5 Springs Assessment

Introduction

Springs are groundwater dependent ecosystems that are highly threatened by human activities, and often are ecologically impaired throughout the world. The overuse of springs for domestic use, mining, and livestock, as well as contamination of groundwater supplies, has led to impairment or destruction of many of these ecosystems (Stevens and Meretsky 2008; Kreamer et al. 2015). Understanding the status of springs across a landscape begins with collecting quality data on the current condition of springs, followed by a methodical evaluation of that information for management planning and actions.

We present the Springs Ecosystem Assessment Protocol (SEAP) to assist springs stewards in assessing the condition of their springs and inform management goals. The purpose of the SEAP is to provide credible, repeatable evaluation of springs ecological integrity. This method is specifically designed to be scaled up to evaluate springs condition across a landscape and over time.

This assessment approach will be improved as it is more thoroughly tested. It will help inform and guide decision-making based on the status, importance, and potential for restoration of individual springs considered in a regional context. Such an ecosystem health assessment is fundamental to improving springs ecology and stewardship.

Springs Assessment Protocols

Several springs ecological integrity assessments have been developed over the last two decades (Paffett et al. 2018). In the North American Southwest, the most prominent assessment protocols have been the Department of Defense method for the White Sands Proving Grounds (Thompson et al. 2002), the National Park Service protocols developed for the Mojave and Chihuahuan Deserts (Sada and Pohlmann 2006), the Bureau of Land Management's Proper Functioning Condition (PFC) tool for lentic and lotic systems (Prichard 1998, 2003, respectively), and the U.S. Forest Service groundwater dependent ecosystem model (USFS 2012). Nearly all of these protocols focus on common elements (e.g., flow, water quality, habitat area, human impacts, sensitive species, etc.), and no single approach has been widely accepted. The number of factors, amount of qualitative versus quantitative decision-making, and the resolution of individual valuations, varies considerably between these methods.

The Springs Stewardship Institute's Springs Ecological Assessment Protocol (SEAP; Stevens et al. 2012) integrates elements of the aforementioned springs-specific protocols. In developing the SEAP, we also reviewed several riparian assessment protocols (Stromberg et al. 2004; Stevens et al. 2005) and dozens of Rapid Assessment Methods that have been developed for other ecosystem types (Fennessy et al. 2004; Dorney et al. 2018). We incorporated the collective field experience of many experts, including the SSI staff and many of our collaborators who have developed or utilized springs, wetland, riparian, and playa rapid assessment protocols. Based on this review and consultation, we distilled a number of principles. We have clarified the SEAP around these principles.

Foundational Principles

Assessments need to begin with actual measurements (or quantified estimates). Ecosystem assessment should be an efficient, data-driven process. There are intrinsic trade-offs between efficiency and information content; however, actual quantitative measurements are less biased, more precise, and more repeatable than qualitative evaluation procedures. We recommend the measurement of a rather wide array of ecological and anthropogenic impact variables, including flow, water chemistry, native and non-native species distribution, and other variables of management interest. We recommend using the Springs Inventory Protocol to fulfill this requirement.

Assess the site deviation from the natural condition. When completing a SEAP, the inventory team assesses the degree to which the site condition differs from that hypothesized to be the natural condition.

Begin with the geomorphic context. The comparison between current site condition and "natural" condition should begin with evaluation of the geomorphic context. There are several reasons for this. First, springs are best classified based on their geomorphology. This is because the geomorphology of the spring is a strong indicator of how it functions and interacts with the surrounding landscape. Also, springs geomorphology does not readily change without direct and dramatic human intervention (e.g., a helocrene spring can be excavated to form a limnocrene spring, and groundwater overdraft can create a hypocrene spring out of any other springs type). In contrast, the hydrology and biota of a spring are moving targets, often varying dramatically among seasons and years, with or without human intervention.

Assessment should be based on existing conditions, not potential conditions. Future conditions at springs are not predictable, and therefore the assessment team should evaluate existing conditions and threats, not potential ecosystem responses to future conditions.

Use reference sites to understand and recognize natural springs condition. Reference sites are useful to achieve a variety of goals. They can be used to examine and understand the range of natural variation in ecosystem variables, to scale SEAP scoring, and to train assessment team members. Analyses of reference site data are likely to reveal information gaps and biases about causal relationships and human impacts (Brinson and Rheinhardt 1996). In most landscapes, reference sites have yet to be designated. To remedy this problem, a panel of independent authorities may be convened to recommend sites and characteristics that are geomorphically and ecologically functional and consonant with expected natural conditions.

Reference sites are best located in parks, wilderness areas, and other protected landscapes, and should be georeferenced, described in detail, assessed using the SEAP, and used to scale the scoring of similar types of springs. The array of reference types should include different springs types, be distributed across elevation, slope, and aspect, and be relatively free from conspicuous anthropogenic impacts, especially livestock grazing, water diversion, pollution, roads, and ground water extraction.

Assessment should be repeatable by different inventory teams. Without repeatability, the results are relative and of little use for comparisons, long-term planning, or stewardship. There are two aspects to achieving this metric. First, the assessment should be designed with well-defined, clearly worded rating criteria for evaluating springs ecological condition. Clearly defined criteria reduce human error, miscommunication, and drift in evaluation technique. Second, and just as importantly, the assessment team should be properly trained to conduct the assessments.

Individual ecosystem characteristics should be rated separately, and those ratings should build to a rating for the entire springs ecosystem. A single composite site score is useful for judging site health and developing regional restoration priorities. However, it is important to recognize that a single summary score should not constitute the final interpretation of ecosystem condition. For example, a springs ecosystem may be functioning well physically, but be biologically degraded. Alternately, a springs' hydrology and geomorphology may be highly altered, but the ecosystem may still support a high diversity of native species. To fully understand a site's ecological condition and make management recommendations, it is crucial to examine category scores as well as the overall site score.

Springs management goals should be considered when interpreting site condition scores. While the basis of the SEAP is comparing the site condition to an unaltered, "natural" condition, it is important to remember that springs are frequently managed for specific purposes. In many cases, successful implementation of management goals will create conditions that are farther from "natural," leading to lower assessment scores. In these cases, we recommend using the SEAP results as guidance for seeking a balance between anthropogenic management goals and ecological function.

SEAP Refinement. We recognize the SEAP to be a pilot effort, one that undoubtedly will be refined through additional data analyses and review. Testing and review is needed and welcomed to guarantee its continued scientific relevance, cost-effectiveness, and flexibility. Such revisions will help improve land, wildlife, cultural, and socioeconomic resource management (Rapport et al. 2003).

Conducting A SEAP Analysis

Overview

The assessment process should begin in the office by compiling background information on the springs in the landscape of interest (see Pre-Field Activities, below). This information is used to understand the landscape context of the springs and to prioritize sites for inventory and assessment.

Once sites are selected, they should be visited and inventoried using the Springs Inventory Protocol. This data is used to produce site summary reports and also directly informs the SEAP.

Surveyors should complete the SEAP scoring after completing the Springs Inventory Protocol. Scoring should be completed on-site in the field, or immediately afterwards, while memory of the site is fresh.

The entire SEAP assessment process uses four suites of information. These are: 1) background information gathered prior to the field site visit; 2) the results of the Springs Inventory Protocol; 3) The SEAP field form, which includes 42 variables covering 6 categories; and 4) the SEAP Scoring Criteria document, which guides the team on scoring each assessment question.

Each step and component in the SEAP scoring process is described below.

Assessment Team Composition

The SEAP is designed to be conducted by a team of experts or highly trained technicians, and scoring is based on the expectation that the team will make informed and unbiased scientific judgments about the site (Stevens et al., 2016). The team should include expertise in hydrogeomorphology, aquatic biology, riparian ecology, and sociocultural issues. Team members should be thoroughly trained in: springs inventory, classification, and assessment techniques; interpretation of geomorphic consistency; and detecting subtle site historical impacts. The team should be informed as to regional background data (below). A team leader should be designated who is responsible for oversight, team safety, and data wrangling.

Pre-Field Activities

Dedicated office time is required prior to the field visit to compile background information on the springs in the landscape of interest. This will aid in site selection and also will provide a valuable regional context for the interpretation of site conditions when in the field.

In order to effectively evaluate springs ecological functionality, it is necessary to understand the regional cultural, hydrogeological, biological, and cultural context in which the springs exist at landscape and regional scales.

Springs Distribution

Springs distribution should be compiled and integrated through a Geographic Information Systems (GIS) analysis. This step is crucial for planning field logistics. If possible, georeference springs source elevations to 3-meter accuracy. Such accuracy is necessary for groundwater modeling.

Cultural Context

Incorporation of cultural expertise will contribute to the inventory and lay the groundwork for the compliance activities often needed for restoration. Traditional Indigenous on-reservation and off-reservation land use history and practices should be compiled, as well as applicable archaeological and traditional cultural property information in the study area.

Historical Land Use

The historic role of natural and anthropogenic land uses and disturbance plays a strong role in existing ecosystem traits and functions. However, the impacts of previous land uses are often difficult to interpret in the field. Therefore, we recommend compiling all information available on local and regional land use history, including: descriptions of prehistoric, historic, and traditional cultural uses and values; verbal histories of elders; matching of historical photographs; administrative history; contemporary land management, including well-drilling, springs piping, and road construction history; land and water rights ownership, state and federal groundwater management policy, and other legal issues; economic resources distribution; and current demography and economic trends.

Aquifer Hydrogeology

To better understand aquifer hydrology in the landscape of interest, it is valuable to summarize all available information on these topics: regional climate; regional and springs-specific geology; groundwater supplies and dynamics; springs distribution; groundwater and springs geochemistry; hydrography and trends in springs discharge; the extent of groundwater use, well distribution, ground- and surface water pollution, and spring discharge regulation; major surface flow event history; surface stream sedimentological history; seasonal trends in flow and water quality; basin soils; and any other relevant physical factors.

Numerical groundwater flow models, such as the U.S. Geological Survey's three-dimensional, finite-difference MODFLOW program (Harbaugh and McDonald 1996), use a series of equations for flow and water budgets to describe water movement through aquifers (Anderson and Woessner 1992). Modeling predictions for springs should be developed for varying climate conditions and groundwater extraction rates.

Biological Context

Springs management is often focused on sensitive, threatened, endangered, endemic, and non-native taxa. Prior to field visits, it is useful to research and compile a list of species expected at the site. Separate lists of expected sensitive, threatened, endangered, and noxious or exotic species are also useful.

Field Data Collection

While the SEAP can be completed in the office by a steward who is extremely familiar with the spring, in most cases we recommend completing an ecological inventory of the spring prior to doing a SEAP assessment. A carefully executed springs inventory provides the data necessary to assess the site condition and verify the assessment. The SSI Level 2 Springs Inventory Protocol was designed to inform the SEAP assessment.

SEAP Scoring

SEAP Field Form and Scoring Criteria

Following the field inventory, the next step is for the team to fill out SEAP field form while still in the field. This form is included as page 9 in the SSI Level 2 Springs Inventory Protocol field forms. The SEAP field form guides the team through an assessment of the ecological integrity of the spring and includes space for the surveyor to provide management recommendations. The variables considered in the assessment are grouped into these six categories:

- Aquifer, Flow, and Groundwater Quality (AFWQ)
- Site Geomorphology (GEO)
- Habitat and Microhabitat Array (HAB)
- Site Biota (BIO)
- Freedom from Human Uses and Influences (FHI)
- Administrative Context (AC)

The first four categories describe the condition of the spring's natural resources, and the fifth category accounts for changes due to human activities. The sixth category, Administrative Context, is best evaluated through a discussion with the land or resource manager, focusing on the steward's expectations, desires, and level of satisfaction with the current status of the springs ecosystem.

Within each category, the surveyor ranks the spring's condition and risk based on 5 to 8 variables. The rankings are assigned based on a 0 to 6 scale (Fig. 5–1). For the site condition assessment, a score of 0 indicates extremely poor condition and 6 indicates a pristine condition. For the risk assessment, a score of 0 indicates no risk whatsoever to the springs ecosystem, and 6 indicates extremely high risk (and likely unrecoverable conditions) to the springs ecosystem. Risk is interpreted as the potential threat or the "condition inertia" (the inverse of restoration potential) of the site condition associated with that variable. In other words, what is the probability that variable will remain unchanged? Condition scores below 4 indicate an impaired condition, and risk scores above 2 indicate elevated risk.

The assessment team should use the SEAP Scoring Criteria guide that defines the scoring criteria for each variable. Use of the same scoring guidelines for each assessment is crucial in order to be able to compare assessment results among springs and to detect trends in the condition of a spring over time.

In some cases, the inventory and assessment team may not have sufficient information in the field to answer a question but may, with additional office research, answer the question in the office. In such cases, leaving a score blank among the Assessment Questions signifies that the team is committed to promptly scoring that question when they return to the office. Also, some of the questions may not be applicable to a given springs type. For example, a springbrook may naturally not be a feature of a helocrene ciénega. In such cases, those should be scored with the number 9, which indicates that assessing the variable would be inappropriate.

Qualifiers

Two qualifiers are important modifiers of SEAP scorings: dewatering a springs, and obliteration of the source area. These two qualifiers are included on the SEAP field sheet as variables AFWQ-0 and GEO-0. Answering either of these qualifiers with a "yes" response has the result of scoring the entire category with a condition of "0: Site is in extremely poor condition."

Discharge, whether seasonal or perennial, is a fundamental ecosystem component, and dewatering or flow augmentation strongly affects springs ecosystem characteristics. Springs and springs streams may support aquatic, wetland, and riparian vegetation, invertebrates, fish, and wildlife, as well as human uses (Stanford et al. 1996; Poff et al. 1997; Grand Canyon Wildlands Council 2002; Kreamer and Springer, this volume; Stevens et al. springs model, this volume). If a known perennial springs has recently been dewatered through aquifer depletion or pre-orifice abstraction, most functional components and processes are likely to be interrupted or eliminated (Stevens and Springer, this volume). Dewatering a springs system even briefly is likely to reduce or even eliminate aquatic and some

Condition	Risk
0 Site is in extremely poor condition	0 No risk to site
1 Site is in very poor condition	1 Neglible risk to site
2 Site is in poor condition	2 Low risk to site
3 Site is in less than moderate condition	3 Moderate risk to site
4 Site is in moderate condition	4 Serious risk to site
5 Site is in good condition	5 Very great risk to site
6 Site is in excellent condition	6 Extreme risk to site
9 Unable to assess condition	9 Unable to assess risk to site

Fig. 5–1. General scoring guidelines from the SEAP Scoring Criteria document. The assessment team uses that document to score each of 42 variables listed on the SEAP field form. The team assigns a condition score and a risk score for each variable.

wetland species. Prolonged dewatering will eliminate most or all springs-dependent species and alter site geomorphology (Unmack and Minckley 2008). Similarly, springs orifices are sometimes entirely obliterated by site or water development projects, including well drilling, water extraction, springhouse construction, and other human activities.

Interpretation of SEAP Scores

Category Scores

The first step to interpreting SEAP data is to calculate SEAP category scores. The result will be a single condition score and a single risk score for each of the six SEAP categories (Table 5–6 and Fig. 5–2). Springs Online will complete this calculation automatically once the SEAP data are entered. SEAP category scores are useful for quickly interpreting what type of management attention a spring might require.

Composite Scores

The three composite SEAP scores described below are useful for stewardship planning.

The natural resource condition score is calculated by averaging the AFWQ, GEOM, HAB, and BIO condition scores for an individual spring. This composite score provides a reasonable estimate of ecosystem condition, with sufficient detail to inform managers of specific areas of concern, particularly when calibrated against similar information from reference sites.

The Freedom from Human Influences category condition and risk scores provide insight into the impacts of humans on the site.

The Administrative Context category condition score is designed to serve a tool to facilitate dialogue with the steward(s), to determine whether the springs are providing expected resources and benefits to the owners.

SEAP scores provide indications to stewards regarding management issues and direction for prioritization at a single springs ecosystem or across a broader landscape. For example, a low natural resources condition score generally reflects habitat degradation at a spring. Springs indicates high ecological integrity, with little need for restoration action and little potential for site improvement.

Table 5–6. SEAP category scores for Teresa Lake Spring in Great Basin National Park, Nevada, as assessed by an SSI field crew in September 2019. As is reflected in the high condition and low risk scores, the crew considered this spring to be almost pristine. SEAP category scores are useful for quickly interpreting what type of management attention a spring might require.

Category	Condition	Risk
Aquifer, Flow, and Groundwater Quality	5.3	1.2
Site Geomorphology	5.4	1.0
Habitat and Microhabitat Array	5.0	1.0
Site Biota	5.5	1.0
Human Uses and Influences	5.6	1.4
Administrative Context	null	null

Fig. 5–2. Teresa Lake Spring, Great Basin National Park, Nevada.

Landscape Analysis

Composite SEAP scores are useful for landscape-scale springs assessment. For example, Fig. 5–3 is a scatterplot where each spring in a landscape is represented by a point. The natural resources condition score (x-axis) provides guidance on the ecological significance of the springs, while the freedom from human influence risk score (y-axis) provides insight into the extent of anthropogenic impact on the site. This matrix creates a framework for understanding interactions between site health, conservation, legal, and economic values, as well as interaction conflicts. Collectively, these variables can reveal which springs in a landscape are likely to benefit from management attention, or in the case of repeated SEAP scoring, the rehabilitation progress of a springs ecosystem following rehabilitation efforts. Springs with both moderate natural resource condition and moderate human risk scores also may warrant adaptive ecosystem management to resolve multi-stakeholder conflicts (Holling 1978, Walters 1986, Lee 1993, Gunderson et al. 1995).

Summary

Springs are among the most productive, biologically diverse, and threatened ecosystems on earth, and a comprehensive, broadly applicable assessment protocol is needed to determine their health and prioritize conservation at local, regional, national and global scales. We present a comprehensive, efficient, and effective springs ecosystem assessment protocol (SEAP) that uses the SSI Level 2 springs inventory protocol and the springs classification system of Springer and Stevens (2009) to evaluate the condition, biogeographic significance, and administrative context of springs management. This approach provides a checklist and scoring criteria that, when performed by experts will reduce the subjectivity of springs ecosystem ecological integrity assessment. Quantitative methods also allow SEAP scoring to be used as a research and monitoring tool, permitting comparison of ecological conditions of a springs over time. Scores of individual variables, categories, and whole sites can be used to evaluate status, trends, and management priorities and effectiveness, and may also serve as tools for exploring interrelationships among variables.

By encouraging managers to consider the broader role of springs in the landscape, the SEAP approach also provides a foundation for improved stewardship and adaptive management of springs ecosystems, a foundation that is likely to be appropriate for springs that are both ecologically and economically important. Scoring methods for ecological health assessment are inherently arbitrary, but initial tests of this SEAP by Springer et al. (2015) and Ledbetter et al. (2016) indicate that the premises on which the SEAP is based appear to be logical and worthy of further, quantitative testing. The SEAP presented here is sufficient to initiate that process, and we expect and welcome its improvement as more data are compiled and further analyses are undertaken.

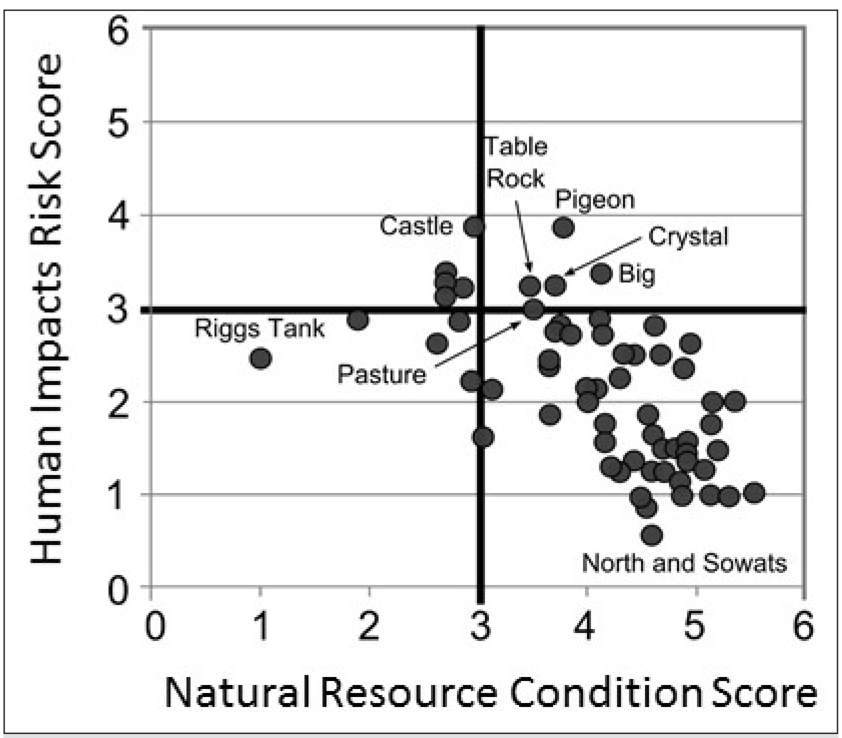

Fig. 5–3. SEAP landscape analysis for several springs in the Kaibab National Forest, Arizona. Springs with moderate natural resource condition scores and moderate risk scores are often the most promising candidates for rehabilitation. In these cases, a smaller investment of time and money may produce successful results.