

Structured Decision Making for the Selection of Surrogate Species: A Case Study in the Klamath River Watershed

*A Case Study from the Structured Decision Making Workshop
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Decision Problem

The U. S. Fish and Wildlife Service (FWS; Service) released its Draft Guidance for Selecting Species for Design of Landscape-scale Conservation (hereafter Guidance; USFWS, 2012) in July 2012 to provide guidance for directing Strategic Habitat Conservation towards achieving and maintaining functional landscapes. Beginning in the summer of 2012, scientists and managers from three Klamath field offices in Arcata and Yreka, California and Klamath Falls, Oregon came together with those from the Klamath National Wildlife Refuge complex in Tulelake, California and the Pacific Southwest regional office in Sacramento, California to define conservation objectives for a functional landscape in the Klamath River watershed and to pilot a surrogate species selection process at a USFWS/USGS Structured Decision Making (SDM) workshop at the FWS National Conservation Training Center. Our workshop problem statement was:

We are using the process of Strategic Habitat Conservation in conjunction with a surrogate species approach to develop innovative and strategic approaches to species and ecosystem conservation in the Klamath River watershed. We will:

1) Develop specific objectives to identify ecosystem condition goals across the Klamath River watershed;

and

2) Develop a process with which to engage our partners in strategically choosing surrogate species to facilitate the measurement and evaluation of progress towards selected objectives.

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The Guidance directs that surrogate species be chosen in order to support a Service objective “to characterize and maintain functional landscapes.” To this end, our approach was not to simply choose a subset of our highest priority species to be surrogates. Rather, our approach was to select surrogate species (which may or may not also be Service Priority species) that represent key physical and ecological conditions and processes, which in turn collectively support functional species assemblages. Our long-term goal was to use surrogate species to guide our work, and to provide a measure of progress toward our objectives. This could be best achieved by developing a scalable and transparent framework that will guide the use of a focused monitoring effort to inform adaptive management.

Background

The Klamath River watershed (Basin) is a large (>40,000 km²) drainage basin comprising diverse upland and aquatic habitats in northern California and southern Oregon (Figure 1). The Basin provides important habitat for several significant tribal and public trust species including anadromous fishes and migratory birds as well as several listed and candidate species, such as the northern spotted owl (*Strix occidentalis caurina*), Pacific fisher (*Martes pennanti*), and Lost River (*Deltistes luxatus*) and short nose (*Chasmistes brevirostris*) suckers.

Although multiple species depend upon Basin ecosystems, introduced ecosystem stressors have caused these species to often have competing management needs, and the ability of the Basin to sustain the quality and diversity of its habitats is increasingly strained. The Basin has been the subject of extensive negotiation and discussion with partners and stakeholders relative to the removal of four dams and how that effort would improve both water quality and quantity for important resources. This altered ecosystem, which formerly held contiguous habitats, has now become fragmented, and land use practices such as logging, fire suppression, energy production, and agriculture have also resulted in degraded ecosystem function, as well as the introduction and spread of invasive species. Additionally, and perhaps most significantly, agricultural and other interests have created water demands that have often exceeded the capacity of the landscape. Reduced water quantity, along with other factors, has contributed to degraded water quality as well. These factors, along with fishing demands, have strained native fish populations. Fish species are a focus of the Service in the Basin not just because of their status as listed or public trust species, but also because of our Tribal trust responsibilities: indigenous tribes depend upon functioning ecosystems, and particularly native fishes, for their way of life.

Resource managers in the Basin face a significant challenge because they must balance the competing needs of multiple species and overall ecosystem health, as well as needs driving the local economy and local social and native cultural values. Reduced funding and increased scrutiny of government spending underscores the need for efficiency and priority-setting in every branch of the Service. The Service has responded to this need in two ways. First, by adopting a “One Service in the Basin” approach to working together synergistically across office and program boundaries towards our common Service goals, including those we have developed collaboratively with Basin partners. And second, by embracing a Strategic Habitat Conservation (SHC) framework that is focused on defining those common goals and finding efficient

mechanisms to accomplish them, and to identify and reduce scientific uncertainties, through the use of strategic management and best available science.

Strategic Habitat Conservation

SHC was adopted by the Service in 2006 to increase our efficiency in managing species at a whole-population, landscape scale under scientific uncertainties and the increasing constraints of limited time and conservation funding. By taking a landscape-level perspective on species conservation goals, we can consider different management strategies and determine the most strategic places to apply the most effective strategies for addressing the conservation need (NEAT, 2006; USFWS, 2008). Although the SHC approach is applied to populations, it is a landscape-level approach because it is applied to the full geographic range of the population of interest. SHC can be used to target strategies for conservation of Service Priority species such as listed species, or it can be used with surrogate species that represent other species or aspects of the environment (Caro, 2010; USFWS, 2012). When carefully selected to represent conservation objectives and paired with targeted monitoring, surrogate species can be used to help identify strategic management actions and reduce uncertainties through adaptive management (Williams et al., 2009).

The Service's Guidance (USFWS, 2012) provided a 10-step approach for the selection and effectiveness monitoring of surrogate species. This is a proactive approach for the Service to define, achieve and maintain functional landscapes that support “self-sustaining populations.” The intent is to improve the overall efficiency of Service conservation by integrating species-specific management goals and metrics with management actions focused on the processes and states of functional landscapes. The Guidance was not intended to be prescriptive, but rather to be flexible to allow managers to effectively address unique needs within each geographic area in which it was applied.

One Service in the Basin

The Service's scope of activities in the Basin includes land management, habitat restoration, and other conservation measures, as well as monitoring and research. Additionally, the Service has coordinated with Basin partners in the development of the Klamath Basin Restoration Agreement (KBRA, 2010), which represents a long-term effort to identify collaborative solutions to ecological and water use problems and prescribes a collaborative, adaptive management approach for the explicit identification and reduction of uncertainties through targeted monitoring (Williams et al., 2009). This approach is consistent with National Resource Council (NRC, 2008) recommendations that Klamath Basin stakeholders work towards “connecting science and decision making” and employ conceptual and simulation models linking management actions and species responses towards that end in a Basin-scale adaptive management framework.

We continue to work towards a “One Service in the Basin” approach to working together within the Service and to further develop and work towards Basin-level conservation objectives. Our

long-term goal is to use surrogate species to guide our work and provide a measure of progress toward objectives in our conservation objective hierarchy within a scalable and transparent framework. A primary strategic objective for this process is to maintain clear communications and transparency of purpose so that we will be better able to engage and coordinate with our partners as we move forward with finalizing the surrogate species approach after the final Guidance is issued. One reason for using a Structured Decision Making approach in this pilot effort was its transparency: documentation of the objectives, methods, and uncertainties that were inherent in the process.

Our approach in this prototype surrogate species selection process was not to select species as surrogates because they are species of concern for the Service. As part of a proactive landscape conservation approach, we developed a process to select surrogate species that represent key physical and ecological conditions and processes, which collectively support the habitats and functional interactions of many other species across the Basin.

Decision Structure

Nature of Decision Problem

The focus of the decision analysis is on the design of an efficient and representative process by which a set of surrogate species can be selected for a defined jurisdiction or area. The selection of a single surrogate species fits into the framework of multiple criteria decision analysis (MCDA; Herath and Prato, 2006). Each potential surrogate species is evaluated by superimposing our comprehensive set of landscape conservation objectives on to the ecological needs of that organism. Scores reflect how closely the biology and/or life history of that species align with the identified ecological criteria. Based on these multiple and sometimes competing criteria, we then need to strategically choose a single species from the set of available species. This selection is based on weighting criteria according to how well they inform our understanding of the conservation objectives, and more practical concerns (e.g., cost, feasibility of monitoring, existing long-term monitoring records, etc.).

Approaching species selection in this way requires that we reduce the complexity of the problem from the selection of multiple species to the selection of a single species for a single purpose (i.e., a conservation objective). We would then repeat this process as necessary according to the number of conservation objectives that we wanted to represent (and the number of species we wanted to select) and the specific species selection criteria for each one.

This approach raised two important questions: 1) What are the goals for selecting species?
2) How many species should we select?

To address these questions we looked to the Guidance. The primary conservation objective specified guides us:

To characterize and maintain functional landscapes capable of supporting self-sustaining fish, wildlife, and plant populations (the goal is sustainable populations).

The purpose of the surrogate species approach, then, is to efficiently and reliably represent landscape conditions. The specific number of surrogate species to select was deliberately not stated; the guidance stipulates completeness of ecosystem representation, rather than an absolute range in the numbers of species:

The number of species selected for any particular geographic area will depend on the characteristics of the landscape: its size, ecological and geographic complexity and conservation challenges and the total number of species it supports. The number of species chosen should represent both terrestrial and aquatic components of the landscape based on existing science, knowledge and best professional judgment (Appendix 3, Frequently Asked Questions).

Although the guidance indicated that the number of surrogates should be scientifically chosen to best represent an area, it is likely there will also be practical constraints to the number of species selected. This may depend to some extent on the costs associated with monitoring particular species. If financial or other practical constraints would limit our final actions, the way in which those constraints were applied could influence the surrogate species that receive priority actions.

In order to approach the decision problem of selecting surrogate species, we needed to first address the unanswered questions above and anticipate others that we would encounter during this process. We did this by interpreting the Guidance in the context of the landscape, scale, and resource management challenges of the Klamath River watershed. Through this process, we articulated several assumptions about the effective and appropriate use of surrogate species to address our conservation challenges. Synthesizing these assumptions and integrating them with the tools and techniques of structured decision analysis enabled us to develop a prototype process for the selection of surrogate species.

Assumptions and Interpretations of Draft Technical Guidance

According to our interpretation of the Guidance, our primary assumptions guiding this process were:

- 1) Conservation objective hierarchy. The first step of the surrogate species selection process is the development of a conservation objective hierarchy. This hierarchy would begin with an interpretation of the Service's fundamental objective of functional landscapes for the Basin, and be stepped down to levels that described both the major ecosystem components necessary to achieve functional landscapes, and the defining ecological characteristics of those ecosystem components.

- 2) Number of surrogate species. The number of species that could potentially be selected for a complete picture of functional landscapes is roughly determined by the number of objectives representing major ecosystem components, although a methodology will be developed for scaling up in a systematic way such that fewer species could be chosen to represent more generalized objectives.
- 3) Type of species chosen as potential surrogates. Potential surrogate species should not be chosen because they are species of concern for the Service. Rather, they should be chosen primarily based on their ability to reliably represent one or more conservation objectives, and secondarily on criteria that represent practical considerations, including cost. Priority or trust species should be considered as surrogate species, when appropriate, but other species should also be considered based on their ability to best represent the conservation objective.
- 4) Population metrics. Population metrics should be distinguished from population objectives. Population metrics are “metrics to assess performance of our management actions (USFWS, 2012)” whereas population objectives represent the desired state of the population. That is, metrics are what is measured; population objectives are the target value of the metric. Developing population objectives may be a time-intensive process that requires consultation with partners and/or modeling, but identifying a metric is sufficient for evaluating the adequacy of potential surrogate species. The specific metric influences the cost and feasibility of monitoring (which is considered as a selection criterion) as well as defining the connection to the conservation objective (such as in “metrics to assess performance of our management actions”).

More detail about our assumptions and interpretation of each of the ten steps outlined in the Guidance can be found in Appendix 1.

Decision Maker, SDM Workshop Structure, and Team Composition

The Guidance states that the decision makers for surrogate species selection are the Service’s regional directors: “Fish and Wildlife Service Regional Directors are responsible for identifying the surrogate species selected in their respective regions, following the process for consultation and collaboration outlined in the draft technical guidance.” However, the application of the detailed process described in the Guidance would likely be delegated through assistant regional directors to managers within the geographic area of interest for each surrogate species selection effort, who would in turn employ the expertise of their technical staff in assembling information relevant to the decision process. Because of our existing collaborative efforts and the presence of dedicated SHC staff, FWS decision makers and scientists from the Klamath Basin field offices and refuges were invited to develop a pilot process for surrogate species selection in the Pacific Southwest region.

Our objectives for the pilot process were: 1) to follow the recommendations in the Guidance in pursuit of a scientifically defensible and adaptive management-driven conservation strategy for the Klamath River watershed; and 2) to clearly communicate our experiences, assumptions, and

all components of the decision process in order to maximize the benefit to the Service. We looked to SDM as an ideal approach to break down the decision problem into tractable steps, maintain transparency, and facilitate documentation of decision analysis components.

USFWS/USGS Structured Decision Making workshops (ECS3159; http://training.fws.gov/CSP/Resources/Decision_Analysis/SDM.htm) have been offered by the FWS National Conservation Training Center and USGS Patuxent Wildlife Research Center since 2007. SDM is a structured approach to problem-solving. Based in decision-theory and risk analysis, it provides a flexible framework to decompose problems into discrete components and explicitly integrates science and management, while incorporating uncertainties, to support decisions that address fundamental objectives (Hammond et al., 1999). The process begins with a clear definition of the Problem and the management Objectives. Then, Alternative management actions can be identified, and we can use modeling, expert elicitation, or other means to predict the Consequences associated with each alternative. In multiple objective problems, we also look at the Trade-offs associated with choosing one alternative over another to select an optimal solution. These steps together comprise the PrOACT process (Hammond et al., 1999). The workshops focus on developing a rapid prototype of a decision problem. Rapid prototyping is an approach that involves developing a quick and simple decision analysis as a means of identifying the most important components of the decision problem. While not intended to be final or complete, a rapid prototype is an important first step to developing the decision analysis structure that can be built upon and enhanced later.

FWS decision makers and scientists from the Klamath Basin field offices and refuges submitted a proposal for a case study to develop a rapid prototype for surrogate species selection at the USFWS/USGS Structured Decision Making workshop offered 24-28 September, 2012. Guidelines provided for participants were to: 1) limit attendance to about 10 team members; and 2) preferentially invite managers and decision makers over scientists and technical experts to obtain agreement on the decision structure. Given limited available space and the need to represent the diversity of the geographic region and Service activities within it, workshop attendance was limited to FWS staff for this pilot effort. The final participants represented a cross-section of Basin FWS offices (representing different geographic areas; Figure 1) and FWS program areas involved in conservation activities in the Klamath River watershed; several other FWS staff and managers participated in planning or follow-up activities but were unable to attend the workshop due to space limitations (Table 1).

Problem

Our workshop problem was to 1) develop specific objectives to identify ecosystem condition goals across the Klamath River watershed; and 2) develop a process with which to engage our partners in strategically choosing surrogate species to facilitate the measurement and evaluation of progress towards selected objectives.

Although this was an accurate statement of what we hoped to achieve, a PrOACT decision problem should be more specific with respect to an individual decision. In our case, our objective hierarchy represented not a single decision problem but several similar decision problems: in

each case, the decision problem was the selection of surrogate species, from a suite of alternatives, in support of a conservation objective. Conservation objectives not only must be tied to the Service's fundamental objective of functional landscapes, they must also be developed to an appropriate resolution for the selection of surrogate species such that they, in fact, define each individual decision problem.

During a series of meetings in the six weeks leading up to the workshop, we developed draft objectives that we considered to be fundamental to the achievement of the ecological components of functional landscapes in the Basin. These can be considered Fundamental Objectives for our hierarchy, although they are in fact means objectives for the overall Service fundamental objective (functional landscapes) described in the Guidance. Our initial Fundamental Objectives were: to 1) restore natural hydrologic processes and conditions; 2) restore natural upland processes and conditions; 3) achieve viable populations of priority species by reducing the impacts of threats; 4) improve community resilience and resistance to long-term perturbations, particularly climate change, within identified priority habitats; and 5) mitigate or reduce the impact of wide-reaching environmental stressors (Table 2a). These objectives were refined and reorganized following the workshop (Table 2b), and will be finalized after soliciting input from our Basin partners following release of the final version of the Guidance.

We then decomposed each of the Fundamental Objectives into means objectives (Hammond et al., 1999), sometimes in multiple steps for clarity of process. The Means Level 1 objectives in our draft conservation objective hierarchy (Table 2a) represented our understanding of the ecosystem components or processes that contributed to the achievement of Fundamental Objectives and were used to represent the individual surrogate species decision problems. The selection procedure, then, would select one or more species to represent each of the six Means Level 1 objectives for this Fundamental Objective; a species could be used to represent more than one objective.

To develop a single ProACT decision analysis from the larger decision problem, we chose to first develop the process using the Fundamental Objective "restore natural hydrologic processes and conditions" and its Means Level 1 objective "achieve naturally functioning riverine communities" (Table 2a). For this exercise, then, our decision problem could be more simply defined as the selection of a surrogate species that best represents naturally functioning riverine communities.

One design goal for the prototype species selection process was the ability to adjust the scaling, i.e., movement upward and downward through the objective hierarchy, of the species selection. The need to accommodate potential changes in the number of surrogate species that we use demands a methodology for reducing the number of species while maximizing the representation of key ecosystem components and ecosystem diversity by the final group of species selected.

Our approach to the problem of scaling was to supplement the target Means Level 1 objective, "restore natural hydrologic processes and conditions," with a second Means Level 1 objective, "achieve naturally functioning riparian communities." We then worked through these two separate decision problems: selecting a species to represent each of the two Means Level 1

objectives, and then combining these decision processes to identify a single surrogate species that represents the best tradeoff among both objectives.

Objectives

Objectives in a PrOACT decision process are specific to the simplified decision problem as described above, and distinct from those in our conservation objective hierarchy. The objectives for the decision problem define the selection criteria for a surrogate species; they are the decision criteria that we use to compare the performance of potential surrogate species with respect to a defined conservation objective.

For this problem, we evaluated potential species using two separate sets of decision criteria; for clarity, we will not call these objectives but instead ecological decision criteria and practical decision criteria. Ecological decision criteria are derived from Means Level 2 objectives (Table 3), and evaluated the ability of the species to represent the chosen Means Level 1 objective. Means Level 2 objectives provided more detailed attributes of the component or process described in their parent objective (Table 3), and form the conceptual linkage between the ecological requirements of an individual species and its characterization of the Means Level 1 conservation objective. Because representation of the conservation objective was the primary driver for surrogate species selection, we used this initial evaluation to identify a set of species for further consideration.

Our next step was to refine our species ranking based on relevant practical considerations such as those described in Step 4 of the Guidance. We developed practical decision criteria by considering the factors that might make a species a useful surrogate, given the assessment that the species sufficiently represented the Means Level 1 conservation objective. One consideration was how much a species can spatially or ecologically overlap with many other species (i.e., as an umbrella species; Favreau et al., 2006; Lambeck, 1997). We also considered how well the chosen species metric could exhibit a short or long-term response to changes in the attributes described in the ecological selection criteria. Separate consideration was given to whether the population dynamics of the species could reflect a response to a physical habitat metric; that is, if there existed a well-established relationship between an easily monitored physical parameter and the species metric (*see* Lindenmayer and Likens, 2010). These types of relationships increase the reliability of the metric, and, if sufficiently robust, can reduce the cost of long-term monitoring. Similarly, we considered the monitoring cost of the species metric. This evaluation factor took into account all potential reasons that the cost of monitoring for the Service might be low: monitoring might be very simple and practical, with inexpensive equipment and staff needs; monitoring might be very efficient such that several species could be monitored simultaneously and/or from few sites; or monitoring might simply be cost-effective because a monitoring program already exists and the cost to modify that program to meet our needs might be very low. Our final consideration was whether baseline data for that species were already in existence, such that we could use the data for change detection and realize an immediate benefit to the selection of that species.

Ecological decision criteria for the first Means Level 1 objective, “achieve naturally functioning riverine communities,” were:

- Sensitive to water and/or sediment quality
- Sensitive to (i.e., benefits from) instream channel complexity (e.g., from large wood or boulders)
- Sensitive to (i.e., benefits from) channel sinuosity and/or longitudinal complexity
- Sensitive to (i.e., is negatively affected by) fine sediments in the channel substrate
- Sensitive to (i.e., benefits from) the presence of low-velocity side channels and pools
- Sensitive to (i.e., benefits from) the presence of channel bank cover, such as resulting from emergent aquatic vegetation or bank structural characteristics

Practical decision criteria for the first Means Level 1 objective, “achieve naturally functioning riverine communities,” were:

- Species is wide-ranging throughout the portion of the Basin represented by riverine communities (<33%, 33-66%, >66%)
- Species needs encompass the needs of other species
- Species metric exhibits a short-term response to changes in riverine community attributes (as described in the ecological decision criteria)
- Species metric exhibits a long-term response to changes in riverine community attributes (as described in the ecological decision criteria)
- Species population dynamics track changes in physical habitat metrics
- The cost of monitoring the species metric is low (i.e., monitoring is practical, efficient, and/or cost-effective; include contributions by Service partners)
- Baseline data exist for this species that can be used for change detection

Ecological decision criteria for the second Means Level 1 objective, “achieve naturally functioning riparian communities,” were:

- Sensitive to (i.e., benefits from) the presence of herbaceous riparian vegetation
- Sensitive to (i.e., is negatively affected by) invasive species
- Sensitive to (i.e., benefits from) age diversity of plants, including dead trees and a duff layer
- Periodic flooding is necessary for the species’ survival, growth, and/or reproduction

Practical decision criteria for the second Means Level 1 objective, “achieve naturally functioning riparian communities,” were:

- Species is wide-ranging throughout the portion of the Basin represented by riparian communities (<33%, 33-66%, >66%)
- Species needs encompass the needs of other species
- Species metric exhibits a short-term response to changes in riparian community attributes (as described in the ecological decision criteria)

- Species metric exhibits a long-term response to changes in riparian community attributes (as described in the ecological decision criteria)
- Species population dynamics track changes in physical habitat metrics
- The cost of monitoring the species metric is low (i.e., monitoring is practical, efficient, and/or cost-effective; include contributions by Service partners)
- Baseline data exist for this species that can be used for change detection

Alternatives

The PrOACT alternatives for these decision problems are the sets of potential species that could be used to represent each of the Means Level 1 objectives, “achieve naturally functioning riverine communities,” and “achieve naturally functioning riparian communities.”

The Guidance suggests in Step 3 that some potential surrogates could be chosen from Service Priority species, but also that other species may serve that purpose better than Priority species. Given that the potential set of species could include all species with ranges overlapping the Basin and that this would be an impractically large list, we identified a strategy for narrowing down this set. Because we selected surrogate species to represent Means Level 1 objectives, we used more detailed Means Level 2 objectives to identify potential species; these were used to develop the ecological decision criteria. We identified potential surrogate species using best available knowledge of which species present on the landscape were likely to be influenced by any of the attributes described by the ecological decision criteria.

For this prototype process, we used the knowledge represented by the SDM team in the room due to time and logistical constraints. Not all team members self-identified as subject matter experts for riverine and/or riparian communities, as the primary focus of the workshop was not to make a final species selection for these objectives. Team members contributed a mixture of management perspectives from different geographic regions in the Basin, and scientist perspectives from different geographic regions, program areas, and species expertise areas. Our intent was to develop a process with input from all of these team members that could be later applied using a more complete and robust approach to a broader range of species selection problems; for this reason, we considered our identification of potential surrogates for this decision problem to be preliminary. We have not provided justification of these selections for this reason, though this is a step that we would document more thoroughly in a later process.

Further development of a list of potential surrogate species would include a more complete process, including elicitation of information and feedback from subject matter experts, as well as from published literature and other sources of information, as appropriate. More attention would also be given to the identification of specific population metrics (including life stage) for each potential species that would aid in their evaluation against the decision criteria. Some species might represent more than one different attribute of the conditions or processes represented in the conservation objective. For those species, each attribute may be represented by a population metric that reflects a different life stage and/or is measured using different methodology; these factors must be considered when evaluating species against decision criteria.

Potential surrogate species or species groups identified for the Means Level 1 objective, “achieve naturally functioning riverine communities,” were:

- Aquatic invertebrates
- Western pond turtle
- Tailed frog
- Yellow-legged frog
- Chinook salmon
- Coho salmon
- Redband trout
- Steelhead
- Bull trout
- Lost River sucker
- American dipper
- Belted kingfisher

Potential surrogate species or species groups identified for the Means Level 1 objective, “achieve naturally functioning riparian communities,” were:

- Western pond turtle
- Yellow-legged frog
- Olive-sided and willow flycatcher and yellow warbler
- Swainson’s thrush
- Cottonwood
- Willow and alder
- Beaver
- Mink

Expert Elicitation Methods

We evaluated potential surrogate species or species groups against the decision criteria using an expert elicitation method (e.g., Runge et al., 2011). Because of time limitations during the workshop, and because we had determined that the purpose of this process was to develop a prototype that would be applied more rigorously after the workshop, we used a very simple elicitation method to generate values for exploratory analysis. The twelve workshop participants (Table 1) had diverse backgrounds, roles, and areas of expertise; each individual chose whether or not to participate in the scoring of a given species based on their expertise. We obtained scores for most criteria by reading each species-decision criterion pair and asking each person to indicate a binary response: thumb-up indicated “yes” and thumb-down indicated “no.” Only those individuals providing a response were counted, and a score was developed by counting the numbers of “yes” votes and dividing by the total number of responses:

$$\sum Yes \div (\sum Yes + \sum No)$$

The resulting score was between 0 and 1. Some practical decision criteria had three levels: “high,” “medium,” and “low.” A similar method was used for eliciting these scores: thumb-up indicated “high,” a flat, open hand indicated “medium,” and thumb-down indicated “low.” The scores were then assigned as 2, 1, or 0 and calculated by adding the number of points assigned and dividing by the total number of responses, then dividing by 2 to scale the score to a range between 0 and 1:

$$(2 \times \sum High + 1 \times \sum Medium) \div (2 \times (\sum High + \sum Medium + \sum Low))$$

All scores were scaled so that the least desirable score was 0 and the most desirable score was 1.

Decision Analysis

The selection of surrogate species for the selected Means Level 1 objectives was approached as a tradeoff analysis between multiple decision criteria; MCDA methods were used to facilitate each decision.

For the first Means Level 1 objective, “achieve naturally functioning riverine communities,” we assessed 12 species or species groups across 6 ecological decision criteria and 7 practical decision criteria. For the second Means Level 1 objective, “achieve naturally functioning riparian communities,” we assessed 8 species or species groups across 4 ecological decision criteria and 7 practical decision criteria. These results were summarized in consequence tables, as described below. Simple weighting methods were used to place weights on each of the decision criteria.

Consequence table

We represented the scored performance of each of the alternatives within consequence tables constructed independently for the Means Level 1 objectives representing riverine (Table 4) and riparian (Table 5) communities. We assigned importance weights to the ecological decision criteria representing the means objectives. Additionally, we assigned importance weights among means objectives relative to the Fundamental Objective. We also assigned importance weights to the practical decision criteria. These consequence tables (Tables 4 and 5) show the tradeoffs that were inherent in the decision analysis; no single species scored equally well across all decision criteria. Although several salmonids did score similarly across ecological decision criteria, they differed in their practical decision criteria scores; a more fully-developed scoring process than was possible during the workshop would likely have produced greater variability in results.

We included some attributes in the consequences table that were not used as decision criteria, but were retained as possible decision rule criteria (e.g., is the alternative a Priority species? Is it present in the Upper Basin, Lower Basin, or both?); these were considered as possible “tie-breakers” between closely performing species.

Simple weighting

We elicited values among ecological and practical decision criteria, as well as among the Means Level 1 objectives, using simple relative weighting for each of the three groups. The criteria or objectives were first ranked in order, with the most important given a rank of 1, second most important given a rank of 2, and so on for the number of criteria or objectives being ranked. Then, the most important (rank = 1) criterion or objective was given a score of 100, and scores between 0 and 100 were given to each of the remaining criteria and objective to indicate their importance relative to 100. Final weights were then scaled between 0 and 1.

Tradeoffs and Optimization (Multi-criteria Decision Analysis)

To identify a species for each Means Level 1 objective that best balanced tradeoffs across decision criteria, we first combined ecological decision criteria scores as a weighted sum incorporating elicited importance weights. This weighted sum represents the value-weighted score for how well the species represents the specified ecological decision criteria. We then combined this score with the constructed-scale value of a single (for simplicity and due to time constraints) practical decision criterion, “cost of monitoring,” as a weighted sum. In this case, we weighted the ecological decision criteria 3:1 over the practicality decision criterion as a conservative approach to avoid selecting a species that is practical to survey but of weak value as an ecological surrogate (another way we approached this was through decision rules, discussed below). The result was a score for each potential species that represented its cost-discounted ecological representativeness of progress toward the Means Level 1 objective of naturally functioning riverine or riparian communities.

For the riverine objective, 4 of the salmonid species (Chinook and Coho salmon, redband trout, and steelhead) scored equally well using only ecological decision criteria. Incorporating the “cost of monitoring” criterion gave Chinook salmon a narrow lead over the next highest ranked species (Figure 2; Table 4). In practice, a more robust evaluation procedure, as well as the incorporation of the remaining practical decision criteria, would likely have resulted in more differentiation among species. The worst performing species were tailed frog, Lost River sucker, western pond turtle, American dipper, and belted kingfisher. Incorporating the “cost of monitoring” criterion increased the relative scores of the Lost River sucker and, to a lesser extent, the American dipper and western pond turtle. However, their ecological scores were too low for them to be competitive with other species in representing riverine communities within the Basin.

The riparian objective was represented by Swainson’s thrush. When only ecological decision criteria were used, the yellow-legged frog had a very slight advantage over the two next highest-scored species, western pond turtle and Swainson’s thrush. When “cost of monitoring” was factored in to calculate a composite score, however, Swainson’s thrush ranked highest, followed by cottonwood.

One objective of our prototyping process was to develop a potential strategy for combining species selection across multiple conservation objectives. In this prototype, we explored how we might scale up species selection from the two Means Level 1 objectives, “achieve naturally

functioning riverine communities,” and “achieve naturally functioning riparian communities” to select a single species for their parent Fundamental Objective, “restore natural hydrologic processes and conditions.” To do this, we combined scores for each of the 18 alternative species or species groups; 10 species were alternatives only for the riverine objective, 6 species were alternatives for the riparian objective, and 2 species, yellow-legged frog and western pond turtle, were considered for both objectives. Scores were then combined as a weighted sum as above, incorporating relative importance weights for the Means Level 1 objectives (riverine = 0.68, riparian = 0.32).

When all 18 species were considered for the parent Fundamental Objective, the highest performer (by a slight margin over redband trout) for the combined objectives was Chinook salmon (Figure 4), which was also the highest performer for the riverine Means Level 1 objective. The composite scores clearly reflect the higher weighting of the riverine objective: the 6 “riparian only” species ranked lower than all but 1 of the 10 “riverine only” species, and the 2 species considered for both objectives also ranked lower than the highest-performing “riverine only” species (Figure 4) despite the scoring advantage conferred by representing both objectives.

Uncertainty

Uncertainty is an inherent part of both a surrogate species selection process and the long term use of surrogate species to inform landscape conservation planning, because it is a process that is driven by assumptions (Wiens et al., 2008). We have imperfect knowledge about the ecosystems in which we work and the species that inhabit them, yet we are driven by conservation need to make decisions to take action in the face of uncertainty. A surrogate species approach requires us to make several assumptions and judgments with imperfect or incomplete information. First, we identify which ecosystem components will respond to specific management actions or other human activities on the landscape. Second, we identify which of those ecosystem components most support broader ecological function goals and/or Service Priority species. And third, we determine which surrogate species may best represent those ecosystem components such that we can efficiently track ecologically relevant responses. Additionally, we must make assumptions about how well surrogate species will track the changes that we want in a timeframe that is relevant to management decision-making.

We identified several stages of our prototype species selection process where we encountered uncertainties:

1. Identifying alternatives. Although we want to keep the number of potential surrogate species reasonable to maximize efficiency, we should be inclusive of species that do not at first seem ecologically ideal so that they can be evaluated against all criteria.
2. Scoring. We are limited to best available information and are unlikely to have complete information available on all potential surrogate species. Uncertainty can be incorporated into the scoring process as weights (Tulloch et al., In Press), but regardless of the approach, we should identify uncertainties captured in our conceptual models (as described in the Guidance, step 8) in order to structure the pursuit of new information

around highest priority uncertainties that might later influence our management actions or change our surrogate species selection or management decision processes. We can reduce the uncertainty surrounding “cost of monitoring” and other decision criteria by carefully defining a population metric and considering that metric (associated with a particular life stage, time of year, etc.) in addressing the criteria, rather than attempting a generic assessment of the species as a whole.

3. Weighting. Identifying importance weights, particularly of means objectives to represent their relative contribution to fundamental objectives, is challenging. This is the means by which we must decide how important each of the ecological decision criteria are in representing the overall objective in a way that is most relevant to ecological function and the response of both surrogate and other species on the landscape.

By developing hypotheses and conceptual models that articulate our uncertainties, we can identify the uncertainties that most influence our decisions and work to reduce them using a structured adaptive management approach (Williams et al., 2009). The Guidance explicitly addresses uncertainty in steps 8-10 (USFWS, 2012). Uncertainty will certainly remain after species selection, and by embracing uncertainty we enhance our potential for reducing it through learning, and thus for long term success.

Discussion

Value of decision structuring

Addressing surrogate species selection through structured decision analysis using the ProACT process was beneficial for several reasons. First, it helped us to identify and separate the core components of the process and the decisions required at each step. This helped us to recognize where we needed to clearly state our interpretations and assumptions about the Guidance (Appendix 1) in order to better define the decision problem and agree on an approach so that we could move forward with a prototype.

Decision structuring also provided a framework by which the decision analysis could be broken into components and thus simplified. Instead of tackling the large and intractable problem of selecting all species for the Klamath River watershed, we could instead break the decision problem down into logical components based on our Means Level 1 objectives. This follows a modeling heuristic recommended by Nicholson et al. (2002): “Instead of concentrating on one all-purpose synthesis model, invest in a suite of models, each with a well-defined objective.”

We were then able to work towards an approach of combining decision problems to scale up the solution to higher level objectives, in the event we later needed to reduce the number of surrogate species representing the Basin. The approach that we developed combined scores across objectives using importance weights on the objectives. Because the riverine objective was heavily weighted relative to the riparian objective, the highest ranked species for the combined approach (Chinook salmon) was also the highest ranked riverine species. However, weights strongly influenced this ranking, and it was clear from exploring the model that the highest

ranked combined species would not always be the highest ranked species from either objective. Swainson's thrush was the highest-ranked riparian species, but yellow-legged frog ranked much higher than Swainson's thrush in the combined ranking, because of its presence in both river and riparian communities. Although some species were ranked very similarly in our prototype approach, this was likely a result of our simple scoring method and our use of only one practical decision criterion.

Further development required

We identified several areas that would benefit from further development following the workshop, some of which are further discussed under "Recommendations" below:

1. Further development of the conservation objective hierarchy, and definition of terms used to clarify understanding.
2. An inclusive approach to developing weights for objectives. All managers should participate in weighting Fundamental Objectives, and subject matter experts representing the Basin should participate in weighting means objectives and decision criteria.
3. A more structured approach for selecting species as potential surrogates for the decision analysis. We intentionally selected some unlikely species in order to understand how their inclusion might influence the selection process, but we agreed that species lists should be solicited and refined from a larger group of subject matter experts and from the literature, where appropriate.
4. Development of population metrics prior to scoring. This would decrease uncertainty around parameters such as cost and species life stage or time of year, all of which may influence cost and ecological representativeness.
5. Reduction in semantic uncertainty. Terminology in the decision criteria and the scoring methodology need to be clearly explained, discussed, and agreed upon before final scoring.
6. More inclusive and robust method of scoring. Information should be obtained from consultation with relevant subject matter experts and from the literature, and scoring ranges should be broad enough to represent the variability in scores.
7. Consideration of different geographic areas within the Basin. Definition of terms in objectives may clarify different nuances to be applied within different Basin geographies; also, we may need to consider using different surrogates to reflect those nuances.
8. Further consideration of the implications of combining results across objectives.

Prototyping process

The rapid prototyping process encouraged us to move through the decision analysis very quickly. To do this, it was necessary to immediately identify the critical components of the problem and to make the assumptions necessary to move forward with a decision process. Rather than focus on the implications of the outcome of the species selection process, we accepted the process as an end in itself. The species chosen, in contrast, were considered as a way to illustrate the process and were not a final or even a preliminary selection. This understanding removed many of the concerns and allowed us to focus on developing the process. Although we needed to work through the steps of the decision analysis in order to identify some of the areas that will require further development (as described above), our primary focus was to develop a prototype process so that Basin decision makers and subject matter experts could collectively understand the approach and further develop it after the workshop.

Recommendations

Generic Prototype Process

We consolidated most of our recommendations into a generic prototype process for selecting surrogate species (Figure 5). This process is inclusive of steps 1-7 of the Guidance (although it interprets step 7 as population metrics; see Appendix 1).

Step 0. Define a geographic area. It is necessary to first define a geographic area before conservation objectives can be developed. While we agree with the Guidance that Landscape Conservation Cooperatives (LCCs; Millard et al., 2012) are a good place to start, many LCCs may be too large to be practical for the use of a surrogate species approach (Wiens et al., 2008).

Step 1. Develop a weighted objective hierarchy and choose a means objective.

- The objective hierarchy should be stepped down from the Service's functional landscapes objective (USFWS, 2012) to a level that represents the ecological attributes necessary for functional landscapes.
- In developing these, we recommend anticipating the effects of climate change by separating *types* of functional species interactions from specific interactions that might currently exist among particular species. To accommodate expected shifts in ecological communities, we focused on ecological processes and the functional aspects of species assemblages as opposed to specific groups of species in particular geographic areas.
- Clear definition of terms and discussion of meanings is critical and should be in writing where possible. The development of the objective hierarchy is a critical step. It will not only inform surrogate species selection; it can help guide all of the work that we do.
- Weights for highest level (fundamental) objectives should be provided by decision makers; lower level (means) objectives should be weighted by subject matter experts.
- For a given surrogate species decision problem, pick a conservation objective representing the level at which you want to select a species.

Step 2. Develop and weight ecological decision criteria.

- Use the means objectives from your chosen conservation objective to develop ecological selection criteria.
- Clear definition of terms and discussion of meanings is critical and should be in writing.
- Subject matter experts should weight the criteria.

Step 3. Identify physical metrics. Where commonly used physical metrics are associated with the ecological decision criteria, those should be identified for later consideration in conceptual models.

Step 4. Identify potential surrogate species. Subject matter experts for the chosen conservation objective should provide input of potential species that may reflect the ecological decision criteria and relate to the physical metrics. Literature may also be consulted for this step.

Step 5. Develop population metrics. After potential surrogate species are identified, identify a population metric that captures the relationship between the species (considering its life stage, time of year, etc.) and the ecological decision criteria. For example, density of nests, or % escapement relative to number of redds.

Step 6. Species scored, weighted by criteria, ranked.

- Scoring methodology should be clearly defined and in writing.
- Subject matter experts can participate in this, or scores can be elicited from literature or other sources, if appropriate. Score development should be documented, and a similar effort should be made for each prospective surrogate species.

Step 7. Determine and apply threshold for high performers. A minimum standard may be set for ecological scores, below which a species would no longer be considered, and thus eliminate the possibility that a very low performing species could be selected on the basis of a high practicality score alone. This could be a percentile or similar approach.

Step 8. Reflection; qualitative “gut check.” Those who participated in the decision process should examine and evaluate the list for consistency with expectations. If inconsistencies are found, it should be determined whether any objectives are missing or improperly weighted based on consensus opinion. If this was the case, the problem could be corrected and the species re-scored.

Step 9. Develop and weight practical decision criteria.

- Subject matter experts should develop practical selection criteria with consideration to the needs of the objective.
- Clear definition of terms and discussion of meanings is critical and should be in writing.
- Subject matter experts should weight the criteria.

Step 10. High performing species scored, weighted by criteria, ranked.

- Species not eliminated from the process in Step 7 continue.
- Scoring methodology should be clearly defined and in writing.

- Subject matter experts can participate in this, or scores can be elicited from literature or other sources, if appropriate. Score development should be documented, and a similar effort should be made for each prospective surrogate species.

Step 11. Determine thresholds and/or decision rules to develop a final ranked list of species.

Decision team should evaluate whether additional threshold or decision rule approaches should be applied.

Step 12. Reflection; qualitative “gut check.” Those who participated in the decision process should examine and evaluate the list for consistency with expectations. If inconsistencies are found, it should be determined whether any objectives are missing or improperly weighted based on consensus opinion. If this was the case, the problem could be corrected and the species re-scored.

Embracing Uncertainty

Following selection of species using the process outlined above, it will be necessary to address steps 8 through 10 of the Guidance, which describe the need to test and monitor the effectiveness of the selection and the approach, as well as the need to identify uncertainties and data gaps. The use of surrogate species in ecology has a long history, but it is also far from tested and validated (Caro, 2010). Only by embracing the unknown, by developing and testing hypotheses, can we improve the science.

Nicholson et al. (2002) recommend that interdisciplinary modeling projects, as are a major component of many landscape conservation planning efforts, should “maintain a healthy balance between the well-understood and the poorly understood components of the system. All system models are balancing acts between what one knows and understands and what one does not know. The temptation is to put too much emphasis on those parts of the system where understanding and data are good and to ignore or gloss over the areas where little is known.”

Uncertainties that should be identified and tested when applying a surrogate species approach fall into two broad categories: 1) those that relate to our understanding of how surrogate species relate to their habitats, as expressed through their population metric; and 2) those that relate to our broader understanding of ecosystem function in relation to surrogate species population metrics and to physical habitat metrics. Models developed to relate surrogate species to their habitat components and to broader ecosystem response elements can be used to develop monitoring targets: expected ecosystem response measures that can be used to evaluate hypotheses represented through surrogate species conceptual models. Information obtained through monitoring can then provide new information to reduce our knowledge gaps and uncertainties and increase our understanding of ecosystem function and/or species-specific ecology (Figure 6), which can then improve our conservation decision making.

Acknowledging and even fully embracing uncertainty are critical to the success of the approach, because it is the most effective way for us to learn and to reduce those uncertainties through

adaptive management (Williams et al., 2009). A rigorous adaptive management approach should be focused on identifying and prioritizing uncertainties according to the management benefit; that is, the highest priority uncertainties are those that would result in a change in management action (Runge et al., 2011) or perhaps a change in the choice of surrogate species used to represent an objective.

Long-term Landscape Conservation Planning

Surrogate species selection is not a stand-alone decision process. It is an integrated part of a proactive approach to conservation on landscape scales, and it must be approached from that perspective if the selection of surrogate species is to be useful for landscape conservation planning. A carefully developed and weighted objective hierarchy is a prerequisite to surrogate species selection because species will be chosen to represent components of the hierarchy. But it could also be considered a prerequisite to any conservation decision making that we do within a landscape (Figure 7), particularly if we are faced with competing objectives or need to develop collaborative approaches with partners.

Landscape level planning requires that we collaborate with other land managers to accomplish common goals. Greater collaboration with partners should also be a focus of applying this approach, and there are opportunities. A recent analysis of the U. S. Forest Service's 2012 planning rule, for example, recommends a combined coarse and fine scale approach, with the selection of focal species to represent coarse scale (i.e., landscape level) factors (Schultz et al., 2013), a similar approach to that which we are proposing here. Where possible, we should invite collaboration and work with partners to find commonalities in both our conservation objectives and our approach.

Developing an objective hierarchy is a worthy cause in itself because it can help us to make decisions and communicate the reasons for them. If we think of surrogate species as representatives of our objectives, then we can use them in the context of conceptual system models to help guide the work that we do while effectively allocating resources to meet those objectives. By clearly articulating our assumptions and uncertainties, we can develop adaptive management frameworks that use surrogate species as one indicator (along with physical and other species metrics) that can feed back information to inform management decisions and increase our success. For the selection of surrogate species to be a meaningful exercise, it must be integrated with our landscape conservation approach as part of a long-term commitment to conservation on a landscape scale.

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Table 1. Workshop participants and contributors, SDM Workshop 24-28 September, 2012. Contributors participated in reviewing objectives and/or this report, providing verbal input during meetings, answering surveys, or otherwise providing input to this process.

*Indicates non-participant who contributed significantly to pre-workshop planning and post-workshop activities; FWO = Fish and Wildlife Office; NWRC = National Wildlife Refuge Complex; office locations are shown in Figure 1.

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Table 2a. Objective hierarchy used at the Structured Decision Making workshop, 24-28 September, 2012. Basin-level Fundamental Objectives are targeted to achieve the biological component of the Service’s fundamental objective of “functional landscapes.” Surrogate species were chosen to represent the Means Level 1 objectives “achieve naturally functioning riverine communities” and “achieve naturally functioning riparian communities.”

Fundamental Objective	Means Level 1 Objective
Restore natural hydrologic processes and conditions	Achieve naturally functioning riverine communities Achieve naturally functioning riparian communities Restore natural hydrologic connectivity Restore natural stream flow Improve the quantity, quality, and distribution of wetland communities Reduce the hypereutrophic state of lentic systems in the upper Basin
Restore natural upland processes and conditions	Improve the quantity, quality, and distribution of forested upland communities Improve the quantity, quality, and distribution of non-forested upland communities Improve connectivity and distribution of habitats
Achieve viable populations of priority species by reducing the impacts of threats	Maintain genetic and life history diversity Improve population resiliency Improve priority populations' ability to resist perturbation Achieve sufficient population redundancy
Improve community resistance and resilience to long-term perturbations, particularly climate change, within identified priority habitats	Increase native biological diversity Achieve appropriate levels of habitat heterogeneity Preserve the roles of strongly-interacting species that influence community structure
Mitigate or reduce the impact of wide-reaching environmental stressors	Contaminants, climate change, and others

Table 2b. Updated objective hierarchy, restructured and following the Structured Decision Making Workshop, 24-28 September, 2012. Basin-level Fundamental Objectives are targeted to achieve the biological component of the Service’s fundamental objective of “functional landscapes.”

Fundamental Objective	Means Level 1a Objective	Means Level 1b Objective
Sustain or improve species resistance and resilience to stressors within the Klamath River watershed	<i>Conserve, restore, rehabilitate, and enhance hydrologic and other physical processes that provide conditions supporting self-sustaining populations of native species dependent on natural and managed aquatic systems</i>	<p>Conserve, restore, rehabilitate, and enhance hydrologic and other physical processes that provide conditions supporting self-sustaining populations of native species dependent on <u>instream</u> (below bank full) systems</p> <p>Conserve, restore, rehabilitate, and enhance physical and biological processes that provide conditions supporting self-sustaining populations of native species dependent on <u>riparian</u> systems</p> <p>For wetland systems:</p> <ol style="list-style-type: none"> 1) Create managed wetlands to re-establish key ecological functions that support target and/or native wetland-dependent species in areas where hydrology has been modified beyond practical restoration potential 2) Conserve, restore, rehabilitate, and enhance isolated palustrine wetlands where appropriate (based on historic presence) to re-establish physical and biological processes that provide conditions supporting self-sustaining populations of target and/or native wetland species assemblages <p>Conserve, restore, rehabilitate, and enhance physical and biological processes that provide conditions supporting self-sustaining populations of native species dependent on <u>lacustrine</u> systems</p> <p>Conserve, restore, rehabilitate, and enhance physical and biological processes that provide conditions supporting self-sustaining populations of native species dependent on <u>spring</u> systems</p> <p>Conserve, restore, rehabilitate, and enhance physical and biological processes that provide conditions supporting self-sustaining populations of native species dependent on <u>estuarine</u> systems</p> <p><i>Conserve, restore, rehabilitate, and enhance physical processes that provide conditions supporting self-sustaining populations of native species dependent on natural and managed upland systems</i></p> <p>Maintain, create, improve, and restore <u>forest</u> composition, distribution, and ecological processes that better support native species</p> <p>Maintain, create, improve, and restore <u>non-forested upland</u> composition, distribution, and ecological processes that better support native species</p>
Reduce or eliminate stressors that contribute to the disruption of ecological processes within the Klamath River watershed	<p><i>Reduce or eliminate ecological stressors where feasible, including disease and invasive species</i></p> <p><i>Reduce or eliminate physical stressors where feasible, such contaminants, fish passage barriers, water diversions, and infrastructure barriers to hydrologic processes</i></p>	
Reduce or eliminate stressors that directly contribute to the decline of, or hinder recovery efforts for, Federally listed, tribal trust, and public trust species within the Klamath River watershed	<p><i>Separate objectives will be developed for each Priority and trust species</i></p>	

Table 3. Means Level 1 objectives chosen for the prototype surrogate species selection process, and their Means Level 2 objectives used to develop ecological decision criteria for the selection of surrogate species to represent the Means Level 1 objectives.

Means Level 1 Objective	Means Level 2 Objective
Achieve naturally functioning riverine communities	High water/sediment quality Complexity from vegetation, logs, and/or boulders Diverse geomorphic features (i.e., sinuosity and longitudinal complexity) Within-channel with silt-free cobble/gravel substrate for spawning, incubation, and/or rearing Presence of low-velocity side channels and pools including cover Channel bank cover including emergent aquatic vegetation and/or bank structure
Achieve naturally functioning riparian communities	Herbaceous riparian vegetation Absence of invasive species Plant age diversity including dead trees, duff layer Periodic flooding

Table 4. Consequences table for species considered for the “achieve naturally functioning riverine communities” objective, showing decision criteria, weights, and scores.

	Uses riparian areas?	Uses high-gradient stream reaches?	Uses low-gradient stream reaches?	Federal trust species?	Sensitive to changes in water/sediment quality	Sensitive to instream channel complexity	Sensitive to channel sinuosity and/or longitudinal complexity	Sensitive to fine sediments in channel substrate	Sensitive to presence of low-velocity side channels and pools	Sensitive to channel bank cover	Weighted EDC Score	Wide-ranging within community type	Short-term response to change	Population dynamics track changes in habitat	Species' needs encompass others	Practicality / Low cost of monitoring	Baseline data available for change detection	Unweighted Average	Weighted Composite Score
	Unused Criteria				Ecological Decision Criteria (EDC)						Practical Decision Criteria (PDC)								
Within - EDC Weights	N/A				0.20	0.18	0.22	0.15	0.16	0.09		Not weighted for prototype							
EDC & PDC Weights											0.75	(used Practicality/Cost only)						0.25	
	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	EDC	H/M/L	Y/N	H/M/L	H/M/L	H/M/L	H/M/L	PDC	
western pond turtle	1.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0	0.8	0.40	0.4	0.0	0.3	0.2	0.5	0.5	0.3	0.43
tailed frog	1.0	1.0	0.0	0.0	1.0	1.0	0.0	1.0	0.0	0.0	0.53	0.0	1.0	1.0	0.5	0.0	0.0	0.4	0.40
yellow-legged frog	1.0	0.0	1.0	1.0	1.0	1.0	0.5	0.0	1.0	0.0	0.65	0.0	1.0	0.8	0.5	0.5	0.5	0.5	0.61
aquatic inverts	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	0.6	1.0	0.94	1.0	1.0	0.9	0.9	0.8	0.8	0.9	0.90
Chinook salmon	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.00	0.5	0.0	1.0	0.8	0.8	1.0	0.7	0.95
Coho salmon	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.00	0.5	0.0	1.0	1.0	0.6	1.0	0.7	0.90
redband trout	0.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.00	0.3	1.0	0.9	1.0	0.8	0.7	0.8	0.94
steelhead	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.00	0.5	0.0	1.0	1.0	0.5	0.5	0.6	0.88
bull trout	0.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	0.84	0.0	0.7	0.9	0.5	0.8	0.0	0.5	0.82
Lost River sucker	0.0	0.0	1.0	1.0	0.0	0.0	1.0	1.0	0.5	0.0	0.45	0.3	0.0	0.8	0.5	1.0	1.0	0.6	0.59
belted kingfisher	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	1.0	0.0	0.8	0.4	0.8	0.8	0.6	0.21
American dipper	1.0	1.0	0.0	1.0	0.0	0.8	0.3	1.0	0.0	0.3	0.36	0.4	0.5	1.0	0.6	0.7	0.8	0.7	0.44

Table 5. Consequences table for species considered for the “achieve naturally functioning riparian communities” objective, showing decision criteria, weights, and scores.

	<i>Uses high-gradient stream reaches?</i>	<i>Uses low-gradient stream reaches?</i>	<i>Federal trust species?</i>	Sensitive to herbaceous riparian vegetation	Sensitive to invasive species	Sensitive to plant age diversity	Requires flooding as a direct effect	Weighted EDC Score	Wide-ranging within community type	Short-term response to change	Long-term response to change	Population dynamics track changes in habitat	Species' needs encompass others	Practicality / Low cost of monitoring	Baseline data available for change detection	Unweighted Average	Weighted Composite Score
	Unused criteria			Ecological Decision Criteria (EDC)					Practical Decision Criteria (PDC)								
Within - EDC Weights				0.20	0.18	0.22	0.15		<i>Not weighted for prototype</i>								
EDC & PDC Weights								0.75	<i>(used Practicality/Cost only)</i>							0.25	
	<i>Y/N</i>	<i>Y/N</i>	<i>Y/N</i>	<i>Y/N</i>	<i>Y/N</i>	<i>Y/N</i>	<i>Y/N</i>	EDC	<i>H/M/L</i>	<i>Y/N</i>	<i>Y/N</i>	<i>H/M/L</i>	<i>H/M/L</i>	<i>H/M/L</i>	<i>H/M/L</i>	PDC	
western pond turtle	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.69	1.0	0.0	0.3	0.0	0.2	0.4	0.6	0.3	0.63
yellow-legged frog	0.5	1.0	1.0	1.0	1.0	1.0	0.0	0.71	0.1	1.0	1.0	1.0	0.5	0.2	0.5	0.4	0.59
flycatchers	1.0	1.0	1.0	0.0	0.5	1.0	0.0	0.42	1.0	1.0	1.0	0.8	0.9	0.7	1.0	0.5	0.49
Swainson’s thrush	1.0	1.0	1.0	1.0	0.0	1.0	0.0	0.69	0.7	1.0	1.0	0.8	0.9	0.7	1.0	0.9	0.70
cottonwood	0.2	1.0	0.0	0.0	0.3	0.7	1.0	0.56	0.4	0.0	1.0	1.0	0.9	1.0	0.8	0.7	0.67
willow and alder	1.0	1.0	0.0	0.0	0.0	0.3	0.8	0.37	1.0	1.0	1.0	0.8	0.8	1.0	0.9	0.7	0.53
beaver	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.41	0.8	0.0	1.0	0.2	0.8	0.8	0.6	0.8	0.49
mink	1.0	1.0	0.0	0.5	0.0	1.0	0.0	0.55	1.0	0.0	0.7	0.2	0.5	0.0	0.0	0.6	0.41

Figures

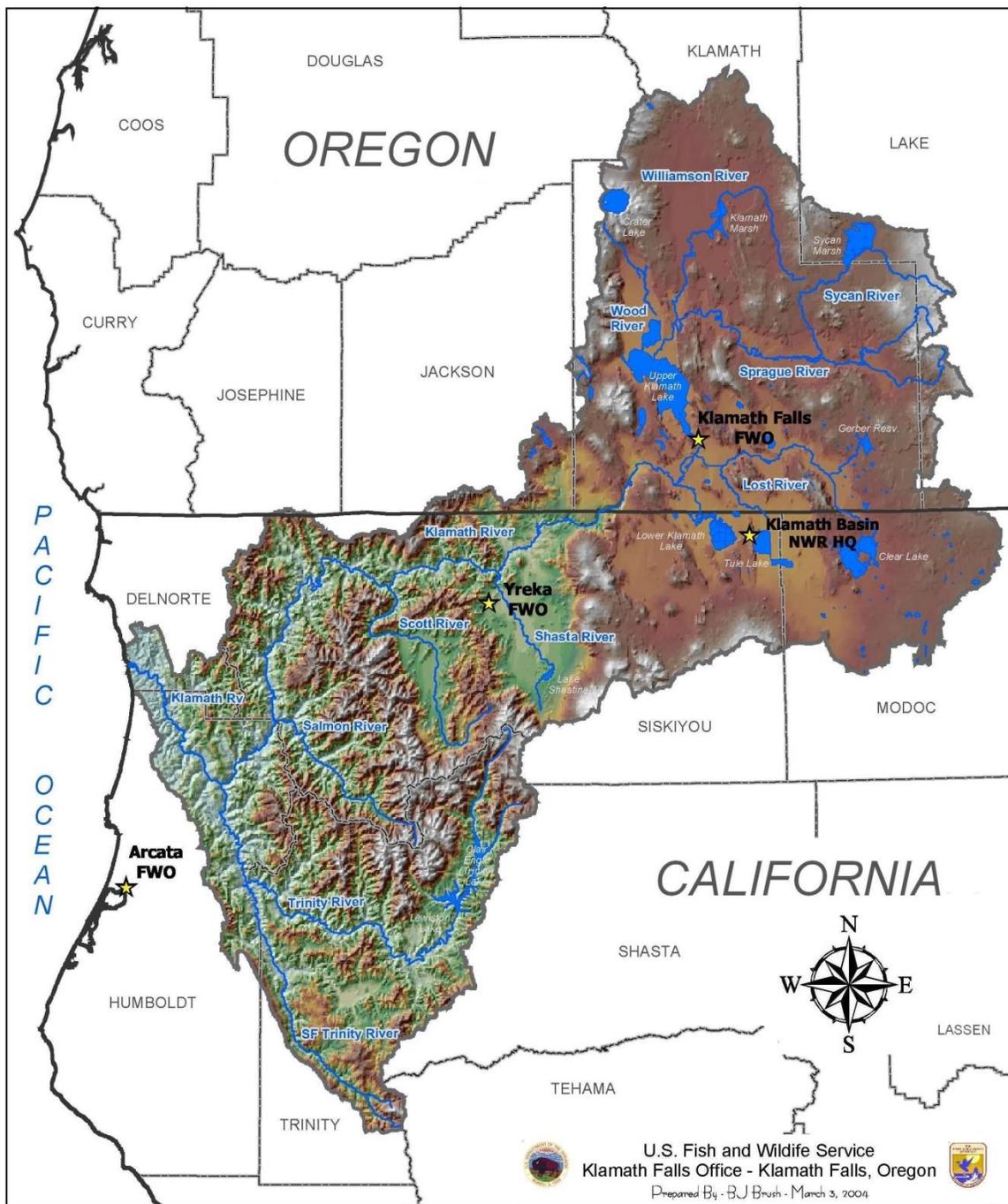


Figure 1. The Klamath River watershed, showing the Klamath River and its major tributaries and water bodies. Each Fish and Wildlife Office (FWO) location (Arcata, Yreka, and Klamath Falls), and Klamath Basin National Wildlife Refuge Headquarters (NWR HQ) is indicated with a star.

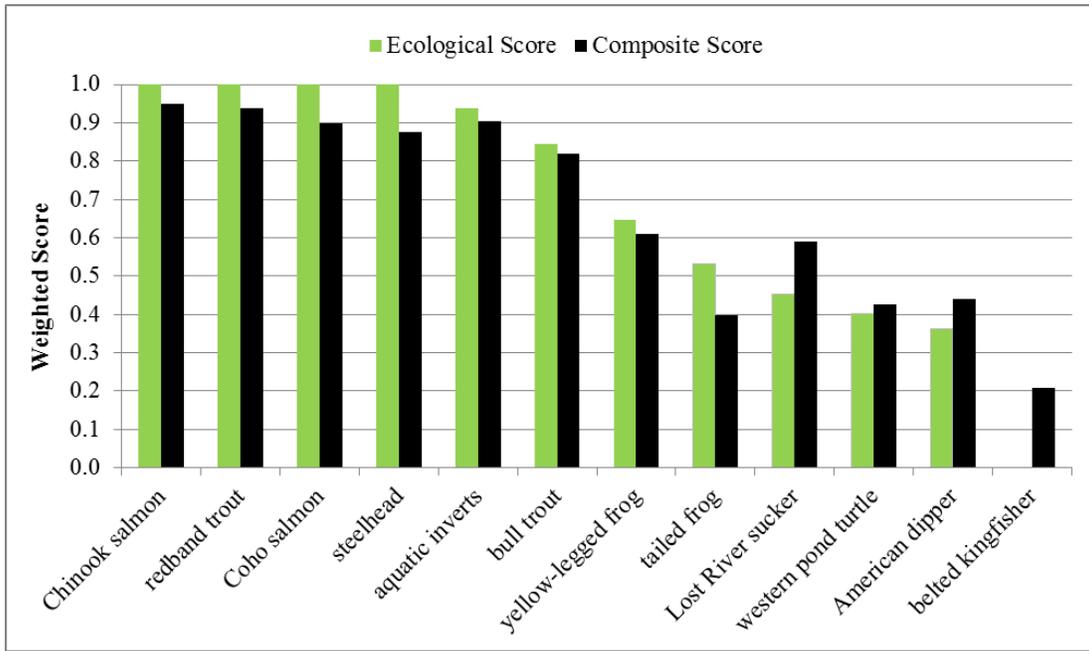


Figure 2. Scores of species considered for the “achieve naturally functioning riverine communities” objective. Ecological scores represent weighted scores of ecological decision criteria, whereas Composite scores represent combined weighted scores of ecological and practical decision criteria. Ecological decision criteria are weighted 3:1 over practical decision criteria.

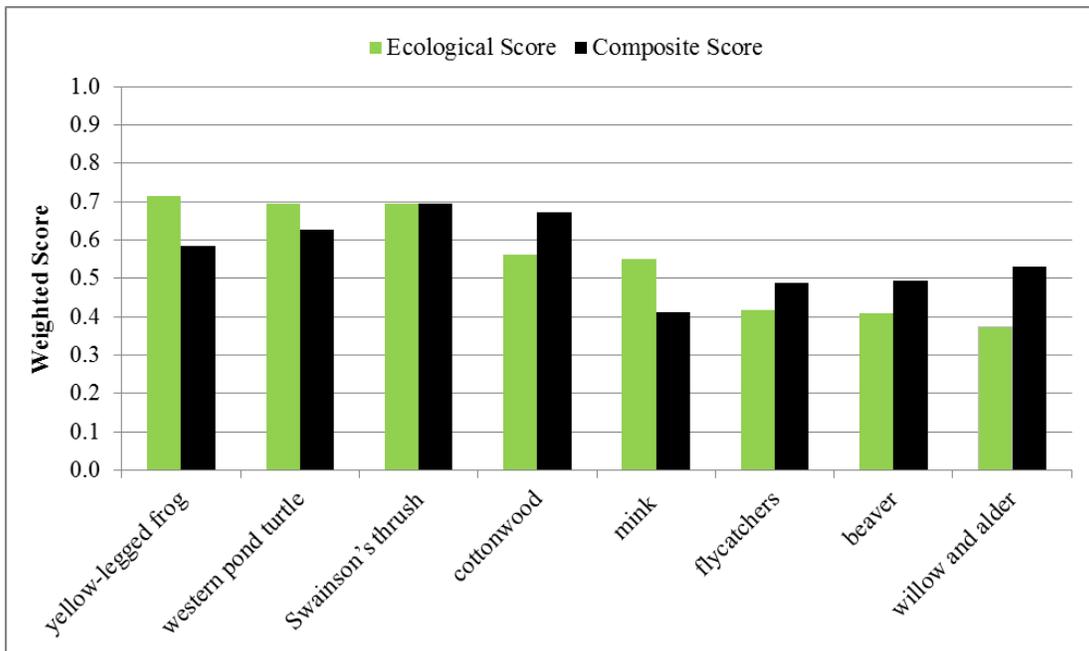


Figure 3. Scores of species considered for the “achieve naturally functioning riparian communities” objective. Ecological scores represent weighted scores of ecological decision criteria, whereas Composite scores represent combined weighted scores of ecological and practical decision criteria. Ecological decision criteria are weighted 3:1 over practical decision criteria.

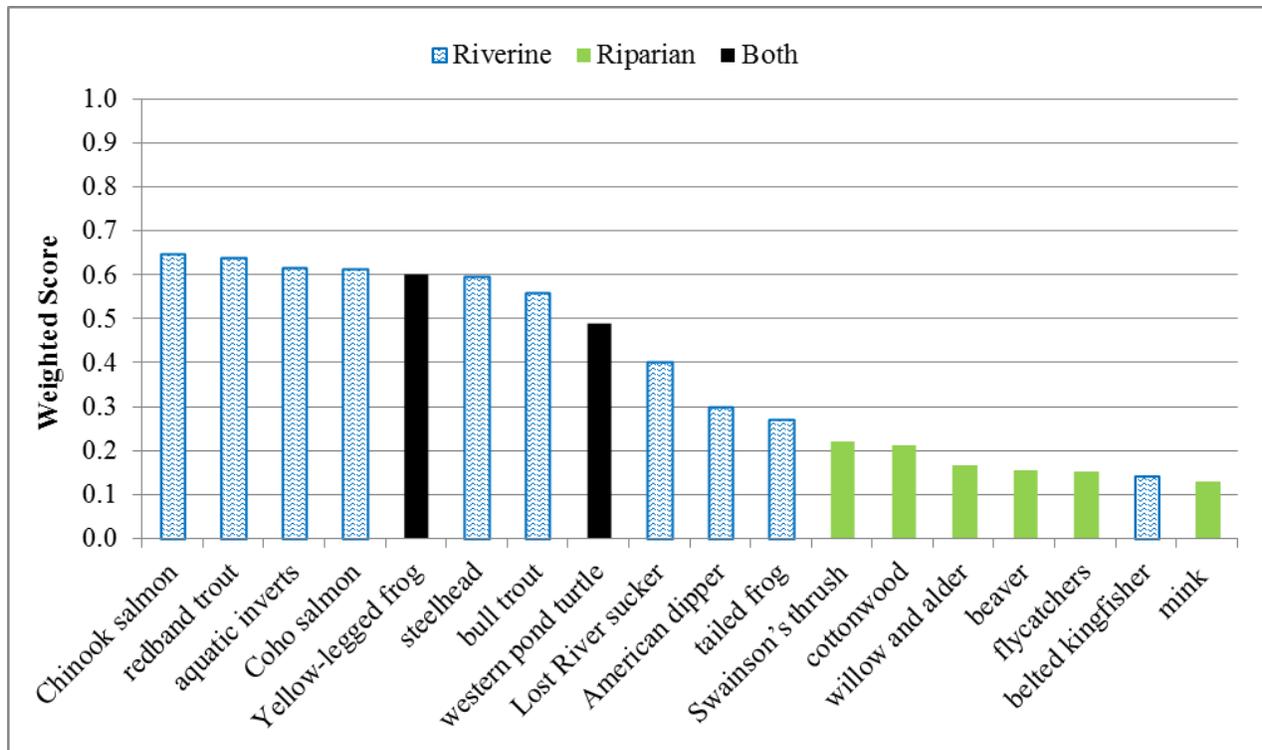


Figure 4. Composite riverine and riparian scores. Composite scores represent combined weighted scores of ecological and practical decision criteria (3:1 EDC:PDC). Riverine scores were weighted 68% and riparian scores were weighted 32%.

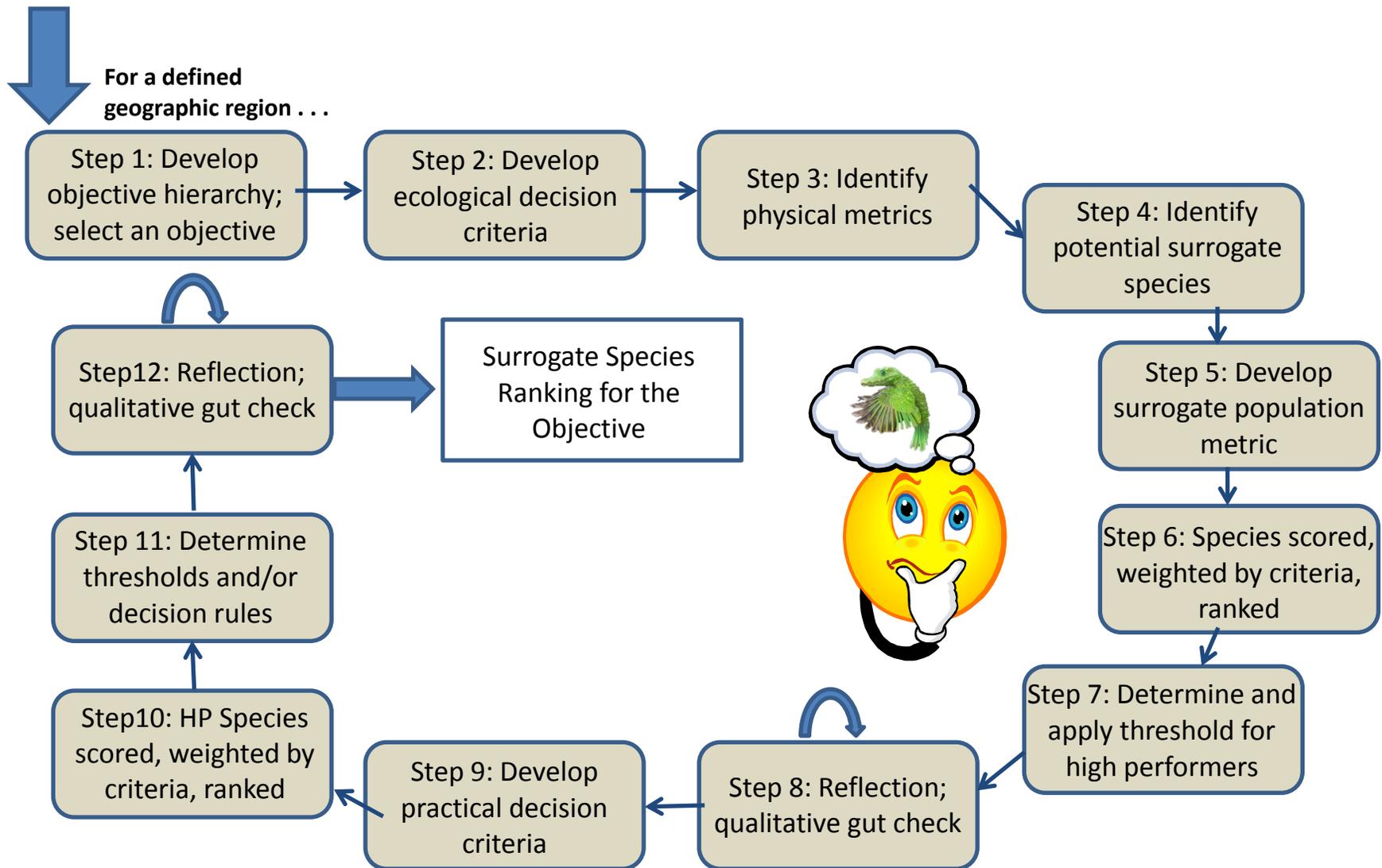


Figure 5. Generic prototype process for selecting a surrogate species to achieve an ecosystem condition goal in pursuit of achieving the Service’s fundamental objective of functional landscapes.

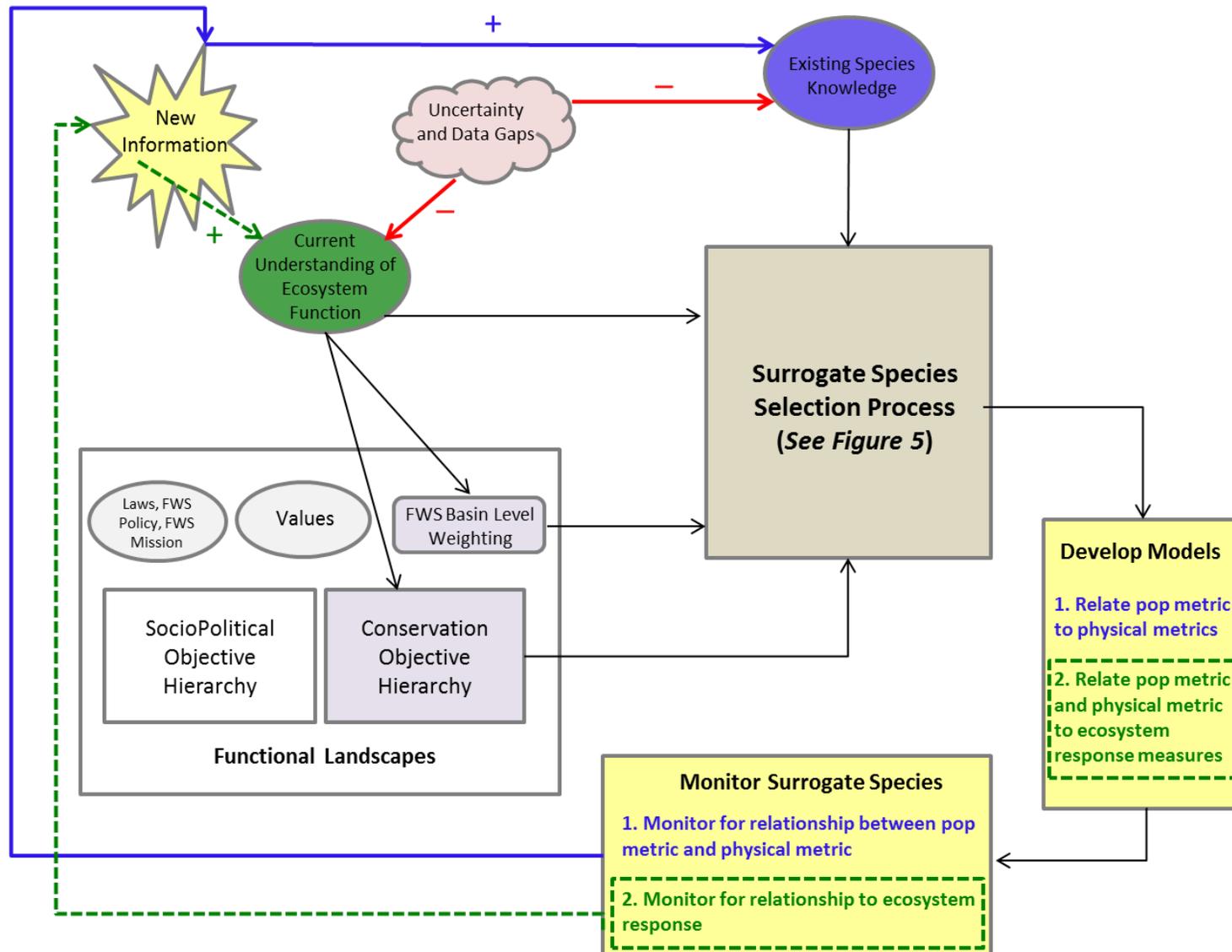


Figure 6. The incorporation of new information, from modeling and monitoring of surrogate species, into our objectives and into the surrogate species selection process.

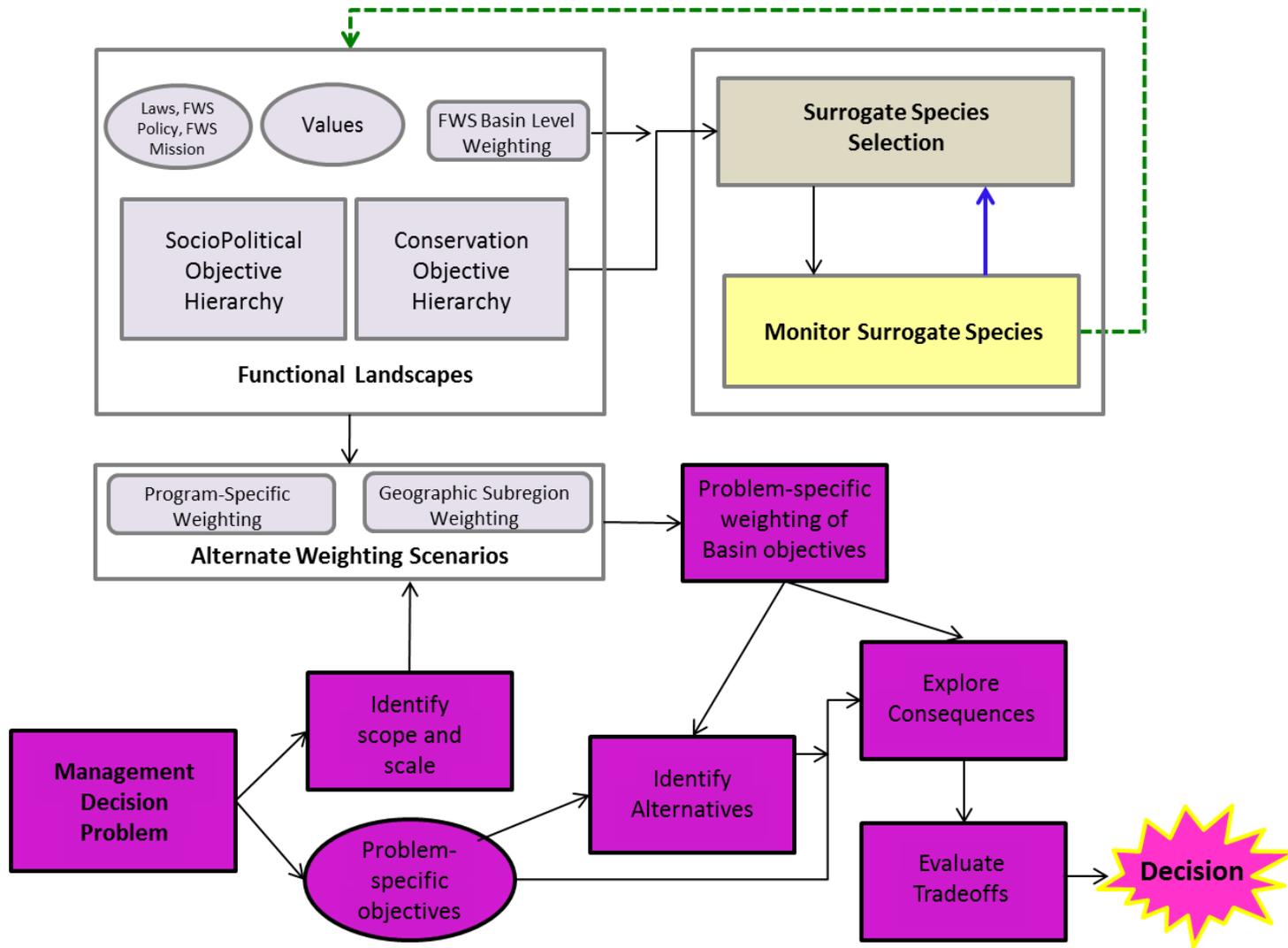


Figure 7. The connection between surrogate species and management decision problems, as influenced by functional landscape objectives and alternative objective weighting scenarios.

Appendix 1. Assumptions and Interpretations of Draft Technical Guidance.

To develop a process from the 10 steps presented in the Guidance that matched the scale, extent, and Service organization in the Basin, we first needed to interpret the Guidance and also to clearly define our assumptions for our pilot process.

Step 1. Develop and clearly specify the management or conservation objectives for surrogate species selection approach.

Although the Guidance specified that management or conservation objectives should be developed for the purpose of selecting surrogate species, the only conservation objective given in the Guidance was:

To characterize and maintain functional landscapes capable of supporting self-sustaining fish, wildlife, and plant populations (the goal is sustainable populations).

“Functional landscapes” were further defined as:

Lands and waters with the properties and elements required to support desirable populations of fish and wildlife, while also providing human society with desired goods and services, including food, fiber, water, energy, and living space.

We interpreted the Guidance to say that the above conservation objective should be viewed as the overarching fundamental objective for the Service in selecting surrogate species. We concluded that a hierarchy of fundamental and means objectives (Gregory et al., 2012) should be developed to clearly articulate what constitutes a “functional landscape” within the Klamath River watershed.

We further determined that since surrogate species would be chosen to represent aspects of the functional landscape captured in our means objectives, selection criteria should focus on their ecological characterization of functional landscapes. Their selection is based only on their ability to characterize our ecologically-based goals for a functional landscape, and as such their selection is an independent action that has no influence on or from management objectives that originate from other concerns.

Functional landscapes, as defined above, clearly include social and political concerns, and no implication should be made from the above argument about the relative importance of those concerns. Rather, we see those concerns as equally deserving of the development of explicitly stated sociopolitical objectives. However, those sociopolitical objectives would be used in conjunction with conservation objectives in decision problems that are distinct from the selection of surrogate species, such as deciding about the application of a particular management action. Surrogate species, in that context, are representations of the conservation objective(s) relevant to that decision. The selection of any particular species does not imply priority status for the related conservation objective(s). Instead, the species are an effective means of capturing the qualities of the functional landscape in the context of that management action.

Selecting surrogate species, then, is clearly not itself a management decision, or the prioritization of limited resources. Rather, for complex, interdisciplinary decision problems, surrogate species simplify the monitoring and communication of conservation objectives in the face of ecological complexities. When viewed in this way, the selection of surrogate species becomes an objective analysis of which of the available species incorporates the ecological characteristics that best represent a conservation objective. This decision is made in the context of the practical considerations (such as the cost or reliability of monitoring, or the existence of long-term data) that make a species a good surrogate.

Although this approach simplifies the actual decision problem, it demands a comprehensive conservation objective hierarchy and transparently-derived relative weights of objectives and sub-objectives within that hierarchy. Under our “One Service in the Basin” approach, the development of the Service’s Basin-level goals and objectives, and their consolidation across geographic and program boundaries, was recognized as a prerequisite for working more effectively both within the Service and with partners to achieve our common goals. A consolidated objective hierarchy is necessary for the selection of surrogate species, but it is also needed to guide management decisions on a Basin scale. Our goal is to develop a conservation objective hierarchy to guide our selection of surrogate species at the Basin scale, but also to create a hierarchy that is scalable and that includes alternative objective weightings for application to problems that are specific to a particular geography or Service program as well.

Step 2. Identify geographic scale.

The issue of scale is one that clearly drives the selection of surrogate species and especially the number of surrogate species required to adequately represent conservation objectives (Wiens et al., 2008). Scale in this context includes the size of the area being considered for surrogate species selection as well as the grain or resolution at which the area will be considered (Wiens et al., 2008). However, the discussion of scale in the Guidance is limited to the geographic extent of target areas for selecting surrogate species, so it is left to the decision maker to identify an appropriate spatial and conceptual resolution for the development of conservation objectives and the number of surrogate species needed to adequately represent them.

The geographic extent for our pilot approach was the Klamath River watershed and required little deliberation. The identification of an appropriate scale was more challenging, in part because we were uncertain of the implications of surrogate species selection and therefore the constraints that might be associated with the number and/or type of species selected. We interpreted the guidance to mean that we should look to the conservation objectives as targets for surrogate species selection, and identify the lowest (i.e., most specific) level in the conservation hierarchy for which surrogate species could adequately represent components of a functional landscape as identified in the objectives. However, since we were aware that constraints may later be encountered, a goal was to develop a selection process that was focused on a fine scale but could be optimally scaled up to more generically represent broader scale objectives.

Step 3. Determine which species to consider in the identified landscape (these are the species that will be represented by the surrogates).

In identifying species to be represented by surrogates, we looked to our conservation objectives. We determined that if a species has been determined to be a priority, such that it had unique or specific landscape objectives, then most effective way to incorporate that objective is by means of an explicit objective in the hierarchy (this would fall into the category of Priority species described in Step 6). However, we interpreted Step 3 to mean that the needs of species should be used to help us identify key ecosystem components that may be limiting to these and other species on a broader scale.

Our approach was to identify a suite of species that represented a set of key ecological conditions (represented by our objectives) that define a functional landscape. Those ecological conditions would then support a larger set of species.

We wanted to avoid representing a whole population with a surrogate of a species or group of species because of the difficulties in meeting the assumptions required in such an approach (Caro et al., 2005; Cushman et al., 2010). However, such an approach may be useful when addressing the effects of specific management actions within a limited timeframe and management area, and when such a representation is supported by data (e.g., Athearn et al., *in prep*; Athearn et al., 2012).

A necessary process that is implied - but not explicitly described - in this step is identifying the set of potential surrogate species which can be considered as the set of “alternatives” for the MCDA approach, and their associated population metrics. These will have to be evaluated against ecological and practical decision criteria (“objectives”). For the purpose of our pilot approach, we chose to obtain these through expert elicitation of workshop participants in consideration of selected conservation objectives.

Step 4. Decide which criteria to use in determining surrogate species.

Selection criteria would function as “objectives” in a MCDA approach, and be used to compare alternatives (i.e., potential surrogate species) by scoring them against the selection criteria. The examples of selection criteria provided in Step 4 of the Guidance are criteria that evaluate how well a species could perform as a surrogate from a practical point of view (e.g., cost of monitoring, and large spatial needs of species that would cause it to overlap with many other species).

Although this is a logical step, we assumed that this step could not be applied until we had first identified the conservation objective for which a surrogate would be chosen, and also identified a set of potential surrogates that adequately represented the conditions described in that objective and could be considered as “alternatives” for MCDA. That process implies the need to first apply another level of surrogate selection criteria to the set of potential species that specifically addresses the ability of the potential species to represent the conservation objective; this set of selection criteria would be derived from the conservation objective hierarchy and would represent the ecological characteristics that describe the lowest level objective for which a species would be selected.

Step 5. Establish surrogates.

This step describes the ideal characteristics of a process that is used to select surrogate species. In particular, the Guidance calls for “the documentation and justification of a science-based, transparent, and documented process that was used for identifying the surrogate species selected.” Our interpretation was that Structured Decision Making was an ideal approach for us for developing this process because of its transparency and our ability to document the science decisions that were made as prerequisites to the selection of species.

Step 6. Identify species requiring special attention.

As described above in our discussion of Step 3, we identified that Service priority species whose needs would not be addressed through a “functional landscape” approach would be explicitly included within our objective hierarchy. However, we also recognized that where such species are constrained by their habitat, they may function well as a surrogate for ecosystem condition goals as well. In that case, those species will be considered as potential surrogates. Considering that many such species have existing information and/or ongoing management strategies, these species will likely have a strong practical advantage over other species when evaluated against selection criteria and so are more likely to be chosen as surrogates. It is nevertheless imperative that the primary selection criteria first address the conservation objective under consideration.

Step 7. Identify population objectives.

The Guidance states that “the purpose of population objectives is to link conservation actions to measurable population responses.” It further states that population objectives “describe the desired state of a population” and are:

- Expressed as abundance, trend, vital rates, demographic variable, or other measurable indices of population status, based on the best biological information
- Used to compare the current state of the population against future conditions
- Metrics to assess the performance of our management actions
- Indices that can relate back to an estimate of current population versus habitat base and estimates of habitat needed to support desired future populations
- scale-dependent

In interpreting the Guidance, we made a distinction between population metrics (i.e., “metrics to assess performance of our management actions” as described above) and population objectives (the desired state of the population). Metrics are what, specifically is measured; population objectives are the target value of the metric. Identifying a metric is important because the specific metric influences the cost and feasibility of monitoring (which is considered as a selection criterion) as well as the connection to the conservation objective (such as in “metrics to assess performance of our management actions”). Despite the emphasis on setting whole-population objectives in this step of the Guidance, we identified the selection of the metric itself as the most important component of this step. We determined that setting a target value for this metric in reference to a given conservation objective would then come from modeling the relationship between management-influenced ecosystem components and the surrogate species.

Steps 8 - 10. Test for logic and consistency, Identify knowledge gaps and uncertainties, and Monitor the effectiveness of the approach.

As mentioned above, we would develop target values (i.e., population objectives) for population metrics for a given conservation objective by modeling the relationship between management-influenced ecosystem components and the surrogate species. Because we want to improve the efficiency with which we evaluate management actions, models should include physical characteristics that can be represented with physical metrics whenever practical. The modeled linkage should be established between the conservation objective, the anticipated physical system response to management actions, the anticipated response of the surrogate species as reflected by the population metric, and, if applicable, the response of target species (including Priority species) that are expected to benefit from the ecosystem changes. Effectiveness monitoring could then include measurements of each component (considered within temporal and spatial response frameworks) to evaluate consistency with the modeled relationships. In some cases, a strong and established relationship between an easily-measured physical metric and ecosystem response could be used to reduce the effort required to directly assess surrogate species population metrics and liberate resources for other priorities.

The Guidance suggests that the surrogate species selection process is meant to be adaptive and to account for adjustments in response to new information from monitoring or scientific studies. We assumed that by explicitly acknowledging uncertainties that are inherent in the process, we will be empowered to use an adaptive management framework (Williams et al., 2009) to improve our knowledge and understanding of the effectiveness of chosen surrogates to represent our conservation objectives, and to iteratively modify that selection where appropriate. Our selection of surrogates is thus not permanent but is the best selection we can make with the currently available information. By documenting this iterative and adaptive process, we can contribute to and improve the science of surrogate species for the broader conservation community.

Appendix 2. Glossary of terms used.

Consequences²

The results of different management actions, in terms that are relevant to the management objectives. Often, we predict the consequences of the alternative actions with some type of model. Depending on the information available or the quantification desired, consequences may be modeled with highly scientific computer applications or with professional judgment elicited carefully and transparently. Ideally, models are quantitative, but they need not be; the important thing is that they link actions to consequences.

Consequences Table

A table that is used to record the consequences of choosing different alternatives with respect to the chosen decision criteria. In the surrogate species decision problem, the consequences table contained the scores for each potential surrogate species in relation to each decision criterion.

Conservation Objectives¹

Conservation objectives are statements that are clear, realistic, specific, measurable, and lay out the desired set of conditions managers wish to achieve through conservation action.

Decision Criteria

PrOACT objectives for a Multi-criteria Decision Analysis; used here to distinguish Conservation Objectives used to define the surrogate species decision problem from objectives used to select surrogate species.

Decision Maker²

Person or team with the responsibility and authority to allocate resources and implement the decision.

Decision Rules

Strategies for making decisions that are decided and agreed upon by a group of decision makers.

Ecological Conditions¹

The term “ecological condition” refers to the state of the physical, chemical, and biological characteristics of the environment, and the processes and interactions that connect them.

Ecological Decision Criterion

Derived from Means Level 2 Objectives. These are the selection criteria that are used to evaluate the effectiveness of a potential surrogate species for representing a Means Level 1 Objective.

Ecological Processes¹

The diverse set of life processes and adaptations, including the complex relationships among species, (predation, pollination, etc.) the movement of materials and energy through living communities, and the abundance and distribution of all life forms within ecosystems.

Functional Landscapes¹

Lands and waters with the properties and elements required to support desirable populations of fish and wildlife while also providing human society with desired goods and services, including food, fiber, water, energy, and living space.

Fundamental Objective²

One of the ultimate goals of the decision. An objective that we care about for its own sake, or which is an end in itself. See also Means Objective.

Guidance

USFWS 2012, DRAFT Guidance on Selecting Species for Design of Landscape-scale Conservation.

Heuristic²

A rule of thumb.

Hydrologic Processes and Conditions

See “Ecological Processes” and “Ecological Conditions,” applied to aquatic ecosystems.

Landscapes¹

Landscapes are large, connected geographical regions that have relative homogeneous environmental characteristics, such as eco-regions, watersheds, coastal areas, or forest ecosystems.

Landscape Conservation¹

A landscape-scale conservation approach examines ecological processes across space and time to more fully recognize natural resource conditions and trends and natural and human influences; and to target local resource conservation opportunities based on landscape scale assessments to sustain fish and wildlife populations at desired numbers and distributions. The approach seeks to identify fish and wildlife habitat, important ecological values, functions and processes, and patterns of environmental change, to inform conservation delivery at local land and water conservation sites. In addition, linking local conservation action to landscape-scale assessment considerations informs the development of local, State, and federal policies aiming to ensure a future for fish and wildlife.

Landscape Features¹

These are characteristics describing landscape composition (e.g., land cover, soil types, riparian cover) and landscape structure (e.g., elevation, forest block size, aquatic substrate).

Management Action²

An action affecting a managed system, taken as a result of a management decision. In the context of natural resources, management actions typically influence the status of resources or the processes that control resource dynamics.

Management Decision²

A decision to take a management action. In adaptive management, decision making typically is driven by management objectives, with active stakeholder involvement. Adaptive decision making takes into account both the current status of resources and the level of understanding about them.

Means Objective²

An objective that is not sought for its own sake, but as a means of achieving a more fundamental objective.

- Means Level 1 Objective

The most generic means objective; used to represent the individual surrogate species decision problems. Surrogate species were chosen to represent this level of objective

- Means Level 2 Objective

More detailed objectives than Means Level 1 Objectives; used to develop the Ecological Decision Criteria for the selection of surrogate species to represent the Means Level 1 Objective

Metric²

A standard of measurement.

Model²

Any representation, whether verbal, diagrammatic, or mathematical, of an object or phenomenon. Natural resource models typically characterize resource systems in terms of their status and change through time. Models imbed hypotheses about resource structures and functions, and they generate predictions about the effects of management actions, an explicit approximation of reality, typically expressed as a series of mathematical relationships.

Multi-Criteria Decision Analysis (MCDA)²

Measures preferences by eliciting and ordering judgments from people affected by a decision.

Objective²

An explicit statement of a desired outcome, typically expressed in subject-verb-object sentence structure. Objectives (even those that are stated in scientific terms) are always a reflection of values, so setting objectives falls in the realm of policy and should be informed by legal and regulatory mandates as well as stakeholder viewpoints. A number of methods for stakeholder elicitation and conflict resolution are appropriate for clarifying objectives.

Objective Hierarchy

A set of objectives that have been organized into fundamental and means objectives, where means objectives for a given fundamental objective are organized as nested under the fundamental objective.

Population Metric

A metric to assess the response of a surrogate species to a change in the environmental condition(s) that it represents. A metric is what is measured; a population objective, in this context, is the target value of the metric.

Population Objectives¹

Population objectives describe the desired state of the population. They may be expressed as abundance, trend, vital rates or other measurable indices of population status, based on the best biological information. They are used to assess the performance of our management actions and are scale dependent.

Practical Decision Criterion

Derived from the Guidance, and from careful consideration of the surrogate species selection problem. These are the selection criteria that are used to evaluate the effectiveness of a potential surrogate species for performance as a surrogate species, including such concerns as feasibility and cost.

Priority Species¹

Species demanding extra time and resource commitments due to legal status, management need, vulnerability, geographic areas of importance, financial or partner opportunity, political sensitivity, or other factors.

ProACT²

An approach to decision making consisting of eight core elements starting with identifying the Problem, Objectives, Alternatives, Consequences, and Trade-offs – then moving on to clarify and evaluate uncertainty, risk tolerance, and linked decisions. Described in detail in Hammond et al. (1999).

Prototype²

An original type, form, or instance that is a model on which later stages are based or judged.

Rapid Prototyping²

An approach to structured decision making that involves quickly framing a simple prototype of the decision problem then stepping back to assess its basic structure and major components. Rapid prototyping is very useful for quickly validating objectives, evaluating model components, and setting parameters for sensitivity analysis with a minimum investment of time. The rapid prototype concept comes from engineering (quickly building a trial version of a new device or machine to see if it will work), and is useful for structured decision analysis and biological model building in natural resource management.

Strategic Habitat Conservation¹

Strategic Habitat Conservation (SHC) is the conservation approach adopted by the Service that establishes self-sustaining populations of fish and wildlife, in the context of landscape and system sustainability, as the overarching target of conservation. SHC relies on an adaptive management framework to inform decisions about where and how to deliver conservation efficiently with our partners to achieve predicted biological goals necessary to sustain fish and

wildlife populations. SHC requires us to set goals, make strategic decisions about our actions, and constantly reassess and improve our approaches.

Structured Decision Making²

Is an approach to decomposing and analyzing decisions to identify solutions that achieve the desired objectives, in a manner that is explicit and transparent. Based in decision theory and risk analysis, SDM is a concept that encompasses a very broad set of methods, not a prescription for a rigid approach for problem solving. SDM provides clear roles for stakeholders and scientists when working on problems at the interface of science and policy. Key SDM concepts include making decisions based on clearly articulated fundamental objectives, dealing explicitly with uncertainty, and responding transparently to legal mandates and public preferences or values in decision making; thus, SDM integrates science and policy explicitly.

Surrogate Species¹

Defined by Caro (2010) and adopted by the Service species used to represent other species or aspects of the environment (e.g., water quality, sagebrush or grasslands, etc.). Surrogate species are used for comprehensive conservation planning that supports multiple species and habitats within a defined landscape or geographic area.

Thresholds²

The limiting values of a resource attribute that triggers a change in management actions. Management strategies often include thresholds, such that one action is specified for resource values less than the threshold and a different action is specified for a larger resource values.

Tradeoffs²

In a multiple objective setting, gains in one objective that come at the cost of losses in another objective. In most complex decisions, it is not possible to perfectly achieve all objectives; the best we can do is choose intelligently between less-than-perfect alternatives.

Uncertainty²

Because we rarely know precisely how management actions will affect natural systems, decisions are frequently made in the face of uncertainty. Uncertainty makes choosing among alternatives far more difficult. A good decision-making process will confront uncertainty explicitly, and evaluate the likelihood of different outcomes and their possible consequences.

Weight

An importance score given to an objective or decision criterion to indicate its importance relative to others in the same group and hierarchical level.

¹Definitions from USFWS 2012, DRAFT Guidance on Selecting Species for Design of Landscape-scale Conservation.

²Definitions from CSP3171, Introduction to Structured Decision Making Glossary, http://training.fws.gov/CSP/Resources/Decision_Analysis/dec_08/glossary.pdf