The following is excerpted from "*Outcome Measures for Habitat and Recreation Land Acquisition and Regulatory Programs: A Science-based Review of the Literature*." Institute for Natural Resources, Oregon State University, Corvallis, Oregon.

Effective Outcome Measures

Performance of a program or action is measured through a set of indicators and the choice of indicators will directly impact the results (Mayoux, 2002; Baylis et al., 2016). Appropriate indicators should be environmentally meaningful, responsive, measurable, and reflect perceived importance to key stakeholders (Mayoux, 2002; Baylis et al., 2016). Because indicators must reflect specifics of socio-ecological systems, there is no specific blueprint for identifying the right indicators to use to produce relevant, credible and useful information for all purposes in all contexts (Mayoux, 2002; Baylis et al., 2016).

As many of the Washington habitat and recreation land acquisition and regulatory programs have overlapping program goals, the project team categorized the 52 goals that emerged across the 13 programs into 12 topic areas. Based on the effective outcome measures found in the peer-reviewed and gray literature, communications with managers from similar programs in the U.S., and the project team's professional opinion, the following finding is discussed in this section:

> There is very little literature that focuses specifically on outcome measures as they relate to land acquisition intended to protect and conserve species, habitats or to expand outdoor recreation; however a number of states and regions have implemented outcome measures for acquisition, and guidance is available from the extensive literature on restoration program and project effectiveness.

We present the finding by the topic areas that are represented in the Washington habitat and recreation and regulatory programs (i.e., species and habitat, recreation, wetlands, forests, etc.) and distinguish between outcome measures (indicators and metrics) noted in the literature and used in practice. ***Indicators*** help measure change over time and are a means of detecting progress or lack of progress toward short-, medium- and long-term outcomes and higher-level objectives. ***Metrics*** are observable, quantifiable measures to track and assess a specific indicator.

Where possible, we used criteria developed by the National Resource Center to characterize types of effective practices. *Effective practice* is an umbrella term that includes best practice, promising practice, innovative practice, or uncharacterized. *Best practices* are evidence-based and have been demonstrated through comprehensive research and evaluation to help organizations reach high levels of effectiveness and produce successful outcomes. *Promising practices*, on the other hand, have been shown to work and produce successful outcomes, but are not validated with the same rigor as best practices. This type of practice is supported to some extent through anecdotal reports (subjective data) and feedback from subject matter experts (objective data). Lastly *innovative practices* are defined as processes, activities, or strategies that have worked within one organization or program and show potential to be replicated and to have long-term impact. We also characterized *common practices*, defined as prevalent use of an approach, methodology, activity, strategy, system, process, technique, or tactic that may or may not be effective, promising, or innovative (See Table 1).

Due to the complexity and nuances of the topic areas individually and as a whole, this is not intended to be a comprehensive compendium of effective outcome measures. Rather it is a compilation of effective outcome measures and practices based on our literature search, conversations with program managers, and the opinions of the project team within the timeframe of the project.

Each section contains a summary of results of the literature search, and a discussion of programs and practices used in other jurisdictions in the country identified by the project team from interviews and analysis. Each topic then has a table of identified indicators and metrics, from the literature, a program, or both. The sections end with a list of references, including citations from the section, or other key references that inform the conclusions.

Table 1. Criteria for characterizing types of effective practice[1]	
Common Practice	• The prevalent use of an approach, methodology, activity, strategy, system, process, technique, or tactic that may or may not be effective, promising, or innovative
Effective Practice	• Proven effectiveness in addressing a common problem • Proven effectiveness in more than one organization and in more than one context • Replication on a broad scale • Conclusive data from comparison to objective benchmarks, with positive results • Conclusive data from a comprehensive and objective evaluation by an external, qualified source (most often an academic institution or individual with the appropriate academic credentials)
Promising Practice	• Effectiveness in addressing a common problem • Effectiveness in more than one organization and in more than one context • Replication on a limited scale • Supporting data from comparison to objective benchmarks, with positive results • Supporting data from an internal assessment or external evaluation
Innovative Practice	• Suggested effectiveness in addressing a common problem • Successful use in one organization and context • Potential for replication • Limited supporting data from comparison to objective benchmarks, with positive results • Limited supporting data from internal assessment

[1] Adapted from National Resource Center. 2010. Identifying and Promoting Effective Practices. U.S. Department of Health and Human Compassion Capital Fund National Resource Center, Washington, D.C. http://www.strengtheningnonprofits.org/resources/guidebooks/Identifying%20and%20Promoting%20Effective%20Practices.pdf

1 Species and Habitat Acquisition

WA Programs:

- Washington Wildlife and Recreation Program (WWRP)
- Trust Land Transfer Program
- DNR Natural Area Program

Literature Review

There have not been many papers that specifically address outcome-based indicators for habitat and natural area acquisition-focused protection programs, primarily because these programs are not very extensive in the U.S., and the programs that exist in most states tend to be very small. In general, it has been assumed that the number of occurrences (populations) of species, particularly those at risk of extinction, included in the lands acquired and added to a network of reserves sufficiently describes the outcome for species (Turak et al., 2017). Similarly, either having examples of all the habitat and ecosystem types represented in the network of conservation lands, or the percentage of all of the at-risk habitats that are included is most frequently used (Heinz Center, 2008). However, acres of protected natural areas, specific habitats or species are more similar to outputs than outcomes, as they primarily reflect effort.

A number of papers have proposed the concept of “ecological integrity” as a way of identifying the condition of specific properties, with the idea that improving or maintaining ecological integrity will assure that species and habitats persist over time (Parrish et al., 2003). This concept has been tried in Missouri by their Natural Areas Program, in some states in the upper Midwest, and is being tested in Washington by the Natural Heritage Program, as well as by the U.S. Forest Service nationally. This idea involves measuring the condition of ecosystems based on how “natural” they are. Naturalness is based on, among other factors, the ratio of native to introduced species, the degree of other obvious disturbance, and the presence of late-seral species (those primarily found in undisturbed areas), or the similarity to what is believed to be the composition of the habitats at the time European settlement of North America began. The concept of focusing habitat acquisitions on natural or pre-settlement conditions is based on the assumption that these are what will be most limiting, and therefore a priority.

To date, ecological integrity assessments (EIA) have been evaluated on a number of individual natural areas, and could be used as an indicator of the status and trends of natural habitats. However, since it is generally used as a field-based tool applied locally to individual natural areas or wildlife areas, it is somewhat problematic as an indicator of how well the natural area acquisitions are protecting species and habitats statewide. NatureServe (Comer and Faber-Langendoen, 2013) and Washington DFW are exploring methods to apply EIA across multiple landscapes, using remote sensing tools. If the methodology can be applied statewide, it has promise as a way to evaluate habitat quality on and off protected lands, although this currently remains untested. In addition, the departure from natural or historical conditions requires a somewhat subjective decision as to what a natural condition should be in any given place. In the past, agencies and scientists have used historical or pre-settlement vegetation to define what a natural condition is in a place. Some states – including Michigan, Wisconsin and Oregon – have spent considerable resources identifying historic vegetation through reconstructing the original land surveyors’ notes. Yet maintaining “natural” conditions based on historical conditions, even if they could be objectively identified, may no longer be possible due to what appears to be irrevocable changes in climate or human developments.

In practice

Best practice: Florida Forever

Massachusetts, Virginia, Minnesota, Arkansas, and Florida have natural area acquisition programs. The state of Florida has developed what appears to be a best practice in the implementation of "Forever Florida", a large ($1 billion over 10 years) habitat acquisition program (http://www.dep.state.fl.us/lands/fl_forever.htm). This website describes the outcomes of the acquisition program succinctly. The state was able to develop these indicators because, among other things, the Florida Legislature specifically listed in legislation, Florida Statute 259.105(3), a set of outcomes they wanted to achieve. The law provides acquisition funding to multiple agencies to achieve goals including protection of at-risk species; important habitats; recreational opportunities; groundwater resources; important wetlands, lakes and rivers; and sensitive coastal areas.

The legislature increased the budget of their state Natural Heritage Program (Florida Natural Areas Inventory, FNAI) housed at Florida State University by an additional $50,000 a year over the 10-year duration of Florida Forever to develop new, or complete existing, statewide datasets needed to prioritize properties for acquisition and to report on how well the goals were being met. FNAI was able to direct this funding on one or two indicators per year. It took approximately six years for all of the statewide GIS datasets to be developed with the funding being used to update each of them annually or biennially with new data within the $50,000 addition. However, it is important to note that this program was made possible by previous financial support, FNAI had been funded under the state's Wildlife Action Plan program to create baseline habitat maps for the entire state and to create and maintain a comprehensive map of all of the conservation lands in the state.

While the Florida Forever outcome statements are listed in acres (Table 2, they represent outcome-relevant acres. This is because the data used to target acquisitions are consistent statewide for each goal and the program only counts the acres acquired that directly provide the benefits of interest. For example, the state might acquire a 75-acre parcel to protect an endangered plant species and an endangered salamander that each occupy only a portion of the parcel. Using their methodology, only the 10 or so acres that support the endangered plant and the 15 acres that support the endangered salamander would be counted in the indicator (Table 2 indicator #1) and not the entire 75-acre acquisition. This is a case where an intermediate indicator can be a benefit-relevant indicator.

Another example is the metric that Florida uses for the significant groundwater recharge areas (Table 2 indicator #10). The Florida Legislature has asked FNAI to evaluate acquisitions simply based on their ability to protect a significant aquifer recharge area. They could have taken the evaluation a step further by also determining how many people accessed that aquifer for water; however, this extra step would require a second, more complex analysis. Oregon has experience with more complex analyses, for example, when the Institute for Natural Resources worked with the Department of State Lands to calculate the number of people who benefit from several ecosystem services provided by wetlands that were protected or restored, particularly for flood damage minimization and water quality improvement. This type of analysis is quite a bit more expensive and time consuming than Florida's approach, since both the amount of additional services provided by each wetland and the number of people living downstream of each wetland need to be evaluated. The state of Florida decided that benefit-relevant indicators were sufficient to inform their outcomes of interest.

Table 2: Florida Forever species and habitat related indicators and metrics		
Outcome Measures Category	Indicators and Metrics (units of measurement)	Source(s)
Amount of Land and Water Protected For Specific Outcomes	1. Acres of rare species habitat conservation areas, along with the number of sites protected, the number of rare species protected, and how many were state and federally designated as threatened and endangered 2. Acres of unrepresented habitats or habitats of concern 3. Acres of strategic habitats and greenways as defined by their state wildlife or the statewide conservation plan 4. Acres of properties large enough to represent landscape conservation 5. Acres of floodplains and riparian habitats 6. Acres of areas which include significant lakes and rivers or are important to their functioning 7. Acres of lands conserved to minimize downstream damage from flooding 8. Acres of fragile coastlines 9. Acres of functional wetland areas 10. Acres of significant groundwater recharge areas 11. Acres of sustainable forest lands 12. Acres of land within urban boundaries	FNAI, 2016(a) and (b)

Because all of the data were developed statewide, reporting could include the amount of these resources acquired, the acreage included in the overall network of protected lands, or the percentage of these resources protected. Along with these indicators, FNAI annually reports on the number of archaeological or historic sites conserved and the miles of priority recreational trails created within acquired lands.

Promising practice: Virginia's land acquisition program

The state of Virginia, another state with a large acquisition program, has built a set of measures modified from the Florida program (Smith, 2017, personal communication). They are similar to the Florida Forever measures, although with a larger focus on acres protected from development, partially because their program also includes a relatively large farmland and forestland trust program to protect these lands from development, and partially because it was not built on a statewide conservation blueprint, which Florida was able to have developed. In addition, Virginia, due to rapid and often uncontrolled sprawl, has been largely focusing on acquiring as many remnant natural areas in rapidly developing areas, which creates program outcomes that are difficult to evaluate.

Common practice

The Natural Areas Association regularly reports on the status of state natural area protection programs in the United States that focus on natural area acquisitions and management. Their most recent 2015 report identifies the diversity of these programs and their objectives (Thom and Leahy, 2015). The other primary vehicle for state habitat acquisition programs are fish and wildlife agencies, now often guided by state wildlife action plans required by the U.S. Fish and Wildlife Service. However, the project team was unable to find any examples in the literature of outcome-based indicators for land acquisition programs in these agencies or in practice.

The Association of Fish and Wildlife Agencies (2011) developed a report evaluating the effectiveness of all the State Wildlife Grants (SWG), which represent a major federal investment over the last decade, supported by AFWA's Teaming with Wildlife (TWW) program. This report describes a program to evaluate the effectiveness of the outcomes of the funding. But, early in the report it states, "There are two principal types of monitoring questions in conservation. Status monitoring identifies how populations of species as well as the habitats and natural processes on which they depend are doing over time. Effectiveness monitoring determines if conservation actions are having their intended impacts and how they can be improved are focused primarily on restoration and habitat improvement." The remainder of the report focuses on the important need to measure effectiveness, recommends the use of results chains, and makes a plea to state wildlife agencies to collect and report on effectiveness measure outcomes. They believe this information is critical to maintain congressional support for the SWG funding, as well as assuring that adaptive management is practiced. They do not discuss status monitoring, which is the information needed to address the questions posted by JLARC regarding program outcomes.

State Fish and Wildlife Agencies, state endangered species programs, and the U.S. Fish and Wildlife Service often have identified indicators for the acquisition of habitat to protect threatened and endangered species, which can be tied to the recovery goals identified when a species is state or federally listed. Because outcomes and success are clearly identified, these species-specific indicators are usually quite effective. There is extensive literature on the use of habitat as an indicator of species conservation in Europe, well summarized by Bunce et al (2013). In the 2006, Turner, Wilcove and Swain published a paper that assessed the effectiveness of reserve acquisition programs in protecting at-risk species, focused on the Lake Wales Ridge area of central Florida, which clearly demonstrated the success of these programs.

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2 Recreation

WA Programs

- State Parks and Recreation Commission
- Washington Wildlife and Recreation Program (WWRP)
- DNR Natural Areas Program

Literature Review

Analysis of outcomes from recreation land acquisitions could begin by examining how these acquisitions change the array of recreation experiences available in the area. The Recreation Opportunity Spectrum (ROS) is a well-established tool for classifying and inventorying different types of recreation opportunities, typically via maps generated manually and through digitization by analysts with in-depth knowledge of the region of interest. The ROS allows accurate stratification of outdoor recreation environments by dividing a spectrum of recreation opportunities into broad classes- urban, suburban, rural developed, rural natural, semi-primitive, and primitive (wilderness). Each mapped ROS class is defined by a particular package of setting attributes, activities, experiences, and benefits. Some managers use seasonal ROS maps where opportunities vary significantly by season. With changes in technology—especially increased availability of remotely sensed data and greater use of GIS—recent studies have focused on better utilization of spatial data to generate ROS maps, e.g., USDA Forest Service 2003. This is especially true for biophysical setting attributes, although progress has also been made in bringing social recreation data into GIS environments. The ROS and its many variants—including the Water Recreation Opportunity Spectrum (WROS)—have the benefits of being flexible and easy to understand.

Visitation parameters are practical and widely used recreation indicators. Methods for tracking visitor numbers and related factors (group size, activities engaged in, length of stay, etc.) include direct observation via onsite staff or cameras, devices that record and store visits automatically, and counts of visitor registrations or permits. Inferred counts are based on factors such as number of cars at trailheads or parking lots, or amount of visitor impact. An innovative recent methodology employed publicly available social media data (Flickr database of 100 million geo-referenced images) to assess site-specific visitor parameters and values at state parks in Vermont and several popular recreational rivers in Idaho (Hale, 2017).

Commonly-used indicators for recreation experience quality include visitor density (e.g., number of visitors at attraction sites; number of encounters with other visitors on a trail), type of visitors encountered (e.g., hikers encountering mountain bikers), the condition of the natural environment and developed facilities at a site, and overall level of visitor satisfaction. These elements are usually monitored using visitor surveys. Tracking change in experience quality by monitoring satisfaction or acceptability of certain conditions can be complicated by visitor displacement—the tendency of some users to stop using particular sites if conditions there change (e.g., visitation increases) to the point of unacceptability, and be replaced by visitors who are more tolerant of these changed conditions. Use of a numeric standard or reference conditions, e.g., a particular number of persons at one time (PAOT) can help mitigate for this.

The economic outcomes of nature-based outdoor recreation have been examined extensively and are often locally and regionally significant. Economists distinguish between recreation economic *value* and economic *contribution* (Watson et al., 2007). Recreation economic value is a monetary measure of the benefits received by an individual or group directly engaged in an outdoor recreation activity, calculated as the amount they are willing to pay for the activity, minus their costs to engage in it. These direct use values can be used to evaluate change in access or change in quality that might alter types of activities and enjoyment. The US Forest Service Recreation Use Values Database (updated in 2017) can be used to derive average per person, per day values for 14 outdoor recreation activity sets from studies conducted 1958-2015 in numerous locales. These values can be used in combination with local visitation data to derive empirically grounded estimates of recreation economic values for particular recreation areas.

Recreation economic *contribution* measures the gross change in economic activity associated with recreation in an existing regional economy. This measure includes direct spending on lodging, food, fuel, equipment, guide services, etc. and indirect effects via wages and secondary spending supported. To estimate recreation economic contribution, federal land agencies typically aggregate district-level visitor use data with estimates of per capita, per day spending garnered from onsite or phone surveys, e.g., the USFS Program and the US Fish and Wildlife Service indirect economic contributions are often assessed with the IMpact analysis for PLANning (IMPLAN) model. Segmenting visitors by trip type— e.g., local-day and local-overnight, and non-local day and non-local overnight trips—allows for better estimates of local economic contribution than segmenting by activity only (White and Stynes, 2008). With some exceptions (e.g., downhill skiing, motorized recreation), the type of recreational activity has much less impact on expenditures than trip type. White et al. (2013, updated version forthcoming) provide key parameters to complete economic contribution analysis for individual national forests. These tools could be adapted for state lands.

Washington's rich endowment of exceptional natural landscapes and the high quality, nature-based recreation they support is widely understood to be a significant factor in attracting new employers and workers to the state. *Amenity migration* is the movement of people based on the draw of natural and/or cultural amenities, and could be a benefit of protecting additional natural areas and making them available for nature-based recreation. But quantifying changes in amenity migration, including total employment or wages due to changes to any particular parcel of land or attribute has proven difficult, and is not likely to be separable from the broad suite of factors that collectively attract migrants, including climate, social services and cultural components (Hjerpe et al., 2017).

Public health, wellness, and human quality of life benefits to conserving natural areas have long been recognized. At least some of these benefits fall under the rubric of "recreation" but they also encompass broader issues such as reduced health care costs. Studies assessing health indicators (e.g., obesity) and access to greenspaces commonly find that closer greenspace proximity is correlated with higher rates of outdoor recreation participation and better health. Interest in clarifying and quantifying these benefits continues to grow but establishing causality and linkages to protected areas is challenging due to the many nested and interrelated factors which affect human health. There is a growing evidence base regarding the potential health and well-being benefits of green space and nature-based recreation but the effects are heterogeneous and cannot be summarized as a straightforward exposure-outcome relationship.

Studies examining health outcomes consistently show relationships between recreation opportunities and well-being. Rosenberger et al. (2005), in a study estimating linkages between healthcare expenditures for treatments of circulatory problems, physical inactivity, obesity, and the supply of recreation opportunities in West Virginia, found that counties with more physical activity had higher quantities of recreation opportunities, lower health care expenditures, and lower rates of obesity. Similarly, Rosenberger, Bergerson and Kline (2009), in an analysis of county-level data for Oregon, found a measurable relationship between adult physical activity, overweight, obesity, and recreation supply (trail miles, public land densities, number of recreation facilities) and demand. Biedenweig et al. (2017) empirically demonstrated that a variety of mechanisms for engaging the natural environment, including recreation access, significantly contribute to overall subjective wellbeing, by way of a 13-question survey of 4418 people in the Puget Sound region.

The Florida Communities Trust (FCT) uses 18 public health significant questions out of 60 total—including several specific to outdoor recreation—to assess which land acquisition proposals to fund. Examples include: Will the project provide access to a shoreline or beach and be managed for recreation uses? Will the project enhance or connect local, regional or statewide land-based recreational trail systems by extending an existing trail system or by providing trailhead or trailside facilities? Successful applicants are more likely to score higher on these measures, indicating that FCT land acquisitions support public health in Florida (Coutts, 2010). These selection criteria could also be used to assess outcomes of completed acquisitions, e.g. the degree to which the acquisition enhances or connects local, regional or statewide trail systems.

In practice

General guidance

- Keep track of visitation – a basic but critical information need. Other recreation outcomes (e.g., health benefits) can be inferred to some degree simply by knowing how many people are recreating in an area, and what they are doing. How many people are now using the [newly acquired] area for recreation? How many, and what kinds of recreation experiences does the area support? How are these factors changing over time?
- Actively pursue opportunities to acquire, share and incorporate spatial data for recreation setting attributes and visitation as GIS layers to integrate into an ecosystem service framework for management.
- Key indicators of a parcel's value for nature-based recreation include: proximity to population centers (# of people who will use the area; ease of access, the closer the better), proximity to water, ecological integrity/level of disturbance, degree of ecological and scenic distinctiveness
- When examining economic outcomes, look to USFS research and monitoring for assessment tools and estimators, e.g., the National Visitor Use Monitoring (NVUM) program and spending profiles, and also the U.S. Forest Service Recreation Use Values Database.

Outcome measures

Some of the indicators and metrics found in the literature or from identified effective practices are listed in Table 3

Table 3 Indicators and metrics for recreation outcomes identified in the literature or effective practices		
Outcome Measures Category	Indicators and Metrics (units of measurement)	Source(s)
Recreation Supply, Inventory and Access	• # of recreation sites, by type (e.g., campgrounds, picnic areas, attraction sites) • # of miles (e.g., trail or route; coastline of lake, river or ocean) • Amount (e.g., acres, number of campsites) of recreation experience opportunities in each Recreation Opportunity Spectrum (ROS) class, e.g., *semi-primitive, non-motorized* (by ecosystem type, region or planning area) • Amount and kind of ROS experience opportunities added by a particular land acquisition • % total green space (in predefined region) held in public ownership and managed for public access • Median park size in planning area • People served per park acre • % of residents within a 10-minute walk (½- mile) to a park/greenspace OR population unit (e.g., census area) centroid linear distance from park/green space edge • # of new park facilities developed per year, by type of facility • # of existing park facilities improved per year, by type of facility • # of new non-park recreation facilities (boat ramps, trailheads, wildlife viewing platforms, etc.) developed or existing non-park facilities improved per year, by type of facility. • % of visitors and residents rating the access to recreation activities as good or better - total and by activity type • % of recreation sites that meet ADA standards - total and by recreation activity type	More et al., 2003; Aukerman and Haas, 2004; Manning, 2011
Recreation Participation and Demand	• % of population participating in nature-based recreation. Common outcome measure, assessed via survey, usually broken out by subcategory, e.g. camping, backpacking, boating, wildlife viewing, bird watching; subpopulation (adults, teens, children). • % of participation by population subgroups based on race, ethnicity, gender, socioeconomic status. (A measure for equity of recreation participation.) • % of recreation sites at or above capacity more than X% of the time on high season days - total and by recreation activity type • Park need: Areas farther than 10-minute walk from a park. Prioritize among those areas based on: 1) population density - weighted at 50%; 2) density of children age 19 and younger - weighted at 25%; 3) density of individuals in households with income less than 75% of city median income - weighted at 25%. • # of permits (e.g. fishing, hunting, discover pass/northwest forest pass, wilderness hiking) sold • # of access passes sold per year, per type (Discover Pass, Northwest Forest Pass, etc.) • # of entries in trailhead registers	Manning, 2011

Recreation Experience Quality	*Visitor satisfaction* • % of visitors that report being satisfied or very satisfied with their overall experience • % of visitors that report being satisfied or very satisfied with components of their recreational experience: 1) quality of facilities, 2) quantity of facilities, 3) access, 4) safety, 5) trail condition, 6) signage adequacy, 7) condition of environment, 8) range of recreation activities available. • % of visitors who report seeing wildlife; #of sightings *Visitor density and related measures* • People At One Time (PAOT) at attraction sites: actual number vs. established standard, change over time • Persons Per Viewscape (PPV) • Vehicles Per Viewscape (VPV) • Encounters (per hour, per day) with other groups (e.g., along a trail): actual number vs. established standard • Percent of time/days a site is at full capacity (e.g., parking lot full, campground full, all picnic sites in use.) • Amount of visitor impact (indirect indicator Percent of visitors feeling “very crowded” or “extremely crowded” using 9-point crowding scale: 1 = not at all crowded; 9 = extremely crowded • # or % of reports of visitor conflict • Evidence of visitor displacement *Condition of facilities; visitor impacts* • % of campsite that is bare ground • # of pieces of litter per unit area, or mile of trail	Manning, 2011; Hale, 2017
Economic Outcomes of Recreation	*Recreation economic contribution* • Direct expenditures by participants • Total business sales generated • # of jobs supported – full time, part-time, all year, seasonal *Recreation economic value (benefits received by an individual or group directly engaged in an outdoor recreation activity)* • Consumer surplus value per day, by recreation activity	Watson, et al., 2007; Manning, R., 2011; Hjerpe et al., 2017; Rosenberger et al., 2017
Recreation Health and Quality of Life Benefits	• Requires survey to represent indicators for monitoring human wellbeing associated with environmental restoration (e.g., 13 question survey of Biedenweg et al., 2017)	Coutts, 2010; Manning, 2011; Biedenweg et al., 2017
Sustainable Development/Smart Growth	• [Degree to which] project provides recreational opportunities and open space areas that direct residential and commercial development away from a coastal high hazard area or a 100-year flood plain, or in ways that reduce sprawl • % of lands permanently safe from development	Manning, 2011

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3 Fish and Salmon

WA Programs

- Salmon Recovery Funding Board (SRFB)
- Puget Sound Acquisition and Restoration Program (PSAR)
- Puget Sound Estuary and Salmon Restoration Program (ESRP)
- DNR Forest Practices

Literature Review

Restoring Pacific salmon populations has been a major focus of state and federal agencies in the U.S. for over 20 years. NOAA Fisheries, Washington Department of Fish and Wildlife (WDFW), other federal agencies and Tribal governmental agencies collect large amounts of information about the number of salmon that return to Washington's rivers from the ocean. They also collect information to judge salmon reproductive success, including numbers of redds, fry and smolts. There are many peer-reviewed papers describing the biology, movement, survival and mortality factors of the different life-stages of salmon in the Pacific Northwest. Because assessing salmon returns and reproductive success has been mainstream business for so many years, there is not much recent literature about methodology or indicators. However, traditional salmon population indicators may be just fine for looking at the outcomes of the state's efforts. However, it may be particularly difficult to link these indicators to habitat conservation and restoration activities due to the influence of unrelated factors, such as survival rates in the ocean or time lags between restoration actions and salmon population responses.

For salmon habitat indicators, the best source of information may come from an ongoing project undertaken by the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) to identify these. The project, which includes staff from WDFW, NOAA Fisheries, ODFW, IFG, USGS, and others, resulted from a high-level indicators for salmon and ecosystem health report PNAMP prepared in 2008. The group is evaluating indicators based on overall relationship to important outputs and measurement feasibility given available or attainable monitoring data.

Efforts to protect non-game freshwater fish and their habitat are less common, and the indicators, methods and best practices to understand whether species or important populations are being conserved are much less studied. The Heinz Center (2008) identified At-Risk Native Freshwater Species and Established Non-native Freshwater Species as the best indicators, but decided that the data was insufficient to report on changes in the percentage of fish or aquatic species that were at risk, or on their populations. The data for the percentage of species at risk in Washington may be sufficient, although aside from salmon, population trend data is probably lacking. A more recent report (Costanzo et al., 2015) identified native fish diversity, non-native fish, and juvenile Chinook salmon as their key indicators for fish in Oregon's Willamette basin; and for habitat they identified channel complexity as the best measure of in-stream habitat and area of floodplain forest as the best indicator of healthy riparian areas.

In practice

Many state departments of Fish and Wildlife include the status and trends of monitored salmon and steelhead populations as their primary indicators of program success. These often include measures that accurately reflect the status and trends in the sampled areas. However, these measures may not reflect overall state status in cases where the ongoing monitoring is established to assess the trends of a watershed or particular population or species group. Conversely, monitoring across large spatial scales may provide information about ESA-listed population groupings (Evolutionarily Significant Units) but with poorer resolution at the scale of individual populations or watersheds. The states of Washington and Oregon currently do an excellent job monitoring salmon trends, especially in their priority watersheds.

Few states have developed statewide monitoring programs to comprehensively assess status and trends for both game and non-game fish species. California has developed one of the few statewide assessments of all native fish, through their native fish-based stream classification system, although it would be difficult to emulate this elsewhere. The University of Missouri has developed a statewide assessment, called their Aquatic Gap Analysis (Annis et al., 2010) in which they assessed the distribution and status of the approximately 130 fish species native to Missouri, as well as all of the native fish that occur in the Missouri River Basin. This included an evaluation of how well these species are protected and how the diversity of streams that support native fish. The Missouri Department of Conservation, which includes their Fisheries agency has taken this distribution data, and used it to monitor the status and trends of all at-risk fish species in the state, as well as to inform the state's water quality regulatory program through their 303(d) and 305(b) regulations (Matthew Combes, personal communication). Because the system covers all of the streams in the state, reporting on overall status and trends statewide is possible.

Outcome measures

Some of the indicators and metrics found in the literature or from identified effective practices are listed in Table 4.

Table 4: Indicators for fish and salmon outcomes identified in the literature or effective practices

Outcome Measures Category	Indicators and Metrics (Units of Measurement)	Source(s)
Salmon Population Recovery	• Returning salmon • # of outmigrating salmon and steelhead	Crawford and Rumsey, 2011; O'Neill et al., 2008
Native Fish Species Abundance and Diversity	• Native fish species diversity across the state • Relative abundance of native versus invasive fish (with a focus on harmful introduced fish, rather than all of them within watersheds or stream reaches • # or status of at-risk fish	Annis et al., 2010; Wagner et al., 2013
Status of Important Fish-supporting Habitat	• Extent of floodplain forests • Channel complexity (length of channel per 100 meters) or suitable fish habitat • Inundation frequency of high quality chinook habitat	Castanzo et al., 2015; Hulse, 2017, personal comm.
Access to Rivers and Streams for Spawning	• Barriers (dams without passage and culverts needing repair) blocking fish passage, and the potential amount and quality of the habitat above the barrier.	IMST, 2007

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4 Water Quality and Quantity

WA Programs

- Department of Ecology Water Quality Program
- Local jurisdictions' stormwater regulations

Literature Review

The Clean Water Act (CWA) requires states to compile a list of rivers, streams and lakes that do not fully support beneficial uses of water such as fish and aquatic life, as well as drinking water, recreation, industrial and agricultural uses called the 303(d) list.

Many states use the decline in the number of water bodies on the 303(d) list acts as the indicator of the success of regulatory programs. However, in practice, rivers and streams are sometimes included on the list because of one particular factor. In the Pacific Northwest, that factor is often a temperature that is too high to support salmon and trout. As a result, inclusion in the list does not do a very good job of describing how clean the water is, or how well the water bodies meet peoples' needs. For 303(d) water bodies, states establish a "total maximum daily load" or TMDL, that defines the maximum amount of the pollutant or factor such as heat, a water body can accept while still meeting the water quality standards. Staying within TMDL limits can be used as an indicator of water quality success. However, the beneficial uses defined in the law actually represent the most important outcomes of the water quality regulatory programs, and would represent the most relevant indicators of program success.

Water quantity and availability are determined by water rights, generally available based on seniority; and often a source of disagreement or uncertainty within water allocation systems. Since most of the watersheds in Washington have more people who want to use the water than there is available water, competition for water can be intense. As a result, measuring the effectiveness of water distribution programs in terms of outputs to communities can be complex.

A major activity used to manage water quality is stream restoration, including riparian buffer management. Many peer-reviewed papers document the success or failure of stream restoration activities, using measures of the array of stream functions (Davis and Jackson, 2006). These papers and a set of relatively new Stream Function Assessment Method (SFAM) protocols identify a number of measures that provide information about the condition of streams, and stream functions. None of these are explicitly tied to outputs, although most assume there are direct links between stream conditions and functions, and meaningful outputs of regulatory or restoration programs. Ecosystem Services researchers papers say that functions only link to outputs if they directly lead to benefits people need (Tallis et al., 2008; Olander et al., 2015).

Water quantity metrics are relatively straightforward compared to other metrics of ecological condition. Nonetheless, they must be tailored to end users' needs, including biota, in order to be effective indicators of outcomes. For Washington State, the identified users are salmon and other aquatic species and the human consumers in the residential, commercial and industrial sectors.

The literature on ecological flows identifies multiple metrics of flow thresholds and durations that support salmon movement and survival (e.g., Willis et al., 2016). More recent research has noted the important synergies between quantity and quality. For example, dam release patterns can have a strong effect on water body temperature. As a result, the recent literature emphasizes a need for indicators to comprehensively characterize the seasonality and variability in stream temperatures or other limiting factors on habitat (Olden and Naiman, 2010; Stahlnaker and Wick, 2000). Generic metrics do not seem to be available, but rather flow requirements are tailored to the geomorphology of the system (Stahlnaker and Wick, 2000; Willis et al., 2016).

The most common water quality indicators described in the literature - and used by agencies in practice - are assemblages of data complied into a Water Quality Index or WQI. Many states use, in lieu of or addition to a WQI, an Index of Biotic Integrity or IBI. IBIs summarize data about a set of aquatic organisms found in the water, characterized by the species that occur in disturbed or more polluted waters, versus species that occur in more pristine rivers, streams and lakes. IBIs, because they require identification of microorganisms and insects, can be more expensive and more difficult to complete than WQIs, but are used because they help differentiate the very high quality areas. However, a problem with both WQI's and IBIs is that they rarely show rapid changes, and the standard methods often do not reflect smaller improvements made by restoration or regulatory programs.

As noted in the wetlands discussion, a few publications, particularly Palmer et al. in 2011 have identified indicators of stream and wetland outcomes, including those related to the hydrologic regime and water quality, with the benefit-relevant indicators concept used to tie the program outcomes with specific communities.

In practice

Promising practice: Massachusetts

The Massachusetts Department of Energy and Environmental Affairs worked with staff at the EPA Office of Water to pilot a set of indicators now integrated into their environmental monitoring program. As part of this work, they evaluated important water needs and beneficiaries within each of the watersheds in the state. This helped define their primary goal for the Massachusetts surface monitoring program, which is to "Collect chemical, physical and biological data to assess the degree to which designated uses, such as aquatic life, primary and secondary contact recreation, fish consumption and aesthetics, are being met in waters of the Commonwealth". The Massachusetts Water Resources Authority has developed monthly and annual Water Quality report cards for drinking water, while Warren Kimball and Massachusetts Department of Environmental Protection worked with Lilian Busse at the California State Water Resources Control Board to pilot an Automated Water Quality Report Card System now being used in both states on a trial basis.

Best practice: Minnesota

The state of Minnesota has developed what appears to be a model program of indicators to assess the effectiveness of their clean water restoration, protection and regulatory programs. The state created the Clean Water Fund, and an interagency team from their pollution control agency and their large Department of Natural Resources, to work together with the other state agencies (Agriculture, Health, Water Resources, etc.) to create the report and integrate their monitoring efforts to address the indicators. The legislature created both the fund, and the requirement that the effectiveness be monitored as an interagency effort, which may explain why these indicators have been so successful. Their biennial reports list both effort and outcome based results. And, because it is tied to funding effectiveness, is likely the one most relevant to JLARC's interests. According to staff who developed the initial report (David Wright, Minnesota Department of Natural Resources and Pam Anderson. Minnesota Pollution Control Authority, personal communication), the development of the first report was relatively expensive ($750,000). The initial cost reflected their need to assure that annual monitoring was in place to update the indicators each year. Yet the indicators and the report were developed so as to allow simple annual updates which their DNR and Pollution Control agencies can accomplish within their existing budgets. The outcome based measures they include are listed in recommendations below, along with those from Massachusetts or the published literature.

Outcome measures

Some of the indicators and metrics identified in the literature or effective practices are listed in Table 5.

Table 5: Indicators and metrics for water quality and quantity outcomes identified in the literature or effective practices

Outcome Measures Category	Indicators and Metrics (Units of Measurement)	Source(s)
Water Quantity	• Water supply reliability index (e.g., % time flow meeting requirements for each / all users) • Extreme low flow duration • Fish supported at measured flows	Paulson et al., 2008; Willis et al., 2016
Surface water quality	• Surface water health (or the rate of impairment vs. non-impairment statewide and by watershed) • Lake and Stream Water Quality (changes in time of key WQ parameters for lakes and streams, which include: temperature, pH, conductivity, dissolved oxygen, phosphorus or nitrogen and physical properties including turbidity, sedimentation, disturbance, intact hydrology • Median concentrations of pesticides of concern in surface water statewide. • Trends of mercury in fish and statewide mercury emissions (MN). Other states replace mercury with toxins as a more general indicator. • Balance between groundwater use and recharge or groundwater levels.	James et al., 2012; Paulson et al., 2008; Davies and Jackson, 2006
Ecosystem services *(Indicators that include the capacity of rivers, streams, lakes and ponds to)*	• Support recreational opportunities such as swimming, bird-watching, fishing and boating. • Provide drinking, wildlife, agricultural and industrial water needs. • Support aquatic biodiversity.	Baron et al., 2002 Keeler et al., 2012; Olander et al., 2015
Groundwater	• Provide sufficient levels of water for drinking water needs, and to monitor changes in time of groundwater water quality (pesticide concentrations, toxins, nitrates)	James et al., 2012

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5 Freshwater Wetlands

WA Programs

- Department of Ecology Wetlands Program
- Local jurisdictions' critical areas ordinances

Literature Review

Wetland conservation follows from Section 404 of the Clean Water Act, which identifies wetlands as an important resource to the people of the United States because of significant benefits they can provide. These benefits include providing important habitat to many fish and wildlife species, storing water to assist in providing late season water downstream or to help control downstream flooding, removing nutrients and sediments from water to provide cleaner water, assisting in recharging aquifers. Some forested or deep-water wetlands can assist in lowering downstream water temperatures, which supports salmon reproduction and survival. Wetlands also provide aesthetic value and have been shown to support property values since home near wetlands have higher market value, all else equal (Boyer and Polasky, 2008). Outcome measures for freshwater wetland goals will ideally reflect the characteristics of wetlands that generate benefits, whether wetlands are being protected, enhanced or restored.

There is extensive literature documenting the successes and failures of wetland protection and compensatory mitigation and restoration activities. Traditionally, success has been measured by the total number of wetland acres protected, restored or lost, which does not directly measure the outcomes outlined in the Clean Water Act. Progressive state wetland conservation programs, including that at the Washington Department of Ecology, have focused on identifying "wetland functions" to address the fact that all wetlands are not equal and that some wetland acres provide more functions than others, depending on local and regional needs. Wetland functions have been enumerated in many places and they include protecting and improving water quality, providing fish and wildlife habitats, storing floodwaters and maintaining surface water flows during dry periods. Wetland functional indicators usually target ecological attributes of wetlands that can be measured or identified in the field, often as compared to a high functioning wetland. In 2016, the Association of State Wetland Managers (ASWM) published a report online updating the definitions of wetland functions, and providing a list of potential value or outcome based indicators.

A few publications, particularly Palmer et al. 2011, have identified indicators of wetland outcomes, including those related to the hydrologic regime, sediment removal, support for fish and wildlife, and water quality. In addition, Olander et al. (in press), have identified a few different outcomes, such as flood amelioration and temperature support. Both studies focus on the idea of benefit relevant indicators, which tie the program outcomes with specific communities of beneficiaries.

In Practice

Common Practices – Wetland Dashboards

States across the country use a variety of metrics that span simple acreage measures to detailed evaluation of likely benefits. The U.S. Fish and Wildlife Service publishes an area-based assessment of wetland acreage changes across the U.S. using their National Wetlands Inventory's spatial data every 5 years, last completed in 2009. However, most wetland scientists in the western states believe this data, developed largely through air photograph interpretation, is both incomplete and not updated frequently enough to meaningfully represent change. A number of states, particularly Massachusetts, Minnesota, as well as the Chesapeake Bay, have moved to a report card or dashboard concept to communicate program effectiveness. The limitation of these dashboards is that the grading systems tend to be very generalized and may fail to capture important trends in habitat loss or thresholds of ecological function relevant to flood or erosion control. Nonetheless, they inform the public as to conditions and overall trends.

Currently, there are two very different methodologies used or proposed for assessing the status and trends of wetlands in the U.S. The first is a sample-based protocol, which is the basis of EPA's National Wetland Condition Assessment, which is widely referred to in the literature (Paulsen et al 2009, Ode et al. 2008, Yuan et al 2008). The assessment assumes that wetland condition is a direct indicator of the important outcomes wetlands can provide. A random selection of wetland sites are measured using field visits, typically on a cycle of every five years (last reported on in 2011, and sampled in 2016). Individual states have the option of expanding the number of sites selected using the same probability based network that is used by EPA.

Promising Practices – Modeling Wetland Services

The second methodology used is to map all the wetlands in a jurisdiction, and, using desktop GIS methods, model their ecosystem services outputs based on the combination of services they have the potential to provide and the presence of beneficiaries (Olander et al., 2015, FNAI 2016). This approach has the potential to represent meaningful outcomes of wetland changes, but is more experimental, built on a spatial modeling representation of rapid assessment protocols (Hruby 2009, Stein et al., 2009), but modified. It has been used in a number of academic studies, but is not in practice widely, although some states incorporate some elements of looking at location context to compare likely wetland function. Further, work to date has aimed to prioritize areas for mitigation or restoration based on the overall, relative benefits rather than using the method to generate an absolute indicator of benefits.

Table 6 Indicators and metrics for freshwater wetlands outcomes identified in the literature or effective practices		
Outcome Measures Category	Indicators and Metrics (Units of Measurement)	Source(s)
Function or Condition Indicators	• Degree of correspondence to reference biological components including benthic macroinvertebrates, amphibians, birds, fish, or phytoplankton • % native species or plant species diversity (relative to characteristic levels), often called Floristic Quality Index (FQI) • Chemical properties, including acidification, conductivity, dissolved oxygen, phosphorus or nitrogen (relative to reference) • Physical properties including erosion or sedimentation, disturbance, intact hydrology (relative to reference), vegetated structure, presence of habitat structures, etc.	Hruby, 2009; Hruby et al., 2009; Faber-Langendoen et al., 2006; Fennessy et al., 2008
Ecosystem Service Indicators *(include the capacity of existing or restored wetlands to provide benefits to communities)*	• The amount of damaging flood water stored by individual wetlands, based on their size, depressional area, soils, hydrology, and downstream development • Amount of carbon stored • Amount of late season water provided to downstream users based on wetland size, soils, hydrology and late-season downstream water needs • Support species and habitats based on the numbers of at-risk, species of concern, or species likely to use wetlands • Amount of pollutants removed, including a) Amount of sediments, based on sediment inputs, wetland physical properties, and presence of sediment concerns in receiving waters (e.g., salmon spawning areas) b) Amount of phosphorus based on phosphorus inputs, wetland physical and chemical properties, and vulnerability of receiving waters (e.g. algal bloom risk) • Amount of cooling provided, based on shading, size and depth, and temperature sensitive species use in receiving water body.	Boyer and Polasky, 2004; Olander et al., 2015; Wang et al., 2010

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6 Tidal Wetlands

WA Programs

- Puget Sound Estuary and Salmon Restoration Program (ESRP)
- Puget Sound Acquisition and Restoration Fund (PSAR)
- Salmon Recovery Funding Board (SRFB)
- Department of Ecology Wetlands Program
- Local jurisdictions' critical areas ordinances

Literature Review

Tidal wetlands are protected because of their ability to support fish and waterfowl, protect shorelines, and regulate water flows and sediment.

The common, overarching goals of tidal wetland monitoring are to reduce stressors, demonstrate beneficial outcomes and promote adaptive management. More specific goals include support of species of concern and promoting resilience of wetlands to sea level rise through sediment accumulation and migration. Programs throughout the US share these goals, so indicators of condition and trends for multiple programs are compared and summarized in the text that follows.

In the broad literature, tidal wetland restoration is evaluated in terms of the goals of preventing shoreline erosion, preventing flooding, providing habitat for wetland-dependent species, improving habitat for species in connected ecosystems (e.g., via improved water quality in estuaries), improving aesthetics, and supporting commercial and recreational fishing, hunting, gathering and wildlife viewing. A relatively new goal of tidal wetland restoration and protection has been to sequester carbon for purposes of mitigating risks of climate change (Sifleet et al., 2011).

In practice, program performance is most commonly assessed with metrics of outputs. Primary metrics include: (1) total tidal wetland area, (2) area restored, or (3) area lost due to human activities. For example, a recommended action metric is the number of acres of coastal habitats a) protected by acquisition or easement and b) restored with assistance from program funding or staff (NOAA, 2010). Total wetland area has also been a common performance metric (NOAA, 2010), but the alternative metrics of area restored or lost have become more popular for continuous tracking because national geospatial data products that map wetland extent are not being regularly updated (US Fish and Wildlife Service, 2017; National Oceanic and Atmospheric Administration Coastal Services Center). Some programs use remote sensing to conduct their own assessments of tidal wetland area (e.g., Louisiana portion of the Gulf of Mexico).

Tidal wetlands integrate a wide variety of landscape, ocean and atmospheric drivers and many assessment metrics are built around assessing the magnitude of these threats or the direct alterations of wetlands. A comprehensive review evaluated threats to salt marsh from land use conversion, agricultural use, hydrologic modifications (diking and tidal restrictions), pollution, non-native invasive species, and climate change (Gedan et al., 2009). Examples of program metrics that reflect these drivers include: extent of aquaculture operations; wetland area under the influence of dikes, tide gates, levees, or other hydrologic modifications; toxicant concentrations in sediments; invasive plant species cover; and invasive herbivore population density.

Scientific researchers use a variety of individual metrics and multi-metric indices to assess outcomes due to presence or condition of tidal wetlands. Much of the research examines the relationships between these stressors and biotic outcomes of hydrologic, biotic, geomorphic, and physio-chemical processes (Palmer et al., 2011) (Table 7). Restoring or maintaining characteristic hydrologic variability (timing, magnitude and duration of wet and dry cycles) is considered a critical condition for success of all other processes and endpoints (Zedler, 2000; Euliss et al., 2008). Vegetation cover, diversity and structural complexity are typically used to suggest whether a marsh is likely to provide refuge and food, or to mediate many physical and chemical conditions necessary to provide habitat (Palmer et al., 2011). Only rarely are biotic outcomes (e.g., waterbird or fish usage, bird breeding success) routinely monitored. Finally, the physical and chemical condition of soils, pore water and surface water are monitored to assess both drivers and wetland condition (e.g., soil organic matter or toxicant concentrations).

Table 7. Wetland condition outcome measures selected by expert panel for tidal wetland outcomes monitoring (all of these are modified from Palmer et al., 2011)

Outcome Measurement Category	Indicators
Hydrologic	Tidal regime (range, inundation duration, velocity)
	Hydrologic connectivity
Geomorphic	Elevation
	Slope
	Topographic complexity
	Area (by physical zone), Edge complexity
	Sedimentation rates
Biotic	Vegetation cover & density
	Canopy complexity
	Vegetation (native) species richness
	Invasive plant species cover
	Invertebrate assessments (species richness, density, community composition)
	Species use (Fish and shellfish abundance, species richness, juvenile densities; wetland-dependent bird abundance; migratory bird counts)
	Breeding success (Bird fledgling counts, nests, eggs)
Physio-Chemical	Pore water salinity and pH
	Surface water quality (T, DO, chl-*a*, TSS, N, P, contaminants)
	Denitrification potential
	Soil properties (Grain size, organic matter, bulk density)
	Nutrient retention / removal

In practice

The literature review and expert panel assessment of Palmer et al. (2011) identified four criteria for choosing appropriate performance measures of restoration investments.

1. Match indicators to goals

2. Separate measures of implementation from performance
3. Capture structural and process changes at ecologically relevant temporal and spatial scales
4. Use appropriate reference criteria for judging progress (which may not be historical conditions).

Although these criteria were developed for tracking performance of environmental restoration investments, they are transferable to evaluating programmatic outcomes. Another criterion, cost-effectiveness, was addressed indirectly by this group. They suggested that managers choose 1) a core set of feasible metrics to be measured in many areas through time and 2) choose an expanded set of metrics to be evaluated at a sample of sites to provide additional insights for tracking progress and adaptive management.

It is clear that the scientific community puts a premium on measuring outcomes rather than outputs to understand restoration effectiveness (Weilhoefer, 2011). A common scientific ideal for matching indicators to habitat goals is to use field observations to track effects on wetland-dependent flora and fauna through time (e.g., change in vegetation community and waterbird populations). However, such indicators are relatively expensive (Weilhoefer, 2011) and respond to multiple drivers, making them difficult to interpret for tracking performance of a given program.

Many scientists also support using metrics of air, land and water drivers, to better understand management needs and constraints on program progress (Euliss et al., 2008). Driver metrics include understanding changes in air, land and water that may affect wetlands. These metrics track such influencing factors as freshwater inflows, land use upslope of wetlands or within watershed, and climatic changes.

Many programs only measure wetland area or change in area due to specific actions, which is the minimum amount of information needed to project whether programs are achieving goals. Such information is not sufficient to fully characterize achievement of habitat and recreation goals. Perhaps more importantly, it does not promote goals to protect and restore the natural processes that create and sustain the nearshore ecosystems, since it does not create incentives to improve wetland condition, such as removing tidal restrictions.

Simple wetland area metrics can be improved by adding some measure of wetland quality. Many quality-adjusted area indicators of tidal wetland condition can be calculated using a desktop GIS analysis (if georeferenced data are available) or surveys that involve one or more site visits (Haering and Galbraith, 2010). Rapid assessment methods that use multi-metric indices are used in some states to suggest overall tidal wetland condition (Carletti et al., 2004). However, the relative advantage of collecting many metrics, as opposed to a parsimonious set of metrics is unclear and many programs choose only a few metrics to reflect tidal wetland condition (e.g., vegetation biomass, community composition) (e.g., Hijuelos and Hemmerling, 2016). Individual metrics can be tailored to specific goals. For example, San Francisco Bay uses area of tidal wetlands above a threshold patch size, as a leading indicator of use by bird species of concern (San Francisco Bay Estuary Partnership, 2015).

Small sets of metrics can be chosen to be proxies for specific goals but may not provide leading indicators of future ecosystem condition. For example, coastal wetland vegetation density, biomass production, and marsh width or size have been associated with storm surge attenuation (Shepard et al., 2011; Barbier et al., 2013). However, if sediment accretion rates are not measured, then programs may fail to characterize potential for wetland loss under sea level rise. An approach to providing cost-effective information on trends is to supplement the routine use of structural indicators (e.g., vegetation area and density) with selected studies of processes (e.g., sedimentation) that can provide more information about system resilience (Carletti et al., 2004; Palmer et al., 2011).

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7 Estuaries

WA Programs

- Puget Sound Estuary and Salmon Restoration Program (ESRP)
- Puget Sound Acquisition and Restoration Fund (PSAR)
- Salmon Recovery Funding Board (SRFB)
- Local jurisdictions' critical areas ordinances
- Shoreline Management Act

Literature Review

Estuaries integrate conditions from land, atmosphere, rivers and oceans and, as a result, their management is a complex undertaking. In Washington State, estuarine condition goals are derived from a combination of federal and state laws, regulations, treaties, and policies and missions of nonprofit organizations and communities. A major consideration for legal compliance is the Clean Water Act, which establishes that water quality should be consistent with public health and public enjoyment of waterbodies, the propagation and protection of wildlife, birds, game, fish and other aquatic life. It also sets a goal that all known available and reasonable methods by industries and others to prevent and control the pollution of the waters of the state of Washington should be implemented. Also relevant for legal compliance with federal law is the Endangered Species Act for the protection of threatened and endangered species that may depend on the estuary or connected ecosystems. A voluntary federal program, in which Washington State participates, requires coastal states to develop a Coastal and Estuarine Land Conservation Program Plan (CELCP) to effectively manage and preserve significant coastal and estuarine areas.

To review the state of the science, we investigated the indicators in use by the major estuary or large water body management programs within the US. Many of those programs have synthesized the published literature and been guided by science advisors in choosing their indicators, so the set of metrics in use by these programs has been vetted from a scientific and feasibility perspective. Further, large water body management programs have similar federal requirements and local goals for maintaining water quality for safe recreation and commercial or other uses, productive fisheries, and protection of species of concern. Also common is the goal to promote the long-term health of the waterbody and associated ecosystems. As a result of these common goals, many indicators are transferable across systems, although priorities for data collection vary.

The management literature on performance metrics for estuaries includes metrics of drivers, actions, and outcomes. *Drivers* include changes in air, land, and water that influence the estuary, such as land cover change in the watershed and freshwater inflow. *Actions* include activities that affect estuaries, such as tidal wetland acres restored. *Outcomes* are desirable results, as expressed through program goals, such as population responses for species of concern.

All the major estuary programs use driver and outcome indicators, only some use action indicators. All programs include water quality conditions to comply with the Clean Water Act and most track seagrass extent as an integrator of water quality and an indicator of fish habitat quality. Most programs also build indicators around commercial fish harvest data.

Beyond some of these common metrics, programs target monitoring to their issues of greatest concern. For example, within the Gulf of Mexico initiatives, Louisiana invests heavily in tracking coastal marsh extent since this outcome is a major program goal (Hijuelos and Hemmerling, 2016). Similarly, the Southern California Coastal Water Research Project Authority (SCCWRP) has made atypical investments in assessing toxics of emerging concern to support their goals of maintaining safe beaches and assessing acidification conditions to protect shellfish and other species (S. Weisberg, 2017, personal communication).

Currently, programs differ markedly in the degree of comprehensiveness of outcomes monitored and whether the metrics represent outcomes that the public can readily understand. Most often, basic changes in ecological structures and processes (e.g., chlorophyll-*a* seagrass extent) are used and not outcomes of fisheries or birds. Impediments to using fish and birds are that they are expensive to monitor and may be responding to conditions beyond the control of the estuary restoration program.

In practice

To provide a set of indicators that 1) tracks progress towards outcome goals and 2) identifies which interventions are likely to be most cost-effective, indicator systems must include metrics of the watershed drivers and the relevant outcomes for the estuary. A critical indicator is pollution loads coming from the watershed, in addition to in situ monitoring, so that actions to alter pollution can be targeted to source sectors (wastewater treatment plants, agriculture, septics and stormwater) or locations.

Driver indicators are useful for correlating trends in water bodies to stressors and identifying management opportunities. Studies in which indicators are measured before and after actions, preferably with control sites to control for weather and other external drivers, offer the best ability to understand effects (as is conducted by PSP). In addition to the typical indicators of land cover and freshwater inflows, we suggest several driver indicators that reflect recent research that impervious surfaces, natural riparian buffers and septic density in riparian zones can have disproportionate effects on estuarine water quality and habitat condition. Metrics of shoreline alteration (i.e., length of bulkheads, riprap, etc.) are also commonly proposed as an estuarine driver, however a recent comprehensive study showed that effects of shoreline hardening can be mixed with some species showing declines (species often found in shallow water such as grass shrimp, mumichogs, killifish) and others showing increases (larger-bodied bottom-oriented species including spot, white perch, and striped bass) (Kornis et al., 2017). The literature also suggests that different types of shoreline erosion control may have differential effects. Recommendations included results for Washington by Dethier et al. that demonstrate specific impacts of shoreline armor on fish, invertebrates, and birds. The summary page that cites the recent publications can be found at https://wsg.washington.edu/research/impacts-of-armoring-on-puget-sound-beaches-diverse-effects-on-diverse-scales/

The ideal estuarine monitoring from a scientific perspective is to collect a comprehensive suite of driver, action and outcome variables to reveal sources of degradation and the effectiveness of actions in terms of outcomes to fish, birds and water quality. However, because such an approach can be costly, states manage the costs by developing a core set of metrics that are routinely monitored and supplement these metrics with temporally or spatially targeted investigations to provide additional data needed for increased understanding and adaptive management. Such targeted investigations also allow programs to take advantage of grants that may not pay for routine monitoring, but will pay for investigations that include extensive data collection.

Some programs, such as the Chesapeake Bay Program, are looking to manage risk of climate and land use change by building system resilience and designing management to be robust to extreme events. One approach is to add forward-looking indicators and metrics (rather than ones related to status) that provide early warnings of changes in drivers or condition. For example, the trajectory of submerged aquatic vegetation regrowth after hurricanes is an indicator that has been discussed as a measure of resilience in the Chesapeake Bay (Wainger et al., 2017). The concept of managing and tracking system resilience is still developing, but may include metrics that quantify recovery time after major acute stressors.

A core set of outcome measures categories for tracking broad program performance (Table 8) was selected by considering three main criteria: (1) the outcome measures category represents a cross section of outcomes that address legal and community stakeholder interests; (2) data are often available to measure representative indicators within these categories to track conditions within large systems, with either existing or cost-effective monitoring; and (3) they include the concept of tracking risk-management activities rather than responding after the fact.

Table 8: Indicators and metrics for estuary outcomes identified in the literature or effective practices

Outcome Measurement Category	Indicators and Metrics (Units of Measurement)	Source(s)
Fisheries	• Commercial harvest & value • Population levels or reproduction rates of commercial or indicator fish • % Shellfish areas safe for harvest • Harmful algal bloom intensity (safe shellfish consumption)	Wainger et al., 2017
Boating and Recreational Fishing	• Boating and water contact recreation areas in compliance with water quality standards for human health • Body burden of toxic contaminants in sportfish species • Public access	Kornis et al., 2017
Biodiversity and Ecosystem Integrity	*Water quality* • Area of estuary in compliance with water quality standards [Based on *in situ* water quality (chl-*a*, nutrients, toxicants, pathogens, sediments, pH, salinity, DO, temperature) integrated over space and time] *Wetland and intertidal habitat* • Extent of seagrass and tidal wetlands (including loss rates) *Species diversity* • Density and diversity of benthic or planktonic organisms (typically scored in terms of relative abundance of pollution-tolerant and pollution-sensitive species present) *Fisheries* • Extent of fish habitat and essential fish habitat (areas meeting reference water quality conditions) • Population size and reproduction rates of species of concern (e.g., chinook salmon, orcas, migratory birds)	Wainger et al., 2017; Sellner et al., 2011; Bilkovic et al., 2016
Mitigating Climate Change Risks	• Hydrologic flow regimes designed to minimize species' risks • Land use planning preserves opportunities for wetland migration due to sea level rise	Wainger et al., 2017

The specific indicators measured within these categories would still need to be determined and Appendix B provides some examples of metrics that have been vetted elsewhere. Some indicators and metrics have not yet been widely employed (e.g., measuring wetland upslope migration potential) but including such indicators could drive an evaluation of existing research, as needed to promote indicators for estuary management that are forward-looking.

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8 Coasts and Shorelines

WA Programs

- Shoreline Management Act
- Puget Sound Acquisition and Restoration Fund (PSAR)
- Puget Sound Estuary and Salmon Restoration Program (ESRP)

Literature Review

Coastal habitats are widely acknowledged to play a vital role in both human and ecological well-being. More than half of the U.S. population lives within 50 miles of the coast, and this area constitutes one of the most important zones of economic activity in terms of both jobs and dollars. Moreover, much of that economy is directly dependent on coastal habitats (e.g., fishing), or indirectly dependent (e.g., desire of people to live near recreational opportunities). Yet these habitats are very dynamic – constantly evolving in response to influences from the land, the deep sea, and storms in the atmosphere. The literature provides few comprehensive discussions on how to monitor these zones. Three sources stand out as providing the best examples of different approaches.

The Heinz Center's *State of the Nation's Ecosystems* (2008) remains the single most comprehensive take on coastal and ocean indicators. The recommendations are based on a series of workshops and committee working groups, drawing on hundreds of experts in the field. The strength of this approach is that it takes a very high level view, addressing many of the key values derived from coastal habitats within a relatively small number of indicators. Its primary weakness is that it does not link directly to specific goals, so there are no targets or benchmarks by which to determine performance. As a result, these indicators function more like vital signs for the coasts, rather than outcome measures. The recommended indicators are:

- Extent and Pattern
    - Coastal living habitats (wetland acreage)
    - Extent of shoreline habitat types (length)
    - Development pattern in coastal areas (indicator development needed)
- Chemical and Physical Characteristics
    - Areas with depleted oxygen (square miles)
    - Contamination in bottom sediments (% of tested sites exceeding healthy benchmarks)
    - Coastal erosion (area managed to control erosion)
    - Sea surface temperature (regional averages)
- Biological components
    - At-risk native marine species (% of species at risk and population trends)
    - Established non-native species in major estuaries (indicator development needed)
    - Unusual marine mortalities (number reported annually)
    - Harmful algal events (indicator development needed)

- Condition of bottom-dwelling animals (% of communities in degraded condition)
- Chlorophyll concentrations

- Goods and services
  - Commercial fish and shellfish landings (millions of tons)
  - Status of commercially important fish stocks (% of stocks decreasing, stable and increasing)
  - Selected contaminants in fish and shellfish (concentrations of mercury, DDT, PCB above thresholds)
  - Recreational water quality (% of beach-mile-days affected by *Enterococcus*).

Lederhouse and Link (2016) tackled the challenge of developing habitat metrics to support ecosystem-based fishery management. They state that while there has been some success in setting habitat metrics at smaller scales (e.g., a specific estuary), these have not scaled-up very well to broader regional scales. Ecosystem-based fisheries management (EBFM) is supposed to account for changes in the overall ecosystem when determining appropriate fishery management or conservation measures. Most work has been focused on developing indicators of ecosystem function (e.g., predator-prey relationships) and socioeconomic factors when setting targets. Yet there is a lack of information that quantitatively links habitat quality and availability to fishery productivity. They propose a set of indicators based on priority habitat types or conservation areas. They place a particular emphasis on fish habitats used during early life history stages, because they assert that these tend to have stronger habitat linkages and serve as bottlenecks for productivity. Also, they are often located in nearshore or coastal areas vulnerable to human disturbances. Their four proposed indicators are:

- % of priority species found within a given habitat area, that have a strong habitat dependence at early life history stages.
- % of priority species found within a given habitat area that have a strong habitat dependence at early life history stages, *and* for which habitat information is included in fishery stock or ecosystem assessments.
- % of key habitat types or areas protected.
- % of priority habitat-dependent species using protected key habitats.

The approach has similarities to a standard gap analysis (e.g., determining the extent of protection afforded to priority species). By monitoring these indicators and evaluating them in combination with fish catch data (or other abundance and population data), fishery managers can, over time, draw quantitative inferences between fish stock productivity and habitat quality.

Schlacher (2014) examined 36 potential indicators to assess ecological condition, change, and impacts in sandy beach ecosystems. Each indicator was evaluated to determine its ability to consistently reflect changes and impacts to the system in six categories: erosion, recreation, fishing, habitat loss, conservation, and pollution. Composite scores were used to rank each potential metric for its overall usefulness. The potential indicators were then ranked by overall sensitivity, practicability, cost, and communications/public appeal, for a final usefulness score. Most of the purely physical metrics scored relatively poorly overall because they are indicative of just a single physical attribute. The four types of metrics that performed best across all six categories were the ones that measured:

1. characteristics of bird populations and assemblages (e.g., abundance, diversity, distributions, habitat use)
2. breeding/reproductive performance of a variety of species (especially relevant for birds and turtles nesting on beaches and in dunes, but equally applicable to invertebrates and plants)
3. population parameters and distributions of vertebrates associated primarily with dunes and the beach splash-zone (traditionally focused on birds and turtles, but expandable to mammals)
4. compound measurements of the abundance/cover/biomass of biota (plants, invertebrates, vertebrates) at both the population and assemblage level

These species-oriented metrics did the best because they were most sensitive to a range of disturbances of interest. The tables in the paper can further help with index selection by illuminating which metrics are best for tracking specific impacts (e.g., erosion vs. pollution), as well as composite measures of overall condition.

In practice

Conservation goals for coastal habitats, and the resulting performance metrics used by states, are strongly influenced by the physical characteristics of the coast (e.g., shallow wetlands in the Gulf of Mexico, sandy beaches and barrier islands along the Atlantic Coasts, and bluffs/gravel shorelines in the West). This can make detailed comparisons among regions challenging.

Innovative Practice: Oregon Plan for Salmon and Watersheds

An example of a rigorous process for setting outcome measures – which is also relevant to Washington's ecological context – is the *Environmental Indicators for the Oregon Plan for Salmon and Watersheds* (2005). The document lays out a case for a suite of environmental indicators that can track the impact of Oregon's collective restoration efforts, for biennial reporting to the Governor and Legislature. The proposed indicators fall into four categories: aquatic and riparian ecosystems, terrestrial ecosystems, estuarine ecosystems and ecosystem biodiversity. For the coastal systems, the most relevant indicators are included in Table 9.

Table 9: Indicators and metrics for coastal system outcomes identified in the literature or effective practices		
Outcome Measurement Category	Indicators and Metrics (Units of Measurement)	Source(s)
Terrestrial ecosystems	• Area, distribution, configuration, and types of established ecological, vegetation or habitat classes • Change in land use and land cover	Schlacher, 2014; Heinz Center, 2008
Biodiversity	• # of native plant and animal species occurring, and changes in their distribution over time • At-risk species (marine and terrestrial; plant and animal) • % of nonnative, invasive species	Schlacher, 2014; Lederhouse and Link, 2016

More important than the specific indicators, the metrics were selected based on clear, conceptual frameworks that link them to changes in pressures, condition, impact and policy response. Each indicator was also evaluated using usefulness criteria as to whether they were: quantifiable, relevant, responsive (e.g., sensitive to changes), understandable, reliable, and accessible (e.g., useful for communication with the public). The authors sought to use indicators common to other monitoring efforts such as the Oregon State of the Environment Report, The Heinz Center's State of the Nation's Ecosystems Report, and EPA's Report on the Environment, and several others, including monitoring as part of species recovery plans – which has the potential to foster streamlined data collection among programs.

Promising Practice: Vision for the California Delta

Several performance evaluation efforts in the California Bay-Delta region can also provide useful guidance. A handy summary document by Healy (2008) lays out an approach to developing performance indicators for the Vision for the California Delta. Example indicators are cross-walked with goals from the Bay Delta Conservation Plan (BDCP), and the CALFED Bay-Delta Program/Ecosystem Restoration Plan (ERP). The indicators are organized using three categories: administrative indicators, driver indicators, and outcome indicators (similar to the policy, pressure and benefit indicators mentioned above). Healy also stresses the importance of setting benchmarks against which to evaluate the indicators – which may be based on historic values, or may be set based on conceptual models of system dynamics for highly altered systems. No actual indices are proposed (but examples are used to illustrate the framework concepts).

Common Practice: Maine and New Hampshire Dashboards

A few states currently report coastal metrics in their online, environmental dashboards. Two examples of states that are often cited as leading best practices in online dashboards are:

- Maine Environmental Trends Dashboard:
  - Combined sewer overflows – millions of gallons discharged per inch of precipitation, declining trend, no target specified
  - Healthy beach days - % of days with no health advisory, based on bacteria monitoring.
- New Hampshire Environmental Dashboard:
  - Eelgrass – acres

- Shellfish harvesting - % acre-days open – indicator of pollution (bacteria)
- Total nitrogen concentration – total nitrogen / liter

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9 Growth Management Planning

WA Programs

- Local jurisdictions' critical areas ordinances
  Shoreline Management Act

Literature Review

The definition of "critical areas" includes wetlands, areas with a critical recharging effect on aquifers used for potable water, frequently flooded areas, geologically hazardous areas, and fish and wildlife habitat conservation areas. This summary will focus on approaches to monitoring outcomes related to overall land use patterns, and their impact on areas designated as "critical" under local critical areas regulations.

In a set of recommendations prepared for the National Fish and Wildlife Foundation, Sellner et al. (2011) conducted an extensive literature review of best management practices and metrics for assessment of projects funded within the Chesapeake Bay. Their proposed metric for the development of code and/or ordinance revisions is to "assess progress made in accomplishing planned milestones," with a list of suggested planning milestones. This approach aligns closely with Commerce's strategy of tracking the development and updating of local plans under the GMA and SMA. However, it leaves open the question of whether the plans are being implemented effectively, and achieving their intended outcomes.

To overcome the obstacle of having customized metrics that are tailored to each local plan, it should be possible to identify the list of "statewide values" that the cities and counties are required to address, and create a set of metrics to assess overall land use and growth trends across the state. Table 10 lists the most commonly cited land use and growth indicators and metrics, drawn from a set of the most widely cited examples of good outcome measurement.

Table 10: Indicators and metrics for growth management planning outcomes identified in the literature or effective practices		
Outcome Measures Category	Indicators and Metrics (Units of Measurement)	Source(s)
Development Patterns	*Area and composition of the urban and suburban landscape* • % of plan area in urban/suburban land use types *Total impervious area* • % of urban/suburban landscape in the plan area with impervious land cover *Rural/urban balance* • % of population growth in urban areas vs. rural areas *Rural growth* • % of parcels developed *outside* of targeted urban growth areas *Conversion of ecologically important lands* • % change of critical areas to developed land *Climate resilience* • The spatial arrangement of buildings, transportation networks, other infrastructure, and interstitial open space can absorb the impacts of climate change with minimal disruption	Thom and O'Rourke, 2005; Heinz, 2008; Sartori et al., 2011; Hamel et al., 2015; Sustainable Jersey, 2016
Natural Lands	*Area and composition of natural lands in the urban/suburban landscape* • May include an analysis of patch sizes to gauge changes in fragmentation of natural habitats *Area and composition of natural lands overall* • % of lands classified as urban/suburban vs. farmland vs. natural lands *Protected natural lands* • % of natural lands in protected status *Road density* • Length of roads per planning area *Land cover change* • % change of forested land to developed land	Thom and O'Rourke, 2005; Sartori et al., 2011; Hamel et al., 2015
Demographics	*Population* • # of people *Population density* • People per unit area *Population growth* • % of growth over time *Population growth in Urban Growth Areas (UGAs)* • % of growth over time	Thom and O'Rourke, 2005; Sartori et al., 2011; Hamel et al., 2015
Housing	*Housing density in low-density suburban and rural areas* • % of plan area in various classes of housing density, with a sufficient number of classes to detect change	Heinz, 2008

In practice

Best practices for "smart growth" call for mixed uses, compact development, revitalizing urban centers, preserving farms and working forests, and protecting open spaces. The scale at which indicators are measured is important because it can significantly influence the results. But the scale of analysis, in practice, is often dictated by availability of data.

Best practices in code and/or ordinance review

The report, *Metrics and protocols for progress assessment in Chesapeake Bay Stewardship Fund Grants* (Sellner et al., 2011) offers a succinct list of the best practices in planning, specifically as it relates to conducting a code and/or ordinance review in order to ensure consistency with GMA and SMA guidelines:

- Select a committee responsible for review.
- Identify existing development rules in the community.
- Identify guidelines to use for review.
- Develop timeline for completion of review.
- Compare existing rules with model development principles (e.g., state guidelines or STAR community certification requirements, see references).
- Identify rules for potential revision.
- Develop a local site planning roundtable to negotiate revisions
    a. Identify and include key local leaders
    b. Use a facilitator to guide discussions
    c. Arrange for and conduct public meetings for public input and/or review
- Draft code and/or ordinance.
- Propose an overlay district for protection of a specific resource (e.g., critical areas).
- Develop a strategy for shepherding the "draft" through the adoption process.

Best practice: STAR Communities Program certification approach

Another approach that aims to reinforce best practices in smart growth at the municipal level is the STAR Communities program (www.starcommunities.org). STAR uses a certification approach based on performance criteria that must be demonstrated by communities that wish to be certified. Key rating factors that relate to the GMA and SMA goals include:

- ***Infill and Redevelopment*** – Focus growth and redevelopment in infill areas to reduce sprawl and ensure existing infrastructure that supports the community is in satisfactory working condition.
    - Option A: Demonstrate at least 51% of new residential and non-residential development occurred in locally designated infill and redevelopment areas, or on infill sites that were previously developed, brownfield, and/or greyfield sites.
    - Option B: Demonstrate an increased percentage of all new residential and non-residential development occurred in locally designated infill and redevelopment areas, or on infill sites that were previously developed, brownfield, and/or greyfield sites.
- ***Natural Resource Protection*** (relates to GMA designated critical areas) – Protect, enhance, and restore natural ecosystems and cultural landscapes to confer resilience and support clean water and air, food supply, and public safety.
    - *Outcome 1*: Natural Resource Areas
        - Option A: Maintain natural resource acreage at 20 acres per 1,000 residents or greater.

- Option B: Maintain natural resource acreage at 11.5% or more of total jurisdictional land area.

– *Outcome 2*: Wetlands, Streams, and Shoreline Buffers
    - Achieve no net loss of wetlands, streams, and shoreline buffers.

– *Outcome 3*: Connectivity
    - Increase the amount of natural or restored areas directly connected to regional natural systems in order to improve ecosystem services.

– *Outcome 4*: Restoration
    - Option A: Reduce the difference between the actual acreage restored and targeted acreage established in the natural systems plan or land conservation plan.
    - Option B: Restore degraded natural resource areas at a ratio greater than 1% of developed land area in the jurisdiction.

Washington State has four STAR Communities recognized under this certification system: King County (STAR certified), Tacoma (STAR certified), Seattle (STAR certified), and Bellevue (Reporting community).

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10 Forestry

WA Programs

- DNR Forest Practices

Literature Review

The maintenance of productive forestlands or sustainable forestry is one of the areas for which very extensive indicator development has occurred, and is one of the few areas in which the best practices matches recommendations from the literature. Measures of forest indicators are widely used to assess sustainable forestry, particularly of interest to the public for describing "green" forest products, generally through the Sustainable Forest Indicators (SFI) or the Forest Stewardship Council (FSC) certification processes; each of which identify a number of indicators. However, the indicators are designed primarily to support certification, so do not generally provide information on the overall success of various regulatory protection measures or voluntary protection or acquisition activities. The most widespread measures and indicators used in North America were identified in a United Nations effort to support sustainable temperate forests undertaken in 1995, and updated regularly, called the "Montreal Process criteria and indicators". Mendosa and Prabhu (2003) evaluate different forest indicators based on their uses globally. However, no papers appear to be more useful than the updated information provided as part of the Montreal Process online publications.

Common and Effective Practice

The Montreal Process indicators are widely used across the country, although the effort undertaken varies in different states and provinces. In Oregon, these were a major focus for the Oregon Department of Forestry until 2014, when changes in staffing and leadership combined with the legislature defunding the Oregon Progress Board caused the state to stop tracking them. In many states in the southeastern U.S., widely distributed but declining forested ecosystem types, such as longleaf pine forests, have been intensively studied, with monitoring protocols developed to report on recovery indicators (Oswalt et al., 2012). In general, since the Montreal Process Indicators are so widely used, are being constantly updated and evaluated, and are outcome based, they represent the best practice.

The indicators are varied, but are organized into themes within the Montreal Process (Table 11). It is important to note that while these indicators and metrics represent a best practice, they are generalized sufficiently to be usable throughout the globe in areas with temperate forests. They are designed to be modified to be relevant in each country or jurisdiction. As a result, a more generalized indicator for protecting water resources included in Table 11, such as last one in the list referring to the streams meeting best management practices or protected, might be made to be more Washington specific by rewriting as "area of riparian forest preserved in conservation easements", if this represents a best management practice in the state.

Table 11: Montreal Process forest categories, indicators and metrics	
Outcome Measures Category	Indicators and Metrics (Units of Measurement)
Conservation of Biological Diversity *(ecosystem, species and genetic diversity)*	• Area and percent of forest by forest ecosystem type, successional stage, age class, and forest ownership or tenure • Area and percent of forest in protected areas by forest ecosystem type, and by age class or successional stage • Fragmentation of forests • # of native forest associated species • # and status of native forest associated species at risk, as determined by legislation or scientific assessment • Status of on-site and off-site efforts focused on conservation of species diversity • # and geographic distribution of forest associated species at risk of losing genetic variation and locally adapted genotypes • Population levels of selected representative forest associated species to describe genetic diversity • Status of on-site and off-site efforts focused on conservation of genetic diversity
Maintenance of Productive Capacity of Forests	• Area and percent of forest land and net area of forest land available for wood production • Total growing stock and annual increment of both merchantable and non-merchantable tree species in forests available for wood production • Area, percent, and growing stock of plantations of native and exotic species • Annual harvest of wood products by volume and as a percentage of net growth or sustained yield • Annual harvest of non-wood forest products
Maintenance and Enhancement of Long-term Multiple Socio-Economic Benefits to Society	• Value and volume of wood and wood products production, including primary and secondary processing • Value of non-wood forest products produced or collected • Revenue from forest based ecosystem services • Total and per capita consumption of wood and wood products in round wood equivalents • Total and per capita consumption of non-wood forest products • Value and volume in round wood equivalents of exports and imports of wood products • Value of exports and imports of non-wood forest products • Exports as a share of wood and wood products production and imports as a share of wood and wood products consumption • Recovery or recycling of forest products as a percent of total forest products consumption
Conservation and Maintenance of Soil and Water Resources	• Proportion of forest management activities that meet best management practices or other relevant legislation to protect soil resources • Area and percent of forest land with significant soil degradation (soil erosion, diminished soil organic matter, soil compaction, or chemical changes) • Area and percent of water bodies, or stream length, in forest areas with significant change in physical, chemical or biological properties from reference conditions • Proportion of forest management activities that meet best management practices, or other relevant legislation, to protect water related resources

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11 Scenic Beauty

WA Programs

- DNR Forest Practices
- State Parks and Recreation Commission
- Washington Wildlife and Recreation Program (WWRP)

Literature Review

Scenic quality is a fundamental element in all nature-based recreation experiences. Nationwide, viewing scenery is the single most popular outdoor recreation activity. Scenery is a public resource that also contributes in key ways to sense of place and quality of life. Research shows that there is a high degree of public agreement regarding scenic preferences. In general, natural appearing landscapes are more valued. The more variety there is in line, form, color, texture (topography, vegetation, geology, water, etc.) the more attractive the landscape is perceived. Specific indicators of scenic quality include relative topographic scale and relief (more is better), proximity of surface water (lakes, rivers, coastlines - more visible is better), variety in vegetation and other scenic elements (more is better), slope diversity (more is better) and elevation (higher is better).

Management of scenic resources typically begins with defining and mapping variations in scenic attractiveness, integrity and visibility, especially scenery that is highly valued. Federal land agency frameworks for analyzing scenery include the USFS Scenery Management System (SMS, 1995), a uniform methodology to inventory scenery resources, assess scenery impacts and maintain landscape characteristics that help define "Sense of Place". Many parks and protected areas have adopted this system or variants of it. Broad physiographic landscape patterns and mosaics serve as the analysis area. The SMS combines biological, physical and sociocultural factors to define Scenic Character - written text and photos describing the landscape's inherent positive scenic identity (physical appearance) as expressed through its unique composition of existing socially valued, positive scenery attributes (such as valued landform, vegetation, water form, wildlife, cultural and historic features). The Scenic Character definition forms the basis for assessing other attributes of parcels or zones within it, such as inherent scenic attractiveness (distinctive/common/minimal) and scenic integrity (degree of disturbance to existing landscape character).

Positive combinations of scenic variety, vividness, mystery, intactness, coherence, harmony, uniqueness, pattern and balance have the greatest potential for high scenic attractiveness. A landscape with very minimal visual disruption is considered to have high scenic integrity. Landscapes having increasingly discordant relationships among scenic attributes have diminished scenic integrity. Visual absorption capability refers to the fact that different landscapes have differing abilities to absorb human alterations without reduction in scenic condition. Human-built structures generally reduce scenic quality in natural landscapes but this is not always the case, e.g., a rustic barn may enhance variety and scenic quality in a pastoral farmland scene. Guidelines for human infrastructure in areas used for nature-based recreation specify use of natural forms, materials and colors in order to maintain scenic integrity.

Landscape Visibility in the SMS incorporates elements (concern level, distance zones) that influence the relative importance and sensitivity of scenery. Concern Level is a measure of viewer concern for scenic quality. Level 1: Areas and travel routes with large numbers of viewers; settings in which scenic quality is critical to the desired experience. Level 2: Areas where visitors express a moderate concern for scenic quality; landscapes of moderate importance associated with local types of recreation, e.g., well-known by local residents but not of regional or national significance. Level 3: Areas where visitation is not dependent on scenic quality, that have been utilized mainly for extractive activities, or where people typically do not go to recreate. Distance zones address the degree of discernable detail in a landscape based on distance from an observer - foreground is defined as 0-.5 mile, midground = .5 – 4 miles, background = 4 miles to the horizon.

The SMS uses information for scenic attractiveness, scenic integrity and landscape visibility to assign a Scenic Class rating (1-7) to each parcel being considered. These ratings indicate the relative scenic importance, or value, of discrete landscape areas. Scenic Class ratings are often incorporated into Recreation Opportunity Spectrum (ROS) maps, and used during planning to compare the value of scenery with other resources. The SMS was significantly revised in 2007 with publication of Appendix J, which updated definitions and procedures. Appendix J recommended the use of two key indicators to measure, communicate and monitor scenery: *scenic integrity*- the degree to which a landscape is free from visible disturbances that detract from the natural or socially valued appearance, and *scenic stability*- a new indicator intended to provide ecological sustainability information necessary to conserve valued scenery for future generations.

The USDI Bureau of Land Management (BLM) Visual Resource Management (VRM) system is similar to the USFS Scenery Management System in that it is based on inventorying and mapping differences in scenic quality. Landscape parcels are given a rating (A,B,C) based on seven factors: landform, vegetation, water, color, adjacent scenery, scarcity, and cultural modifications, each ranked on a comparative basis with similar features within the physiographic province. In general, areas with the most variety and most harmonious composition have the greatest scenic value.

Scenic quality is also affected by air quality. When discussing air quality, the term "visibility" usually refers to the distance viewers can see under different conditions of air clarity; different from how the term is used in the SMS. The most common indicator for visibility in this sense is *visual range* – the number of miles or kilometers the naked eye can see. The IMPROVE program (Interagency Monitoring of Protected Visual Environments) was initiated in 1985. This program implemented long-term monitoring to establish current visibility conditions, track changes in visibility and determine causal mechanisms for visibility impairment in national parks and wilderness areas. The program uses an algorithm to estimate light extinction, which is then converted to the deciview haze index, an indicator of visibility.

The US Environmental Protection Agency (EPA) maintains a regional haze reduction monitoring and reduction program. The Western Regional Air Partnership (WRAP) is a voluntary organization working on air quality issues in the western region, including haze and visibility issues. Airnow maintains and monitors visibility cameras in all 50 states, including nine in Washington.

The Tahoe Regional Planning Association (TRPA) rates and tracks changes in scenic conditions using two indicator systems that are conceptually consistent with the SMS. Travel Route Ratings evaluate the entire travel experience, including the view from the road or lake. Scenic roadway units are divided into three visual environments: urban, transition, and natural (similar to and compatible with the ROS). Scenic Resource Ratings focus on the relative scenic quality of individual scenic resources that are seen from the travel routes and changes in scenic quality resulting from small-scale human use. Ratings for scenic resources use indicators of unity, vividness, variety and intactness to produce a composite rating. Annual monitoring by qualified scenic experts provides a cumulative view of impacts along a section of a given roadway or shoreline travel unit, and for individual scenic resources.

In practice

General guidance

- Practitioners suggest treating the entire landscape in question as intermediate in scenic quality, then decide which areas merit designation as distinctive.
- Areas of outstanding scenic quality are generally well-known and thus the easiest to identify and map; also usually of the most interest to stakeholders. When resources are limited, inventorying and tracking of scenery resources should focus on these areas.
- Coordinate and integrate mapping of scenery resources with mapping of recreation opportunities using Recreation Opportunity Spectrum (ROS) concepts.

Outcome measures

Some of the indicators and metrics identified in the literature or effective practices are listed in Table 12.

Table 12: Indicators and metrics for scenic beauty outcomes identified in the literature or effective practices		
Outcome Measurement Category	Indicators and Metrics (units of measurement)	Source(s)
Scenic Attractiveness *(What scenery is most highly valued, and why?)*	• Relative topographic relief, size or scale of physical landscape features (bigger is better) • Proximity to surface water- lakes, rivers, waterfalls, wetlands, coastlines • Slope diversity (more is better) • Variety in line, form, color, texture (topography, geology, plant communities, water) • Diversity in vegetation – structure, species • Vividness - related to variety and contrast, adding clearly defined visual interest and memorability • Mystery - arouses curiosity and adds interest to a landscape • Intactness - is related to unity and also indicates wholeness, few or no missing parts in a landscape • Coherence - describes the ability of a landscape to be seen as intelligible, not chaotic • Unity - provides a sense of order that translates into a feeling of well-being • Harmony - is related to unity. A pleasant arrangement of landscape attributes • Uniqueness - arouses curiosity; often signifies scarcity, rarity, and greater value • Pattern - includes pleasing repetitions and configurations of line, form, color, or textures • Balance – in some ways reflects unity and harmony but is more a state of equilibrium that creates a sense of well-being and permanence • Naturalness – proportion of natural vegetation/natural succession • Skyline disturbance (by human infrastructure, less is better)	USDA Forest Service, 1995 & 2007
Landscape Visibility *(the relative importance and sensitivity of scenery or degree of visibility)*	• Concern Level - measure of viewer concern for scenic quality: Level 1: Areas and travel routes with large numbers of viewers; settings in which scenic quality is critical to the desired experience. Level 2: Areas where visitors express moderate concern for scenic quality; landscapes well-known by local residents but not of regional or national significance. Level 3: Areas where visitation is not dependent on scenic quality, utilized mainly for extractive activities, or where people typically don't go to recreate. • Distance Zone - degree of discernable detail in a landscape based on distance from an observer. Foreground: Zero to ½-mile. Midground: ½ – 4 miles. Background = 4 miles to the horizon. • Visual range – the number of miles or kilometers the naked eye can see • IMPROVE algorithm (Interagency Monitoring of Protected Visual Environments) to estimate light extinction, which is then converted to the deciview haze index	USDA Forest Service, 1995 & 2007; Uhl and Moore, 2017
Indicators for Tracking Scenic Resources	• Scenic integrity - the degree to which a landscape is free from visible disturbances that detract from the natural or socially valued appearance, including any visible disturbances due to human activities	USDA Forest Service, 1995 & 2007

How can we assess outcomes or changes in scenery we know is valuable?	or extreme natural events outside of HRV. Six levels: 'Very High Integrity' to 'No Integrity.' • Scenic stability - the degree to which the valued scenic character and its scenery attributes can be sustained through time and ecological progression. Focuses on dominant attributes, e.g., large tree character, vegetative cover and diversity, water clarity. Six levels: 'Very High Stability' (all attributes sustainable) to 'No Stability'. • %of public who perceive scenic resources to be in good condition or better according to both: a) residents and b) visitors. • % of seen area, as viewed from public vantage points, containing development that highly contrasts with its surrounding landscape: a) within ¼ mile; b) between ¼ mile and 3 miles; and c) beyond 3 miles. (Variant of SMS scenic integrity.)	

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The Scenery Management System page at RecLink provides links and information, training and case studies for using the SMS and its components: http://www.reclink.us/page/scenery-management-system-sms

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12 Air Quality

WA Programs

- DNR Forest Practices

Literature

One of the main sources of air pollution in Washington is wood smoke. Forest practice impacts on air quality are primarily carbon monoxide (CO), particulate, and volatile organic compound (VOC) emissions from controlled burning of logging slash and residues from wildfire fuels reduction efforts. Forest practices also produce dust and exhaust emissions from vehicles and harvesting equipment. The 1991 revision of the WCAA significantly curtailed open burning of biomass, including logging slash.

Washington's forests sequester huge amounts of carbon. Wildfires release carbon as CO, along with particulates and ozone-forming VOCs. The ways in which forest practices affect wildfire risk, and in turn, relationships between sequestered carbon, atmospheric carbon, air quality and climate change are very complex, difficult to quantify with certainty, and currently the subject of much research and debate. Managers often face stiff opposition to controlled burning due to smoke emissions, even though such efforts can reduce the risk of large wildfires that emit many times as much smoke, but these tradeoffs are also beyond our current ability to quantify with any certainty.

By almost any measure, implementation of the CAA has resulted in dramatic reductions in air pollution since the 1970s. But air pollution continues to harm people and the environment. Today, particulates (PM_{10} - respirable particulate matter; $PM_{2.5}$ –fine particulate matter) and ground-level ozone are the pollutants of greatest concern because they influence human health the most. The pollutant of concern varies by location as a result of such influences as population density, economic activity, landscape characteristics that affect air flow, and meteorology. Such factors also influence which strategies are likely to succeed in controlling pollution.

Population and the resulting traffic are the primary sources of CO pollution in the Puget Sound area, while windblown dust is a major contributor to particulate problems in eastern Washington. Just as there are numerous pollutants, there is also a range of ways to measure and express air quality. The best measure to use depends on the issue at hand. For example, day-to-day variations in levels of some air pollutants are known to correlate with emergency room visits by children with asthma. In this case, tracking this day-to-day variation would be relevant. By contrast, if the issue is long-term cancer risk, annualized average concentrations of airborne toxics would be more useful.

Air quality is widely and conclusively known to impact human health. But directly measuring the health benefits of air quality regulations is challenging because it is difficult to correlate pollution reductions to regulations because trends are slow to emerge as a result of lags in technology adoption and interacting effects that can obscure change such as weather, population growth, or behavior changes. Further, pollution reductions can occur over large spatial ranges, well outside the state. As a result of these complicating factors, sophisticated models are typically used to project health benefit changes from regulation, rather than direct measurements.

Because the correlations between air pollution and health are well documented, they provide strong support for tracking changes in pollutant levels as a leading indicator of health benefits. Emissions levels of pollutants are an important indicator of air quality, but do not give accurate picture of levels that people are actually exposed to. Ambient air concentrations are better for demonstrating effectiveness.

An option for tracking ambient concentrations is the AirNow system developed by the EPA, National Oceanic and Atmospheric Administration, National Park Service, tribal, state, and local agencies to provide public access to air quality information. State and local agencies report the air quality index (AQI) for cities across the US and parts of Canada and Mexico. The higher the AQI value (0-500), the greater the pollution level and health concern. AQI values below 100 are generally considered satisfactory; above 100, air quality is considered to be unhealthy-at first for certain sensitive groups of people, then for everyone as AQI values get higher (EPA 2016).

Each day, monitors record concentrations of major pollutants at over a thousand locations nationwide. These raw data are converted into a separate AQI value for each pollutant (ground-level ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide) using formulas developed by EPA. The highest of these AQI values is reported as the AQI value for that day. The Washington Air Quality Advisory is similar to the AQI, but has a stricter standard for fine particulates ($PM_{2.5}$).

A model for projecting health outcomes is BenMAP-CE, an open-source GIS based computer program that calculates the number and economic value of air pollution-related deaths and illnesses. The software incorporates a database that includes many of the concentration-response relationships, population files, and health and economic data needed to quantify these impacts. BenMAP-CE uses "health impact functions" constructed using information from the published epidemiology literature. A health impact function incorporates four key sources of data: 1) modeled or monitored air quality changes; 2) population; 3) baseline incidence rates; 4) an effect estimate. BenMAP estimates changes in the number of illnesses and deaths that could occur in a population if air pollution levels were reduced by a specified amount (Driscoll et al., 2015).

In practice

Direct outcome goals and measures for air quality regulations are usually quantified as the percentage of time that the NAAQS standards are met and degree of improvement toward attainment of those standards. States also use modeling, and later monitoring, to demonstrate that ambient air quality will not be degraded when new power plants point sources of pollution are built. Less commonly, those ambient standards are translated via models into a variety of measures related to diseases or medical conditions associated with, or aggravated by air pollution.

Emissions are an important indicator, but do not give accurate picture of levels of pollutants that people are actually exposed to. Ambient air concentrations are better for this, since they reflect people's exposure. Because of this, many states and municipalities establish air quality monitoring networks to measure this, and a number of recent papers have reviewed the outcome-based indicators for the effectiveness of these networks (Pope and Wu, 2014; Scheffe et al., 2009).

Air quality indicators and metrics identified in the literature are included in Table 13.

Table 13: Indicators and metrics for air quality outcomes identified in the literature or effective practices		
Outcome Measures Category	Indicators and Metrics (Units of Measurement)	Source(s)
NAAQS and Other Standards	*Non-attainment criteria pollutant(s)* • $PM_{2.5}$ (particulate matter 2.5 micrometers or less in diameter), PM_{10} (particulate matter 10 micrometers or less in diameter), and ozone • Trend in the annual number of days in which the EPA Air Quality Index (AQI) exceeds 100 over the past 5 years • Days above regulatory standard (ozone and particulates) • # of 24-hr periods exceeding the applicable federal or state standards at any monitoring station *PM_{10} (particulate matter 10 micrometers or less in diameter)* • Annual average PM_{10} concentrations at any permanent monitoring station *Ozone* • % of time ozone concentrations are at or below 0.09 parts per million averaged over 1 hour • % of time ozone concentrations are at or below 0.07 parts per million averaged over 8 hours • # of days in which the daily maximum 8-hour average ozone concentration exceeds a standard • Daily maximum 8-hour ozone concentrations *Nitrogen dioxide (NO_2)* • % of time NO_2 concentrations are at or below 53 parts per billion averaged over 1 year (Federal standard) • % of time NO_2 concentrations are at or below 30 parts per billion averaged over 1 year (California standard) • *Carbon monoxide (CO)* • % of time CO concentrations are at or below 6 parts per million averaged over 8 hours	EPA, 2016; Pope and Wu, 2014; Driscoll et al., 2015
Human Health	*Cancer risk* • Community's total cancer risk from hazardous air pollutants is less than 50 per million • Trend in the total cancer risk from hazardous air pollutants in the community over time • National Air Toxics Assessment (NATA) total lifetime cancer risk attributable to air pollution *Other health risks* • Measured reductions in mortality after measured improvements in air quality • # of emergency room visits by children with asthma (per day, per year) • # of emergency room visits by older adults with respiratory problems (per day, per year) • # of person-days that a region has unhealthy air. Person-days: The number of persons living in an exposed region X the	Pope and Wu, 2014; Scheffe et al., 2009

	number of days the pollutant exceeds a health standard (indication of the population burden of air pollution exposure) • Rank on list of national counties with the highest health risks due to diesel particulates • Trends in asthma rate and prevalence • % of schools and daycare facilities within 500 feet of busy roadways • Collated data points from GPS devices embedded in inhalers of people with asthma to identify clusters of inhaler use- indicator of areas with particularly bad air quality • BenMAP-CE health impact functions *Pollutant concentrations* • Contamination of human milk, parts per billion in fat • Maximum levels of pollutant in a given time period • Averages of pollutant concentrations in a given time period • # of days the pollutant exceeds a standard in a given time period	
Visibility	*Visual range* • # of miles or kilometers the naked eye can see • Extinction coefficient , e.g.' California standard for this measure is 8-hour avg. extinction coefficient of 0.07/kilometer – visibility of 30 miles or more due to particles when relative humidity is <70%. • IMPROVE algorithm (Interagency Monitoring of Protected Visual Environments) to estimate light extinction, which is then converted to the deciview haze index	Latimer et al., 1981; Richards, 2011; Uhl and Moore, 2017
Wildfires and Smoke	• Acres of forest land burned annually by wildfire • Length of wildfire season • Days of community smoke avoidance warnings	Uhl and Moore, 2017
Other	*Other indicators and metrics* • Lichen – Trends in population of lichens, which are very sensitive to air pollution	Jovan, 2008

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APPENDIX: Approach

The project operated under a compressed timeline, with the majority of the search being conducted over a two-month period (mid-March to mid-May). The following section describes our approach.

1 Scoping

At the beginning of the project, we worked with JLARC to ensure that the project was reasonable and feasible within the scope, timeline, and available funding. During our initial meeting, we renegotiated Question 1 as written in the request for proposal (Figure 1). Our intent was to directly connect the question to the goals of the Washington programs, individually and collectively (Table 1). The new question also captured that there could be synergies and tradeoffs across the programs and that goal setting (upon which metrics are developed) is not strictly a scientific endeavor.

Original Question 1 as articulated in the request for proposal)

What does the scientific community consider best practices for measuring the outcomes of: a) habitat land acquisitions; b) recreation land acquisitions; and c) environmental regulations?"

Renegotiated Question 1

What metrics have been shown to effectively measure the performance of land acquisition and regulatory actions, in terms of the goals identified for the habitat and recreation land acquisition and regulatory program?

Figure 1. Original and Negotiated Question 1

JLARC also provide us with descriptions of the state's acquisition and environmental regulatory programs that highlighted their scopes, goals, and any known metrics of the programs. Based on this information, we coded the program goals by program type (e.g., habitat, recreation, environmental regulation, and planning), program name, goal number (numbered each goal with each program), initial themes (e.g., air quality, coast & shorelines, fish, land and habitat, recreation, coast, water, wetlands, etc.), and goal type. Fifty-two goals emerged across the 14 programs and combined into 12 themes.

Table 2. Washington Acquisition and Regulatory Programs

Acquisition programs	*Regulatory programs*
▪ Salmon Recovery Funding Board (SRFB) ▪ Puget Sound Acquisition and Restoration Fund (PSAR) ▪ Puget Sound Estuary and Salmon Restoration Program (ESRP)	▪ Growth Management Act regulations regarding critical areas ▪ Wetland Restrictions ▪ Shoreline Management Act regulations ▪ Forest Practices regulations

▪ Washington Wildlife and Recreation Program (WWRP) ▪ State Parks and Recreation Commission (SP&RC) ▪ Natural Areas	▪ Hydraulic Project Approval Program ▪ Clean Water Act ▪ Floodplain Management

2 Literature Review

To discover and document peer and gray literature relevant to the questions, we used a hybrid approach that combined a systematic literature search, interactions with members of the core team and the project's expert panel to discover documents, and traditional literature searches.

A systematic review is a research process that summarizes available evidence on a clearly formulated question or small set of related questions, using systematic and explicit methods to identify, select, and evaluate relevant studies. Systematic reviews were originally developed to help medical researchers and practitioners synthesize results of vast amounts of clinical research and in medical contexts, generally focus on single treatment, single outcome issues. The process for conducting systematic reviews (Table 3) differs from traditional literature reviews by focusing on specific, targeted questions, and the use of a documented, repeatable, a priori protocol for identifying and assessing the literature included in the review.

We used systematic review techniques, including vetting and refining the review questions, developing an a priori literature search protocol and strategy, conducting a search strategy tailored to the questions, and using screening/inclusion criteria to narrow the scope. These techniques have shown promise for increasing the objectivity, transparency, and utility of the resulting science "package" delivered to policymakers and practitioners (Collaboration for Environmental Evidence, 2013).

Table 3. Steps of a systematic review.[2]

Steps	*Description*
Question setting	A process to derive a suitable question or small set of related questions, both in terms of evidence needs and feasibility of the systematic review.
Protocol and search strategy development	A plan for the conduct of the systematic review setting out how each stage will be conducted.
Searching	A systematic search is conducted using a repeatable search strategy tailored to the question and likely sources of evidence.
Screening criteria (inclusion criteria)	Articles retrieved from the search are examined for relevance to the review question using a priori inclusion criteria and resulting in a collection of relevant studies.

[2] Excerpted from Collaboration for Environmental Evidence. 2013. *Guidelines for Systematic Reviews in Environmental Management*. Version 4.2. (March). Collaboration for Environmental Evidence and the Centre for Evidence-Based Conservation, Bangor University, United Kingdom. http://www.environmentalevidence.org/wp-content/uploads/2014/06/Review-guidelines-version-4.2-final.pdf

Assessment of relevance and/or study quality)	Studies are examined for their design and reporting standards and, if appropriate, weighted in terms of susceptibility to bias and validity in terms of the study question.
Data extraction	Appropriate data are extracted from each study and may be subject to further critical appraisal.
Data synthesis	Extracted data from individual studies are synthesized to form an overall view of the evidence. Synthesis can be narrative, quantitative, qualitative or a combination of these.

Search Protocol

Defining the scope of literature that is relevant – and should therefore be included in a systematic review – can be challenging for the more open-ended, complex questions that are common in natural resource management. We used a search protocol to document how and where the literature was sought and obtained. A draft protocol was reviewed and modified following input from the other members of the core team and some of the expert panel. The search protocol was a living document that evolved with the project as new search term possibilities became evident and as the utility of search locations changed.

Search engines, databases, and organizational websites

Academic databases. The following databases, which cover a wide-range of available literature on conservation and restoration, were searched for peer-reviewed literature. As these academic databases are supported by Oregon State University Libraries, the core team was granted access to full-text electronic copies of the publications.

- Web of Science
- AGRICOLA
- Academic Search Premier
- CAB Abstracts
- Environmental Sciences and Pollution Management

Internet search engines. GoogleScholar (scholar.google.com) was also used to identify both peer-reviewed and gray literature. The first 50 hits from each GoogleScholar search were examined.

Specialist sources. Among others, the following specialist organizations were searched for relevant gray literature using manual searches of their websites.

- Conservation Measures Partnership, http://www.conservationmeasures.org/
- Environmental Evaluators Network, http://www.environmentalevaluators.net/
- Conservation Gateway, https://www.conservationgateway.org/Pages/default.aspx
    - Conservation measures, https://www.conservationgateway.org/ConservationPlanning/Measures/Pages/conservation-measures.aspx
- The Nature Conservancy

Search terms

Systematic review processes are designed to allow users to pose very specific questions of scientific literature. The approach outlined above allowed us to specify that only literature explicitly linking outcome measures with conservation and restoration would be included. Based on our knowledge of this literature, we believed that for many programs, particularly those focused on acquisitions, there was likely to be only a small number of relevant peer-reviewed publications and studies, and that many of these may not clearly address outcome measures or indicators. We were interested in peer and gray literature that explicitly addressed how outcome measures are being used, or proposed to be used, in conservation relevant to the goals and themes of the Washington programs. We settled on a keyword search string with three components: general conservation-related terms, performance measurement terminology, and the relevant goal theme and type. Below are terms used for the first two components.

> "land acquisition" OR "conservation" OR "restoration" OR "ecological" OR "environmental"
>
> AND
>
> "outcome" OR "performance" OR "evidence-based" OR "results-based" OR "performance" OR "effectiveness" OR "success"
>
> AND
>
> "indicators" OR "metrics" OR "measures"

Literature inclusion criteria

For each database search, the first 50 "hits" underwent a coarse filter for relevance – i.e. the potential for inclusion and further review – based on abstracts and in some cases, scanning of full text.

In general, relevant literature is that which quantifies or otherwise substantively details/demonstrates the use of environmental and/or socio-economic outcome measures and indicators, rather than outputs. The most relevant literature included that which:

- Directly related to land/natural resource land acquisition and has listed indicators, metrics, or outcome measures
- Directly related to conservation or restoration and has listed indicators or outcome measures
- Are relevant to the Washington programs' goals
- Are being used, written in plans, or in some cases have theoretical basis
- Synthesis and/or case studies of indicators and metrics used or proposed
- Are related to conservation outcomes

The focus of the review was on relevant indicators and metrics that demonstrated outcome-related performance measurement. Exceptions to this exclusion criterion were considered on a case-by-case basis for studies that were particularly robust and/or added substantively to the existing knowledge base.

Evaluating the Evidence

Systematically evaluating the evidence includes a documented search for the literature, a documented assessment of the relevance of the literature, and creating a narrative synthesis.

Documenting the literature

Systematic methods were used to gather and catalogue only those documents that passed through the coarse filter of explicitly linking prescribed fire with climate change. Documents were entered into an Excel spreadsheet and made accessible to the core team via Google Docs. Fields for each document included study citation, where the document was located, and a short summary of the goals or purpose of the document or other key information. A field was also established to denote four document discovery groups: *Group 1* documents consist of the peer-review literature found through an electronic search of academic databases; *Group 2* is the gray literature; and *Group 3* documents found through traditional searches or were provided by the expert panel.

Filter and assess the relevance of the literature

In addition to OSU Library databases, some crosscheck searches were conducted on Google Scholar. The sources accessed and search algorithms used by Google Scholar are not transparent, but the additional relevant literature we found using this tool suggests that it should be included in systematic searches even if science experts have access to a full range of academic databases.

Traditional (non-systematic) searches. The evidence base available to address natural resource questions tends to be both limited in extent and diverse in methodology, with less consensus on keywords and methods for consistently describing and cataloguing published research. This can make it difficult to develop literature search terms and inclusion criteria that are both objective and comprehensive, especially for more complex, open-ended questions.

Our search terms captured some literature where the authors specifically intended to link outcome measures to conservation, and probably successfully excluded a large amount of tangentially-related literature that did not make this linkage. It is likely that some of this latter category of literature contains information that is relevant to the questions, but it was unclear what other search terms to use that would not result in an overwhelming volume of hits. For these reasons, we used some traditional methods to identify additional relevant literature. The most obvious of these methods was to simply ask subject matter experts to suggest such studies, articles, and relevant documents. We solicited input from our expert panel and other experts (e.g., the Tahoe Regional Planning Agency).

Other traditional methods of literature searching include scanning bibliographies of highly relevant papers for additional pertinent references, and checking the websites of recognized experts who are active in the field and authored relevant studies that were already included in the review. There is potential for bias in these methods but that must be weighed against the potential for finding additional relevant studies. We suggest that most, if not all, systematic literature searches and reviews in natural resource fields should be supplemented by such traditional search methods. In short, identifying relevant literature using specific, documented search terms adds substantially to the transparency and objectivity of the review. But in order to be more comprehensive, such methods will usually need to be augmented with traditional techniques for finding relevant literature. This is especially true for more complex, multi-faceted natural resource questions.

3 Case Studies

In our review of the peer and gray literature, in addition to answering Question 1 (metrics that have been shown to effectively measure the performance of land acquisition and regulatory actions, in terms of the identified Washington program goals) and Question 2 (ensuring outcome measurements are accurate, reliable, and linked to programs and projects), we also proposed a complementary case study. The purpose was to identify how active programs around the country have successfully measured performance relative to statuatory and other goals and to document metrics and practices that could not be found in the peer and gray literature review. Early in the project we identified several relevant programs that could possibly be approached to learn about their successes. In addition to the recommendations of the core team and expert panel, later in the project we were also in communication with the Tahoe Regional Planning Agency. They provided us with an additional list of programs. We found that through our search we were able to identify metrics that have been shown to effectively measure the performance for each goal theme.

In examining the practices, we used criteria developed by the National Resource Center to characterize types of effective practices. A *practice* is an approach, methodology, activity, strategy, system, process, technique, or tactic (National Resource Center, 2010b). Different organizations use different criteria to identify and classify effective practices, and there is little agreement on the terms used to refer to an effective practice. This is similar to debates about what constitutes "best available science". Regardless of lack of consensus, clearly defined parameters to assess effectiveness is important. The National Resource Center defines several types of practices. *Effective practice* is an umbrella term that includes best practice, promising practice, and innovative practice. It can also refer to practices that have not yet been characterized. Through objective and comprehensive research and evaluation, *best practices* are evidence-based and have been proven to help organizations reach high levels effectiveness and produce successful outcomes. *Promising practices*, on the other hand, have been shown to work and produce successful outcomes, but are not validated with the same rigor as best practices. This type of practice is support to some extent through anecdotal reports (subjective data) and feedback from subject matter experts (objective data). Lastly they define *innovative practices* as processes, activities, or strategies that have worked within one organization or program and show potential to be replicated and have long-term impact. Table 4 is a comparison each type of practice.

Table 4. Criteria for characterizing types of effective practice[3]	
Effective Practice	▪ Proven effectiveness in addressing a common problem ▪ Proven effectiveness in more than one organization and in more than one context ▪ Replication on a broad scale ▪ Conclusive data from comparison to objective benchmarks, with positive results ▪ Conclusive data from a comprehensive and objective evaluation by an external, qualified source (most often an academic institution or individual with the appropriate academic credentials)

[3] Excerpted from National Resource Center. 2010. Identifying and Promoting Effective Practices. U.S. Department of Health and Human Compassion Capital Fund National Resource Center, Washington, D.C. http://www.strengtheningnonprofits.org/resources/guidebooks/Identifying%20and%20Promoting%20Effective%20Practices.pdf

Promising Practice	▪ Effectiveness in addressing a common problem ▪ Effectiveness in more than one organization and in more than one context ▪ Replication on a limited scale ▪ Supporting data from comparison to objective benchmarks, with positive results ▪ Supporting data from an internal assessment or external evaluation
Innovative Practice	▪ Suggested effectiveness in addressing a common problem ▪ Successful use in one organization and context ▪ Potential for replication ▪ Limited supporting data from comparison to objective benchmarks, with positive results ▪ Limited supporting data from internal assessment