Tidal Wetlands

The Washington State Joint Legislative Audit and Review Committee (JLARC) conducted a review of the state's efforts to conserve habitat and expand outdoor recreation. This work included a review of existing or potential objective outcome measures that could be used to evaluate the success of 13 land acquisition and regulatory programs intended to protect and conserve habitat and expand outdoor recreation. 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, it was found that 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.

Introduction

Developing strategies to effectively measure ecological outcomes linked to specific programs and projects is an essential, but not simple, task that remains generally elusive in practice (Dale and Beyeler, 2001; Sawhill and Williamson, 2003; Niemi and McDonald, 2004; Doren et al., 2009; Margoluis et al., 2013). There are many examples of project-level effectiveness and projects that have laid out clear outcome measures linked to the project goals, such as Hartema et al. (2014). At the programmatic and regional levels, examples of these outcome measures are more difficult to find. For an example of a regional evaluation of the cumulative effectiveness of multiple projects see Diefenderfer et al. (2016). For a model-based evaluation of restoration project impacts at a watershed scale see Roni et al. (2010).

Some researchers note that the increased demand for outcome measurement, particularly ecological outcomes, does not imply that they are useful for decision making or that they are frequently used (Turnhout et al., 2007). Others argue that aligning outcome measures (indicators and metrics) with the mission and goals of an organization, program, or project can change it profoundly.

Margoluis et al. (2013) argue that to measure success in conservation three questions must be answered: (1) are we achieving our desired impact?; (2) have we selected the best interventions to achieve our desired impact?; and (3) are we executing our interventions in the best possible manner? Another question to add to this list is (4) who is the audience and who will care about the effectiveness of our program and our actions?

Outcome measurement processes are based on the selection of indicators and metrics, and the choice of indicators and metrics will directly impact the results of the process (Behan et al., 2017). To understand which indicators and metrics have been shown to effectively measure the performance of land acquisition and regulatory actions, we focused our efforts on peer-reviewed literature, agency publications, and on programs that would help provide information about 'best practices' for outcome measures that were not found in peer-reviewed or agency publications. By best practices we were looking for *outcome measures* (i.e., indicators and metrics) and programs that were effective, innovative, or promising.

Due to the complexity and nuances related to the protection of tidal wetlands in Washington, this section is not intended to be a comprehensive compendium of the indicators and metrics used to create 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. The complete report (Behan et al., 2018) provides many more details concerning the development of outcome-based indicators from the literature, along with information on all of the other related programs and subject areas evaluated in the JLARC study.

Background

Tidal wetlands are protected because of their ability to support fish and waterfowl, protect shorelines, and regulate water flows and sediment. Multiple Washington state programs affect tidal wetlands, including the Puget Sound Estuary and Salmon Restoration Program (ESRP), the Puget Sound Acquisition and Restoration Fund (PSAR), the Salmon Recovery Funding Board (SRFB), the state wetland program at the Washington Department of Ecology, and minor parts of other programs. Tidal wetlands are of special interest in Washington because they provide juvenile salmon with productive feeding sites, refuge from predators, and a transition zone for gradual acclimation to saltwater (Rountree and Able, 2007; Hering et al., 2010; NOAA Fisheries Service, 2012).

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 literature and practice descriptions that follows.

Literature

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, 2014). Some programs use remote sensing to conduct their own assessments of tidal wetland area (e.g., Louisiana portion of the Gulf of Mexico).

Outputs

A short list of outputs identified in agency materials, or provided by JLARC, about the programs relevant to tidal wetlands:

- Change in tidal wetland area (acres lost or gained due to specific actions)
- Tidal wetland area (comprehensive survey)
- Tidal wetland area weighted by quality (e.g., multi-metric indicators of health, characteristics important for birds)
- Sediment retention
- Nutrient retention and transformation

Outcome Statement

The primary outcomes the project team identified from the objectives in the enabling legislation of the program:

- Increase resiliency to sea level rise and protect coastal communities from sea level rise
- Store carbon
- Reduce risk of flooding and erosion
- Support fisheries
- Provide waterbird and waterfowl habitat
- Provide migratory bird habitat or functional migration corridors
- Provide areas for recreation or other cultural uses (boating, fishing, hunting, gathering, birdwatching)
- Promote long-term biodiversity conservation
- Protect and restore the natural processes that create and sustain the nearshore ecosystems

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 10). 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).

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).

The indicators found in the literature or identified practices are listed in Table 1 (below).

Conclusions

Methods for developing meaningful outcome-based indicators are clearly identified in the literature. They are being put into practice successfully in a few states, but generally very sparsely across the country, and rarely for species and habitat focused land acquisition programs. When evaluating program success, most agencies tend to focus on gathering information they need for adaptive management – either data needed to determine if their actions are achieving their goals, or the information needed to develop plans or strategies. These focus on their need to understand the effectiveness of their actions to restore habitats or to address threats to species and habitats on property they manage – both important issues for agencies wanting to understand the priorities for their work. However, understanding priorities for action or the effectiveness of actions may not inform if the overall program is achieving the desired outcomes.

The most effective programs for evaluating program success in land acquisition, water quality protection, and restoration had a few commonalities. First, the legislation that created these programs was relatively specific in describing the types of outcomes desired, so designing an outcome based set of indicators was more straightforward for agencies. Second, the legislation required that indicators of program success be developed and reported on some regular schedule, and at a minimum funded the development of the indicators and their implementation, often requiring interagency cooperation, which is essential as many agencies and local or regional governments may be involved in program implementation. And lastly, they required statewide (or jurisdiction wide for regional governments such as Tahoe) evaluation of outcomes – which helps to assure the development and measurement of the indicators are not focused on plans or projects.

To understand if tidal wetlands are being effectively protected, and providing the expected benefits to citizens of the state, it is critical to have a reasonable understanding of the baseline conditions in all tidal areas in the state. While actions needed to restore or protect tidal wetlands will vary in different areas, assessing their status and trends should be straightforward if collected regularly and consistently. Without this information, it is impossible to understand if any existing programs are making a difference in protecting or restoring the hydrological, biological, chemical and geomorphic elements of tidal wetlands, or the benefits these wetlands provide. Statewide tidal assessments are necessary to understand statewide outcomes.

Getting statewide information on the status and trends of the desired outcomes for all estuaries and tidal wetlands may not be the information agencies need to decide what the priorities for their work should be. If understanding statewide outcomes is important, the legislature must require it be done. As exemplified through some of the large tidal restoration and conservation programs, such as those in the Chesapeake Bay and the Gulf of Mexico, indicators and monitoring programs have been developed that can provide guidance, and the Puget Sound has made great progress in this area. Understanding the status and trends of tidal wetlands in all coastal areas just needs to be a priority to happen.

Table 1. Tidal wetland condition outcome measures selected by expert panel for outcomes monitoring (modified from (Palmer et al., 2011)	
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

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