of Level 1 and Level 2 assessment;
3. Effectiveness of habitat restoration practices.

The goal for the project is to track the long term ecological integrity of lands owned or managed by the agency. The project findings will be evaluated for their contribution to policy decisions and actions regarding natural resource management (Pierce, 2014).

Cedar waxwing. Photo by Kelly McAllister, courtesy of the Washington Department of Fish and Wildlife.

SAGEBRUSH EXAMPLE

THE NRCS SAGE GROUSE INITIATIVE is making measurable progress in applying natural resource information gathered by various entities to define and implement science-based solutions to the conservation of Greater sage-grouse and the sage-steppe ecosystem on which it relies. The approach transcends a regulatory framework and relies on partnerships among government and non-government stakeholders and voluntary contributions of private landowners for the benefit of sustainable ranching and wildlife conservation (Boyd et al., 2014). Sage Grouse partnerships seek to maintain and restore ecosystem processes in the sagebrush-steppe by implementing targeted conservation practices, from improved grazing, conservation easements to prevent conversion to development or tillage or preserve important brood-rearing or winter habitats, to encroached conifer removal, and others that directly address threats in core population areas.
www.sagegrouseinitiative.com

The shrub-steppe region of the intermountain west offers an illustrative retrospective example of the benefits inherent in a more consistent monitoring system. An accessible and standardized set of metrics collected across this eco-type would economize the diverse and uncoordinated stakeholder efforts to characterize the threats and opportunities facing Sage grouse and other threatened species in this landscape. A central, transparent way of mapping that landscape with key variables will create a common forum and viewpoint and could facilitate resolution of key issues (Steve Zack, 2014).

Greater sage-grouse. Photo by Stephen Ting, courtesy USFWS.

IMPLEMENTING THE FRAMEWORK AT THE FOREST SERVICE

LIKE OTHER FEDERAL LAND MANAGEMENT agencies, the Forest Service is actively looking for ways to improve the statistical reliability and utility of inventory, monitoring, and assessment activities and, when practical, increase inventory and monitoring consistency and efficiency among individual units and across hierarchical levels. The requirement to monitor biological diversity and ecological integrity under the 2012 Planning Rule (and the Forest Service's recently adopted national Inventory, Monitoring and Assessment Strategy) combine to create a climate where the Forest Service could seriously consider adopting all elements of the framework proposed here. The planning rule defines ecological integrity as "the quality or condition of an ecosystem when its dominant ecological characteristics (for example, composition, structure, function, connectivity, and species composition and diversity) occur within the natural range of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human influence." (Federal Register 36 CFR 219.19, USDA Forest Service 2012). Success will require recognizing the roles and responsibilities of different internal and external stakeholders, established agency culture, and effective use of agency policy-making practices. The question for the Forest Service is, "Which should take precedence, the benefit of tailoring 124 Land and Resource Management Plans (Forest Plans) each to their local constituency or foregoing some of the local tailoring to increase analytical value of data collected in a more consistent manner across larger landscapes?"

If the proposed framework were adopted it would most likely occur through the revision of the agency's 124 Forest Plans. This strategy could be used to identify priority areas for restoration, reforestation, and rehabilitation after major disturbances (wildfire, flooding, hurricanes, etc.), mitigating for climate change, facilitating ongoing mitigation processes, budget allocation and strategic planning decisions. Although the group that developed these recommendations has yet to identify indicators, the framework as it stands provides a set of principles and criteria that could tier to them and associated indicators that could be estimated from national forest monitoring data. They are:

1. Maintain or restore sufficiently intact landscapes;
2. Maintain habitat features that support native species associated with natural community types;
3. Provide sufficient habitat for all native species, including those at risk;
4. Provide public access to the forests and the ecosystem services they provide.

A successful implementation strategy for the Forest Service would necessitate a coordinated effort by several headquarters staffs including: Ecosystem Management Coordination; Rangeland Management and Vegetation Ecology; Wildlife, Fish, Water, Air & Rare Plants; and Forest Management. Key individuals in each regional office will provide technical support and direction to national forests as they revise their Forest Plans. Raising the awareness and capacity of Regional Directors, Forest Supervisors, and line officers about the importance of a consistent approach could help them increase public trust and achieve resource management objectives. Forest Supervisors and District Rangers are the public face of the Forest Service and during revision of forest plans, Forest Supervisors play a key role in interacting with local stakeholders besides being the deciding official on the final forest plan.

Therefore, creating a partnership among the Washington Office Headquarters staffs, Regional Office staffs, and national forests undergoing plan revision is the most likely path to implementing a coordinated monitoring program for biological diversity and ecological integrity. A key aspect will establish indicators for each criterion that allow individual forests and regions sufficient leeway to measure things that are important to their stakeholders in the local context yet are similar enough to paint a national picture of the status and trends in biological diversity and ecological integrity across all jurisdictions (Jamie Barbour, 2014).

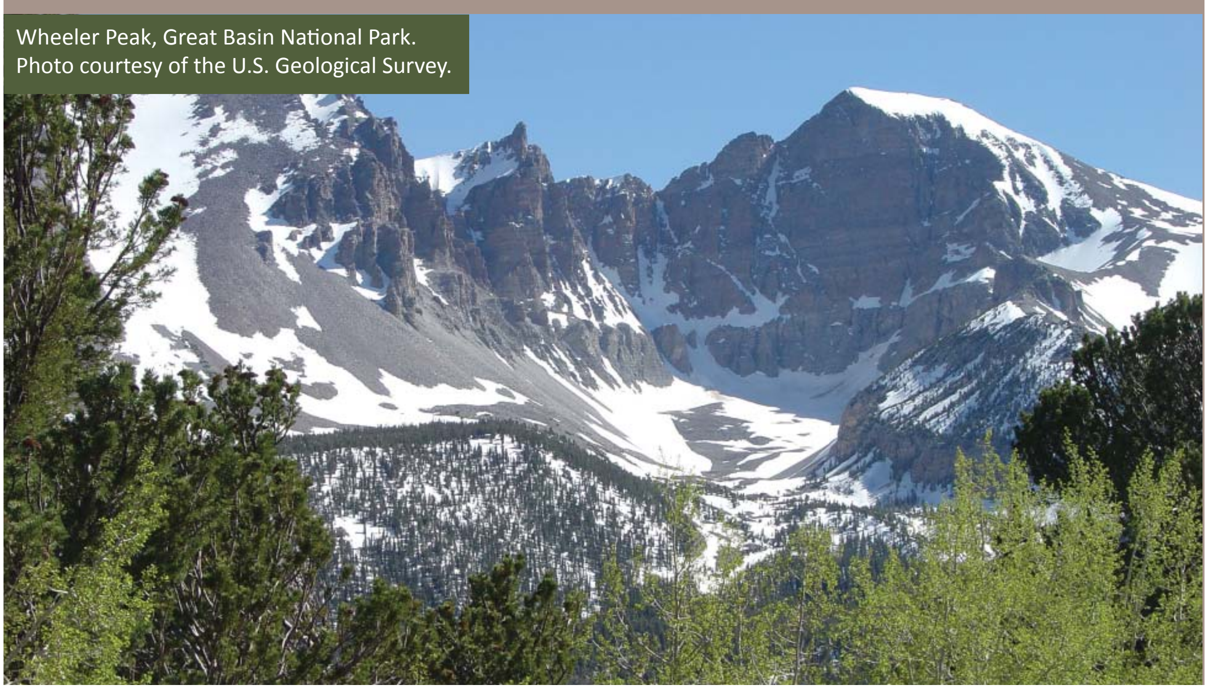
ECOLOGICAL INTEGRITY ASSESSMENT FRAMEWORK AND NPS DECISION SUPPORT: AN EXAMPLE FROM GREAT BASIN NATIONAL PARK

THE NATIONAL PARK SERVICE has a hierarchical planning structure from Park General Management Plans through detailed Implementation Plans for weed management or prescribed fire. The plans provide broad goals for "natural resources" as a general concept and some delineated resources of high value to park managers. Implementation plans focus on short term, task-oriented objectives, and what is consistently absent from this process for managers are science-informed descriptions of natural resources, how they interact, and how they are influenced by past, current, or potential decisions. Often, these are provided during development of a Natural Resource Condition Assessment. The Ecological Integrity Assessment Framework, first developed by scientists in The Nature Conservancy and built upon by NatureServe, was used to structure the condition assessment for Great Basin National Park.

The framework does several things to fill the need for desired conditions of resources. First, given that few park units have sufficient staffing in technical specialties across resource types, the framework helps managers remove some of the complexity of nature. Through a logical progression, park resources are characterized by component terrestrial and aquatic systems, such as Aspen-mixed conifer forest vs. Riparian woodlands vs. spring ecosystems, based on ecological processes that determine patterns in species composition. Detailed conceptual models of these systems give managers a greater understanding of ecological interrelationships among physical and biological resources, at multiple scales. This information adds immeasurable relevance to descriptions of hydrologic, geological and biological resources found in many Park Service environmental analyses. When human drivers, such as groundwater pumping, cause ecological alteration, the framework helps managers develop improved action alternatives. Measurable indicators and thresholds of change provide further insight into management activities, adding much-needed depth of analysis (Greg Eckert, 2104).

See the appendix for more examples.

Wheeler Peak, Great Basin National Park.
Photo courtesy of the U.S. Geological Survey.



Implementation Recommendations

INSTITUTIONAL AND POLICY ISSUES

National leadership is needed to provide direction, support, encouragement, and capacity for the adoption and implementation of a more effective measurement system to monitor ecosystem integrity. The system should be reliable, statistically significant, and accurate – one that can be used by all agencies and other stakeholders with no customization. However, given the decentralized nature of many federal agencies, inherent resistance of states to federal control, and private property issues, any national effort should accommodate unique needs, honor previous and current efforts, and demonstrate that improved consistency and interoperability can be beneficial to those working at a regional, local or project scale.

1. Although in a previous section there are examples of existing policy direction supporting these ideas, the direction is almost as fragmented as the problem itself. Coordinated guidance from the Office of Management and Budget, Council on Environmental Quality, and Office of Science and Technology Policy urging agencies to work together to improve ecological monitoring would highlight the importance of addressing these issues in a timely way.

2. Establish a subcommittee within the Federal Geographic Data Committee (FGDC) devoted to biodiversity to integrate current related subcommittee efforts (vegetation, wetlands, and spatial water data) and expand to address core national spatial data standards for the measurement of biodiversity and ecological integrity.

3. Agencies can provide incentives to staff to work together across agencies, around geographies, in a broader, collaborative fashion. Staff could be assigned to facilitate improved coordination as a primary responsibility, not an additional task that seems burdensome. Other rewards, including reference to effective collaboration, could be included in performance reviews and considered in promotions. Even giving staff impressive titles for working across jurisdictions can be rewarding.

4. An interdisciplinary team is needed to facilitate continued discussion and implementation of the proposed framework. The team could select pilot test sites for the framework, assessing the effectiveness and cost of the application, and making adjustments as needed. The team needs a strong, committed leader, members with enthusiasm for the project, and influence within their agencies and the resources to do the job.

5. More information is needed by field personnel regarding landscape scale monitoring and assessment data for project level planning and management decisions. Federal land management agencies and private-sector partners could hold workshops for field personnel, helping them understand where to find and how to use broad scale, cross-jurisdictional data to inform project level planning and decisions.

6. Public-private partnerships are essential for improving the nation's monitoring system. Considerable capacity exists within states, local government, schools, conservation

organizations, businesses, and with landowners to contribute meaningful data to a well-organized monitoring system. Reluctance to rely on data collected by groups outside government must be tempered by the recognition that involvement by different groups in the process may offer social and educational benefits that have not been fully evaluated. Federal agencies should work more closely with state and private entities that collect data, to ensure that it meets quality standards and can supplement federal data where appropriate.

7. Aligning with other similar efforts like the Landscape Conservation Cooperatives, Western Governors' Association's wildlife habitat initiatives, or Regional Ecological Assessments of the Bureau of Land Management can improve efficiency. There are many other public private partnerships across the country working to improve the quality and extent of natural resource information to support cross jurisdictional planning and management. These partnerships should be engaged in pilot testing and implementation of the ecological integrity framework. (See McKinney, 2010 for more examples of landscape scale conservation projects.)

DATA COLLECTION AND MANAGEMENT

1. Consistent, reliable data on certain attributes of the landscape are essential for multiple applications by all levels of government and the private sector. Although this paper focuses on measuring natural resources condition and trends, information on human infrastructure, natural hazards, land use and other subjects is also essential for planning, emergency response, budget decisions, and other purposes critical to human communities. Federal agencies have addressed the limitations posed by incomplete or inaccurate spatial data, and are recognizing the need for a long-term strategy to improve the efficiency and utility of data delivery to multiple users. Other entities, such as states, tribes, and private companies like Google or the Environmental Systems Research Institute (ESRI) may be able to assist. A set of priorities were developed as part of the collaborative process resulting in this paper.

   a. **Human infrastructure:** This includes, but is not limited to, roads, buildings, utilities, water impoundments, energy projects, and other development.

   b. **Species distributions and observations:** The information available on fish and wildlife species is highly variable. The most extensive information focuses on listed species, and is not collected consistently by agencies or the private sector. Some of this information is restricted to protect the species. A system similar to the U.S. Forest Service Forest Inventory and Analysis program would be beneficial for fish and wildlife. The U.S. Geological Survey has launched an integrated wildlife database called BISON (Biodiversity Information Serving Our Nation). See box on page 28 for description.

   c. **Lakes, rivers and streams:** Water quality and quantity, the integrity of aquatic ecosystems, concern about declining fish populations, and climate change impacts are all priority conservation issues throughout the country. However, the data on streams and rivers is incomplete and inconsistent, caused in part by the fragmented management of aquatic systems across government entities.

d. **Soils and soil organisms:** Understanding the capacity of the soil to support vegetation and associated species, agricultural crops, forest products, and other uses is essential to the management of all ecological systems. Spatial data on soils and soil organisms has advanced considerably through the Soil Survey Geographic Database (SSURGO) effort, but remains incomplete and inconsistent across the country, with the greatest gaps in the Western states. The Natural Resources Conservation Service and U.S. Forest Service should prioritize the completion of this data set nationally, before updating completed areas.

e. **Vegetation:** Complete and consistent spatial data on all types of vegetation, including geo-referenced field observations of dominant species composition, is essential for all natural resource planning and management decisions. The Forest Service supporting their program to develop national imputation data at 30 meter pixel scale from the FIA dataset would significantly move this effort forward.

2. National standards are needed to ensure the quality, consistency and availability of spatial data. Established standards, and a requirement that data collected at federal expense meet those standards, may facilitate collection and use by multiple parties. However, there is concern that if data that does not meet the standard cannot be used by federal agencies, then some imperfect (but better than no) information may be excluded. A quality rating for all data with specific criteria would allow users to determine what level of quality is required for the intended use.

3. Improved transparency and accessibility of data will serve multiple purposes for public agencies and private parties. The Natural Resource Conservation Service collects information on private lands, but struggles to share it due to privacy legislation. Incentives and tools are needed to allow this information to be used in regional and watershed analysis without violating privacy concerns.

OUTREACH AND ENGAGEMENT

1. **Clear, concise language** should be used when communicating with less technical audiences in order to build full and effective participation of stakeholders.

2. **Citizen science** should be incorporated into the biodiversity/ecological integrity framework. Properly trained and supported, citizens can collect useful information on the distribution and status of natural resources, well beyond what can be accomplished by professional agency staff. Citizen engagement may provide benefits well beyond the importance of additional data by enhancing knowledge and understanding of ecosystems and fostering a sense of stewardship. The Washington Department of Fish and Wildlife has incorporated citizen science into the ecological integrity assessment program with considerable success.

There are many ways to engage citizens in monitoring plants and animals. Schools can offer programs for students of all ages. Community groups, retired resource professionals, conservation organizations, watershed councils, private landowners may be willing, even excited to be involved.

A relatively easy way to take advantage of citizen monitoring is with photo points. Agencies can establish photo points and create a repository for images taken at established times to reveal changes in vegetation or visitation by animals if automatic camera traps are used. New and improving technology makes it easy to record time and location of various ecological attributes to help populate spatial databases. For example Picture Post is a part of the Digital Earth Watch network, supported by NASA. It supports environmental monitoring by citizens, students, and community organizations through digital photography and satellite imagery. http://picturepost.unh.edu/

3. **Engage private landowners.** Since 70% of the land base in the United States is in private ownership, land use and management decisions made by private owners will profoundly impact biodiversity. Reliable monitoring is critical to the effectiveness of programs that assist private landowners in implementing conservation measures. With online monitoring programs like eBird [http://ebird.org/content/ebird/], anyone can enter site-specific data into a publically available database. As an added benefit, monitoring efforts that recognize the expertise of landowners can increase the commitment to broad scale conservation efforts. (Ciuzio, et. al, 2013). Private landowners often have extensive knowledge of the condition and potential of their land. They may have directly observed changes over time — both positive and negative — and under the right circumstances, some may be willing to contribute data to populate ecological integrity assessments.

Birders participating in the 2009 Christmas Bird Count, Ash Meadows National Wildlife Refuge, courtesy USFWS.

BISON: BIODIVERSITY INFORMATION SERVING OUR NATION

Researchers collect species occurrence data, records of an organism at a particular time in a particular place, as part of many biological field investigations. These data reside in numerous distributed systems and formats (including publications) and are consequently not being used to their full potential. As a step toward addressing this challenge, the U.S Geological Survey is developing Biodiversity Information Serving Our Nation (BISON), an integrated and permanent resource for biological occurrence data from the United States. BISON has tens of millions of records obtained from many sources, both public and private. This resource will be exceptionally valuable for providing data to populate eco integrity assessments.
http://bison.usgs.ornl.gov/#home

ENVIRO-ATLAS

EnviroAtlas is a collaborative project developed by the Environmental Protection Agency, in cooperation with the U.S. Geological Survey, the U.S. Department of Agriculture's Natural Resources Conservation Service, Forest Service, and LandScope America. Produced by the collective effort of federal employees, contractors, and non-governmental organizations, EnviroAtlas develops and incorporates data from federal, state, community, and non-governmental organizations.

Though critically important to human well-being, ecosystem services are often overlooked. EnviroAtlas seeks to measure and communicate the type, quality, and extent of the goods and services that humans receive from nature so their true value can be considered in decision-making processes. Using EnviroAtlas, many types of users can access, view, and analyze diverse information to better understand how various decisions can affect an array of ecological and human health outcomes. EnviroAtlas is available to the public and houses a wealth of data and research.
http://enviroatlas.epa.gov/enviroatlas/atlas.html

Camp Sherman near the Metolius River in Oregon. Photo by Rick Brown.

EXAMPLES OF CITIZEN SCIENCE PROGRAMS

The Natural Resources Conservation Service, in partnership with Point Blue (formerly Point Reyes Bird Observatory) has developed an outreach program for landowners in California rangelands that applies a unique set of tools. Laminated cards (for each habitat type) contain pictures and information on bird species expected to be present when certain habitat conditions exist. The cards also offer suggestions about management actions to improve habitat. The ranchers know how successful they are in improving range condition by learning to identify the birds and their habitat needs. www.pointblue.org. The Natural Resource Conservation Service has many programs to assist landowners. http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/

The Avian Knowledge Network is a partnership of people, institutions and government agencies supporting the conservation of birds and their habitats based on data, the adaptive management paradigm, and the best available science. Network partners act to improve awareness, purpose, access to, and use of data and tools at scales ranging from individual locations to administrative regions (e.g., management areas, states, countries) and species ranges. www.avianknowledge.net

The Klamath Bird Observatory and U.S. Forest Service's Redwood Sciences Laboratory have developed the Klamath Demographic Monitoring Network, a comprehensive bird-monitoring network in southern Oregon and northern California. The network integrates bird conservation objectives into the ecosystem management process by incorporating academic, scientific, management, and conservation interests to inform the management and conservation process with science. (Alexander, 2014) www.avianknowledgenorthwest.net

iNaturalist is an online social network of people sharing biodiversity information to help each other learn about nature. It's also a crowdsourced species identification system and an organism occurrence recording tool. It's used to record observations, get help with identifications, collaborate with others to collect this information for a common purpose, or access the observational data collected by iNaturalist users. Its primary goal is to connect people to nature — helping people see that the non-human world has personal significance, and is worth protecting. Recording information about nature in a social context is a tremendous way to understand the awesome depth and breadth of life on Earth. A secondary goal is to generate scientifically valuable biodiversity data from these personal encounters. Sponsors believe that just contributing to science without helping people care about the natural world, is not sufficient. www.inaturalist.org

FrogWatch USA is a citizen science program of the Association of Zoos and Aquariums that provides individuals, groups, and families with an opportunity to learn about wetlands in their communities and report data on the calls of local frogs and toads. Volunteers collect data during evenings from February through August and have been submitting data for over 15 years. Data are entered and accessed online. Data are available for ongoing analyses to help develop practical strategies for the conservation of these important species. https://www.aza.org/frogwatch/

The National Phenology Network brings together citizen scientists, government agencies, non-profit groups, educators, and students of all ages to monitor the impacts of climate change on plants and animals in the United States. Phenology refers to key seasonal changes in plants and animals from year to year, such as flowering, emergence of insects and migration of birds, especially their timing and relationship with weather and climate. https://www.usanpn.org/

PROCESS

This report is based on the discussions and recommendations derived from workshops held from 2011 through 2014. These workshops were convened by different organizations at different points. Several were hosted by the Oregon Institute for Natural Resources Biodiversity Information Center, Defenders of Wildlife, NatureServe, and the U.S Geological Survey. The National Center for Ecological Analysis and Synthesis and the National Center for Socio-Environmental Synthesis hosted several workshops. NatureServe provided technical support along with the Oregon Biodiversity Information Center. The process also involved the collection and review of numerous reports and publications and informal conversations with scientists, practitioners, and resource management staff from public agencies and private organizations.

Oregon landscape. Photo by Bruce Taylor, Oregon Habitat Joint Venture.

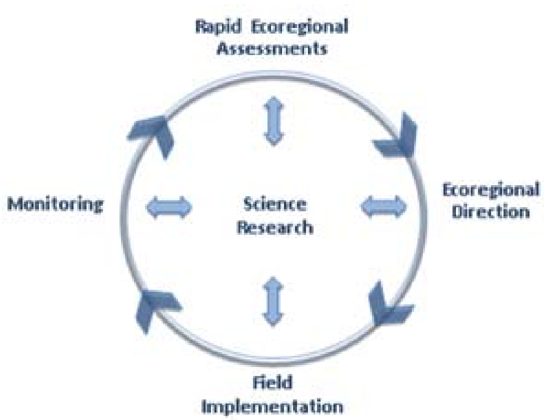
Appendix: Additional Examples

ASSESSING ECOLOGICAL INTEGRITY IN BUREAU OF LAND MANAGEMENT

Rapid Ecoregional Assessments

Introduction

Adaptive management in natural resource conservation implies an iterative approach to decision making. It presumes that knowledge remains incomplete and circumstances change continuously, so management is structured as an ongoing, learning process. Adaptive management commonly includes generalized phases of assessment, planning, implementation, and monitoring. This approach has been formalized by the Bureau of Land Management under their Landscape Approach, where Rapid Ecoregional Assessments (REAs) provide contextual input to subsequent planning decisions. Assessments seek to document past, current, and likely future patterns among key resources and change agents across an entire ecoregion. They document trends that must be addressed to achieve agency goals and provide regional direction for planning. Planning processes then specify management goals and objectives, and commonly take shape within resource management plans that deter-



REAs integrate 'wall-to-wall' data on biodiversity and other key resources, such as dominant vegetation, aquatic ecosystem types and sensitive species. They also document change agents, such as energy development, invasive species, fire or hydrologic regime alteration, and climate change, and their effects on key resources. Each REA analyzes spatially-explicit land use scenarios, including documentation of current conditions and forecasted conditions looking out to 2025 and 2060. Evaluation of current land use scenarios emphasizes documentation of relative ecological integrity for key natural resources. Forecasted land use trends (e.g., renewable energy development patterns) are emphasized in the analysis of the 2025 scenario, and climate change effects are emphasized in the 2060 scenario.

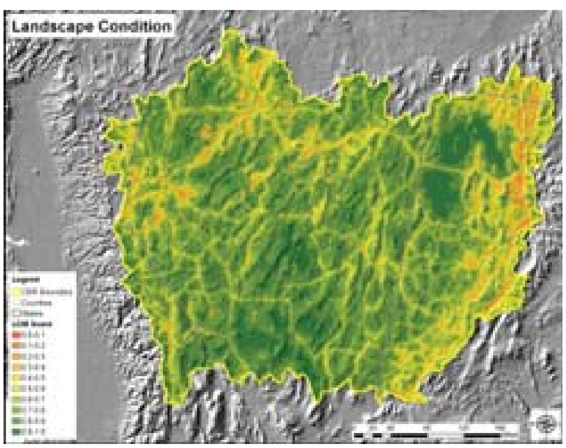
Within several REAs, the NatureServe ecological integrity framework guides the assessment for all ecosystem types and species of conservation concern. This method translates current knowledge of change agent effects on each resource into a "scorecard" of indicators for reporting locally within the ecoregion, and for summarizing up to regional or national levels. Indicators are chosen to gauge a limited set of key ecological attributes, or ecological drivers, for each resource. Given the rapid and regional character of an REA, stressor-based indicators addressed through remote sensing and spatial modeling are most common. With the Central Basin and Range ecoregion, extending from the Sierra Nevada foothills in California east to central Utah, indicators were selected that enabled reporting on resource integrity by 5^{th} level watershed and 16 km^2 square grid cells. Along with several others, indicators included a spatial model of landscape condition, a predictive map of invasive annual grass abundance, and measures of wildfire regime departure. The following figures show the relative scores for each of these indicators overlain on distributing big sagebrush shrubland, which is a dominant vegetation type in the ecoregion. While ecological integrity indicators from the REA aimed to provide an ecoregion-scale snapshot of current conditions, BLM planners and field staff indicated this level of information assists considerably in their decisions pertaining to habitat restoration and monitoring.

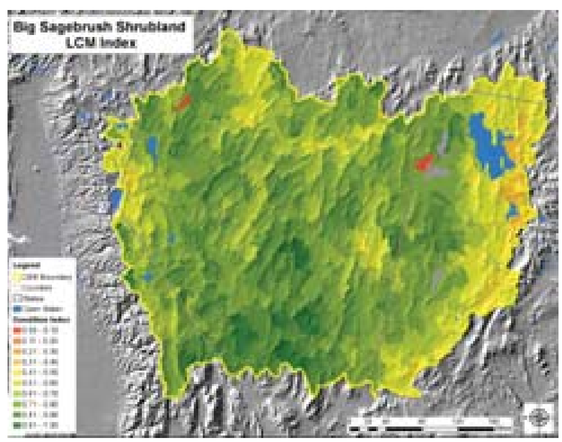
Landscape Condition

The map on the left is a spatial model that integrates over 20 map layers to express common ecological stressors, such as roads and land uses of varying intensity, that cause habitat fragmentation. Scaled from 0.0 -1.0, dark green areas are location of greatest distance from the intensive land uses. This portion of a national model developed by NatureServe has been calibrated for use across the western states, and continues to be evaluated with field samples.

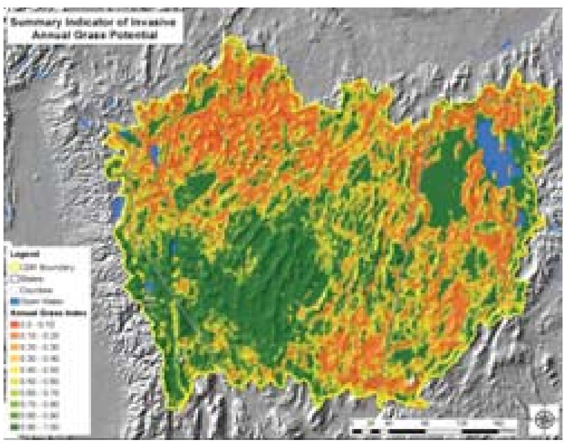
By combining this map with the big sagebrush distribution, that average score is summarized by each of the 600+ watersheds that define the ecoregion (map on the right).

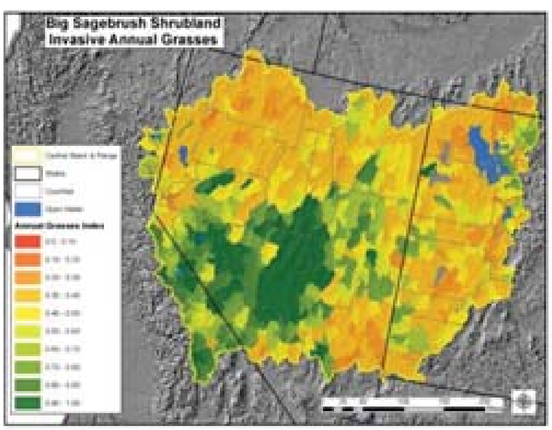
Invasive Annual Grasses





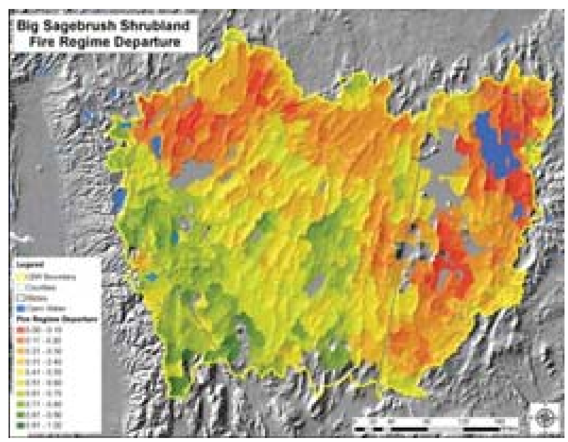
Invasive annual grasses were introduced across the interior west and beyond. They displace native plant species, altering habitat quality for wildlife, and introduce fine fuels that significantly increase spread of catastrophic wildfire. This spatial model developed by NatureServe is scaled from 0.0 -1.0, with dark green indicating areas least vulnerable to invasive annual grass infestation. Again, by combining this map with the big sagebrush distribution, the average score for invasive effect on sagebrush is summarized by each of the watersheds that define the ecoregion (map on the bottom).





Wildfire Regime Condition Class

Wildfire is a key natural process for many ecosystems and habitats in North America but land uses can cause significant departure from expected fire frequency and intensity. Departure is measured by comparing current proportions of different vegetation successional stages to those expected with natural fire regimes. Fire suppression results in buildup of late-successional vegetation while too frequent fire results in loss late successional vegetation. Spatial models of wildfire regime departure, like those developed nationally by the interagency LANDFIRE effort, were scaled from 0.0 -1.0, with dark green areas indicating where wildfire regime of sagebrush is least departed, with the average score for fire regime effect summarized by each of the watersheds that define the ecoregion (Comer, Patrick. NatureServe; Prentice, Karen, BLM, 2014).



DEVELOPING PROGRAMMATIC CAPACITY FOR WETLAND REFERENCE NETWORKS:

AN EXAMPLE ILLUSTRATING AN APPROACH SIMILAR TO ECOLOGICAL INTEGRITY ASSESSMENTS

Developing a reference standard or gradient is critical for ecosystem monitoring and assessment programs. For state and federal agencies that regulate and conserve wetland resources, reference standards for wetlands under their jurisdiction are used to report on trends in wetland condition and to establish measurable restoration objectives where required for wetland mitigation. Many programs have developed assessment methods based on indicators or metrics that help characterize the reference conditions. These methods range from remote sensing to rapid and intensive field-based assessments. Methods vary from state to state, and clarity is needed on the intended outcomes or endpoints of the assessments. NatureServe has worked closely with state partners and with Environmental Protection Agency to develop and test a consistent rapid assessment method applicable for state wetland assessments. This effort is now in the final stages of testing and will make information on the reference network publicly available.

This wetland assessment method is structured around key ecological attributes of wetlands, followed by a series of metrics organized by size, condition, and landscape context. In this current effort, NatureServe and Natural Heritage programs in 10 states and seven EPA regions evaluated a range of wetland condition assessment methods to determine the degree of programmatic flexibility in the choice of methods while ensuring that overall scoring of wetland condition is consistent. Four state Natural Heritage programs (Colorado, New Hampshire, New Jersey and Washington) are leading the effort to finalize the methods and establish a reference network in their states. The main goals are to:

- Provide a plan for validating the reference gradient (all sites from minimally disturbed to degraded) or reference standard (only minimally disturbed sites) for each wetland type in a state, in sub-watershed condition, and offer guidelines for writing descriptions of reference conditions by wetland type;

- Actively transfer methods and develop effective strategies for state partners through regional meetings to discuss implementation of the reference gradient and facilitate training in wetland condition methods (Faber-Langendoen, 2012).

References

Alexander, John D., C. John Ralph, Kimberly Hollinger and Bill Hogoboom. 2014. Using a Wide-scale Landbird Monitoring Network to Determine Landbird Distribution and Productivity in the Klamath – Siskiyou Region. In *Proceedings of the Second Conference on Klamath-Siskiyou Ecology*, ed. K. L. Mergenthaler, J. E. Williams, and J. Jules, 33-41. Cave Junction, Oregon: Siskiyou Field Institute.

Altman, B. and J.D. Alexander. 2012. Habitat Conservation for Landbirds in Coniferous Forests of Western Oregon and Washington. Version 2.0. Oregon-Washington Partners in Flight and American Bird Conservancy and Klamath Bird Observatory.

Andreasen, James K., Robert V. O'Neill, Reed Noss, Nicholas C. Slosser. 2001. Considerations for the Development of a Terrestrial Index of Ecological Integrity. *Elsevier Science Ltd*. Ecological Indicators 1 (2001) 21–35.

Bowser, Anne and Lea Shanley. 2013. *New Visions in Citizen Science*. Washington D.C.: Woodrow Wilson International Center for Scholars. http://www.wilsoncenter.org/sites/default/files/NewVisionsInCitizenScience.pdf

Boyd, C.S., D.D. Johnson, J.D. Kerby, T.J. Svejcar, and K.W. Davies. 2014. Of Grouse and Golden Eggs: Can Ecosystems be Managed Within a Species-based Regulatory Framework? *Rangeland Ecology and Management* 67:358–368.

Bureau of Land Management. 2011. *Introduction to the Assessment, Inventory and Monitoring Strategy.* 2pp fact sheet.

Ciuzo, E. et al. 2013. Opportunities and Challenges to Implementing Bird Conservation on Private Lands. *Wildlife Society Bulletin* 37 (2013):267–277.
http://onlinelibrary.wiley.com/doi/10.1002/wsb.v37.2/issuetoc

Council on Climate Preparedness and Resilience. 2014. *Enhancing the Climate Resilience of America's Natural Resources.* Washington, D.C.

Elliot, Steve, Sally Duncan, Nigel Malone. 2014. *New Nature of Business: How Business Pioneers Support Biodiversity and Ecosystem Services.* Sydney, Australia: University of Sydney. www.newnatureofbusiness.org/

Ervin, D., et al. 2014. *Principles to Guide Assessments of Ecosystem Service Values.* Portland, Oregon: Portland State University, Cascadia Ecosystem Services Partnership and Defenders of Wildlife.
http://www.pdx.edu/sustainability/ecosystem-services-valuation-workshop

Executive Order 13653. 3 CFR 66819 (November 1, 2013). *Preparing the United States for the Impacts of Climate Change*. 78 FR 66817:66817-66824.

Faber-Langendoen et al. 2012. *Ecological Integrity Assessment Framework.* Arlington, Virginia: NatureServe.
http://www.natureserve.org/conservation-tools/ecological-integrity-assessment

Gergely, K.J., and McKerrow, A. 2013. P*AD-US—National Inventory of Protected Areas* U.S. Geological Survey Fact Sheet 2013–3086. http://pubs.usgs.gov/fs/2013/3086/

Graedel, T. et al., 2013. *Sustainability for the Nation: Resource Connections and Governance Linkages.* Washington, D.C.: National Academies Press.

Hall, F. C. 2002. *Photo Point Monitoring Handbook*. USDA Forest Service General Technical Report PNW-GTR-526.

Harwell, Mark A., et al. 1999. A Framework for an Ecosystem Integrity Report Card: Examples from South Florida show how an ecosystem report card links societal values and scientific information. *BioScience* Vol. 49 No. 7 (July, 1999) 543-556.
http://www.researchgate.net/publication/216811555_A_framework_for_an_ecosystem_integrity_report_card

Hunter Jr, M. L. 1990. Coping with Ignorance: the Coarse-filter Strategy for Maintaining Biodiversity. *Balancing on the Brink of Extinction*. Washington DC: Island Press. pp. 266-281.

McKinney, M. et al. 2010. *Large Landscape Conservation: A Strategic Framework for Policy and Action.* Cambridge, MA: Lincoln Institute of Land Policy.

National Fish, Wildlife and Plants Climate Adaptation Partnership. 2012. *National Fish, Wildlife and Plants Climate Adaptation Strategy.* Washington D.C.: Association of Fish and Wildlife Agencies, Council on Environmental Quality, Great Lakes Indian Fish and Wildlife Commission, National Oceanic and Atmospheric Administration, and U.S. Fish and Wildlife Service.

National Fish, Wildlife and Plants Climate Adaptation Joint Implementation Working Group, 2014. *National Fish, Wildlife and Plants Climate Adaptation Strategy: Taking Action.* Washington, DC.: Association of Fish and Wildlife Agencies, Council on Environmental Quality, Great Lakes Indian Fish and Wildlife Commission, National Oceanic and Atmospheric Administration, and U.S. Fish and Wildlife Service. http://www.wildlifeadaptationstrategy.gov/engagement.php

Noss, R. F. 1987. From Plant Communities to Landscapes in Conservation Inventories: A Look at The Nature Conservancy (USA). *Biological Conservation* 41, 11-37.

Olander, L., ed. 2014. *Federal Resource Management and Ecosystem Services Guidebook*. Durham: National Ecosystem Services Partnership, Duke University. http://nicholasinstitute.duke.edu/initiatives/national-ecosystem-services-partnership/federal-resource-management-and-ecosystem

Parrish, Jeffrey D., David P. Braun, and Robert S. Unnasch. 2003. Are We Conserving What We Say We Are? Measuring Ecological Integrity within Protected Areas. *BioScience* Vol. 53 No. 9 (September 2003) 851-860.

Theobald, D. 2013. A general model to quantify ecological integrity for landscape assessments and U.S application. *Landscape Ecology,* Vol. 28 No. 10. 1859-1874.

Tidwell, T. July 26, 2013. *Forest Service Inventory, Monitoring and Assessment Strategy.* Internal Forest Service memorandum.

Turner, M. G. 2005. Landscape ecology: what is the state of the science?. *Annual Review of Ecology, Evolution, and Systematics*, 319-344.

Unnasch, R.S., D. P. Braun, P. J. Comer, G. E. Eckert. 2009. *The Ecological Integrity Assessment Framework: A Framework for Assessing the Ecological Integrity of Biological and Ecological Resources of the National Park System.* Report to the National Park Service. http://www.natureserve.org/biodiversity-science/publications/ecological-integrity-assessment-framework-framework-assessing

U.S.D.A Forest Service. 2012. *Final Programmatic Environmental Impact Statement: National Forest System Land Management Planning.* Washington, D.C.

U.S.D.A. Forest Service, 2013. *2012 Planning Rule Proposed Directives.* Draft 2-14-2013. Washington D.C.

U.S. Global Change Research Program. 2014. *National Climate Assessment.* http://nca2014.globalchange.gov/report

White House Office of Science and Technology Policy. 2011. *Report to the President – Sustaining Natural Capital: Protecting Society and the Economy.* From the President's Council of Advisors on Science and Technology Policy.

Willamette Partnership. 2011. *Measuring Up: Synchronizing Biodiversity Measurement Systems for Markets and other Incentive Programs*. A report to the U.S. Department of Agriculture, Office of Environmental Markets. Portland, Oregon. http://willamettepartnership.org/publications/

World Economic Forum. 2010. *Biodiversity and Business Risk.* A briefing paper prepared by PricewaterhouseCoopers LLP for the World Economic Forum.

Authors, Workshop Participants, Contributers, Reviewers, and Advisors

PRIMARY AUTHORS:

Sara Vickerman, Defenders of Wildlife
James S. Kagan, Oregon Biodiversity Information Center, Institute for Natural Resources

CONTRIBUTORS/REVIEWERS/ WORKSHOP PARTICIPANTS

Jamie Barbour, Forest Service
Barb Bresson, Forest Service, Bureau of Land Management
Frank Casey, U.S. Geological Survey
Marlene Cole, Ph.D, AAAS Science and Technology Policy Fellow
Patrick Comer, Nature Serve
Danielle Flynn, Natural Resource Conservation Service
Wendell Gilgert, Point Blue
William L. Hohman, Natural Resources Conservation Service
Melissa Kenney, University of Maryland
Mary Klein, NatureServe
John Pierce, Washington Department of Fish and Wildlife
Karen Prentice, Bureau of Land Management
Charlie Rewa, Natural Resource Conservation Service
Nikola Smith, Forest Service
Ariana Sutton-Grier, University of Maryland and National Oceanic and Atmospheric Administration affiliate
Gordon Toevs, Bureau of Land Management
Woody Turner, National Aeronautics and Space Administration
Steve Zack, Wildlife Conservation Society

WORKSHOP PARTICIPANTS AND ADVISORS

Matthew Anderson, U.S. Geological Survey
Ann Bartuska, U.S. Department of Agriculture
Josiane Bonneau, Wildlife Habitat Council
Douglas Boyce, Forest Service
Ellie Brown, U.S. Geological Survey
Steve Buttrick, The Nature Conservancy, Oregon Chapter
Jillian Cohen, U.S. Fish and Wildlife Service
Richard Cole, U.S. Army Corps of Engineers
Janet Cushing, U.S. Army Corps of Engineers
Joe Doerr, Forest Service
Sally Duncan, Oregon State University
Steve Elliot, University of Sydney
Rob Fiegener, Oregon Institute for Natural Resources
Dennis Figg, Missouri Department of Conservation
Sarah Gerould, U.S. Geological Survey
Gerald Guala, U.S. Geological Survey, BISON
Chris Hartley, U.S. Department of Agriculture, Office of Environmental Markets
Jena Hickey, U.S. Geological Survey
Leslie Honey, NatureServe
Gladwin Joseph, Azim Premji University, ATREE, India
Ted Maillett, U.S. Fish and Wildlife Service
David Moe Nelson, National Oceanic and Atmospheric Administration
Anne Neale, U.S. Environmental Protection Agency, Enviro Atlas
David Saah, Spatial Infomatics Group
Janine Salwasser, Institute for Natural Resources
John Schmerfeld, U.S. Fish and Wildlife Service
Carl Shapiro, U.S. Geological Survey
Maria Sharova, University of Maryland
Joe Starinchak, U.S. Fish and Wildlife Service
Michael Vecchione, National Marine Fisheries Service