Maximizing Bull Trout Conservation through Workload Allocation under Section Seven of the Endangered Species Act

A Case Study from the Structured Decision Making Workshop
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Decision

A fundamental element of the Endangered Species Act of 1973, as amended (ESA), is the interagency coordination between the U.S. Fish and Wildlife Service (Service) and other Federal agencies under Section 7. This coordination, referred to as Section 7 consultation, is designed to ensure that Federal projects (i.e., projects authorized, funded, or carried out by federal agencies, hereafter Projects) will not jeopardize the continued existence of threatened and endangered species or adversely modify critical habitat. However, the effectiveness of Section 7 consultation can be limited by reduced funding levels and escalating workloads that reduce the availability of staff time for consultation on Projects with potentially negative effects. This can result in the loss of conservation opportunities.

In recent years, the Western Washington Fish and Wildlife Office (WWFWO) in Lacey, Washington, has experienced significant reductions in budget and staffing levels, yet the number of Section 7 consultations remains high. A large percentage of these Section 7 consultations involve Projects potentially affecting threatened bull trout (*Salvelinus confluentus*).

As a result, managers at the WWFWO have difficulty in effectively allocating staff effort towards reducing the negative consequences of potentially adverse Projects while also providing timely responses to Federal Agencies with Projects posing a lower risk to bull trout. Decisions on workload priorities or establishing internal due dates tend to be based upon arrival date or perceived complexity, rather than on a systematic and transparent process that incorporates the relative risk or conservation value of a given Project. Thus, managers typically assign work with little understanding of the potential gain in conservation value associated with a Project.

To address this situation, managers at the WWFWO are seeking a sustainable management approach through the development of a decision-support tool that will allow better alignment between staff effort and conservation value. This decision-support tool should help managers

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identify appropriate prioritization and time investments on a repeatable basis. We describe herein the structure of a decision-analytic process which we used to develop such a decision-support tool.

Problem Statement
How should managers at the WWFWO allocate available staff to Section 7 consultations for bull trout in a way that maximizes conservation benefit to the species?

Background

Legal, Regulatory, and Political Context

Managing and prioritizing ESA Section 7 consultations on bull trout is currently one of the greatest workload management concerns at the WWFWO. Under agency regulatory requirements, the Service must respond to requests for informal consultation within 30 days and formal consultation within 135 days. Stakeholders in the Western Washington consultation process consist of WWFWO staff and management, action agencies that submit their Projects for consultation, and the public.

Informal consultation is the process that Federal agencies use to seek concurrence from the Service that their Projects are not likely to adversely affect listed resources. By definition, these are effects that are discountable or insignificant to listed resources. Formal consultation is required for Federal agency Projects that are expected to have adverse effects on listed resources.

Ecological Context

Bull trout in western Washington were listed as a Federally-threatened species in 1999 (U.S. Fish and Wildlife Service 1999). Bull trout in the Coastal-Puget Sound exhibit anadromous, adfluvial, fluvial, and resident life history patterns with 14 designated core areas encompassing 67 local populations. The primary threats to the species are habitat degradation and loss.

Core areas are landscape planning units that form the basis of the recovery strategy for bull trout. Maintaining viable local populations within each core area is critical to the survival and recovery of the species. Habitat management objectives within core areas generally include maintaining cold stream temperatures, high water quality, complex and diverse channel characteristics, and large patches of well connected habitat.

Decision Structure

The overall structure of the decision-analytic process is represented in Figure 1. This structure consists of the decision problem and its causes, the objectives and constraints, the alternative actions, and the predictive model.

Alternative Actions

We identified two alternatives actions for a given Project (Figure 1): (1) place a Project into a short-term review and response bin (hereafter short bins or short Projects), or (2) place a Project into a long-term review and response bin (hereafter long bins, or long Projects). Projects in short bins will receive a minimal time investment by WWFWO staff, while Projects in long bins will receive substantially more investment with the goal of extracting conservation value from these Projects. Each bin will hold both informal and formal Projects, though the time investment will differ between them.

Objectives and Constraints

The key management objective is to minimize the risk of extinction within bull trout core management areas in Puget Sound and the Olympic Peninsula by maximizing the overall conservation value of Section 7 consultations. In addition, we established 2 primary constraints (Figure 1): 1) complete all Projects within the regulatory timelines, and 2) complete all Projects at the existing staffing level (the available number of full-time equivalent (FTE) employees).

Predictive Model

A prototype model was developed in the R programming environment (version 2.5.1 2007) to establish a decision rule for managers to use when assigning Projects to the short bin or long bin. The decision rule was based upon the "potential value" of the Project. Potential value was defined as the maximum conservation value that could be derived from a Project by investing a given level of staff time. Therefore, Projects with the greatest potential value were placed in the long bin, and the decision rule established a threshold point for the minimum potential value, i.e., any arriving Project with a potential value greater than *x* should be placed in the long bin. Conversely, we assumed that Projects placed in the short bin do not provide any conservation value.

Two classes of variables can be manipulated in the model: the proportion of total informal and total formal Projects assigned to the long bin and the amount of time to expend per Project type (i.e., informal in short bin, informal in long bin, formal in short bin, and formal in long bin). We retained control over these variables because we expected the total conservation value of all Projects combined would change as a function of these variables.

The overall structure of the model is illustrated in Figure 2. "Fixed" input parameters (those outside the scope of management manipulation, 1 – 4) and variable input parameters (those that can be manipulated by management, 5 – 6) are as follows:

1. The percent of a Project's potential conservation value realized as a function of handling time (number of days). This parameter consists of two different numerical relationships (i.e., one equation for informal Projects and one equation for formal Projects) that relate the percent of a Project's total potential value to the amount of time invested in the Project. These equations are applicable only to Projects in the long bin. We imagine that this is a non-linear relationship, subject to the law of diminishing returns.

2. The total number of informal consultations, N_i, and the total number of formal consultations, N_f, received in the WWFWO office in a typical 135-day period.

3. The total available staff days for bull trout consultation work per 135 calendar days (K).

4. The "universe" of possible Projects potentially received by the WWFWO, in terms of the potential value of those Projects. This variable will consist of 2 vectors – the potential value of the universe of possible informal Projects (U_i) and the potential value of the universe of possible formal Projects (U_f).

5. The handling time required, in days, for the 4 different categories of Projects, i.e., informal in short bin ($H_{s,i}$), informal in long bin ($H_{l,i}$), formal in short bin ($H_{s,f}$), and formal in long bin ($H_{l,f}$).
6. The proportion of informal Projects placed in the long bin ($p_{l,i}$).

Given inputs 2, 3, 5, and 6, the proportion of formal Projects to put in the long bin ($p_{l,f}$) is fixed, by necessity, according to the following relationship:

$$K = N_i * p_{l,i} * H_{l,i} + N_i * (1 - p_{s,i}) * H_{s,i} + N_f * p_{l,f} * H_{l,f} + N_f * (1 - p_{s,f}) * H_{s,f} .$$

This is necessary to achieve the constraint that all Projects are completed given available staff.

Based on these parameters, we used $p_{l,i}$ and $p_{l,f}$ along with the universe of possible Projects (U_i and U_f) to develop our decision rule. The decision rule was calculated by finding the x_i = (1- $p_{l,i}$) quantile of U_i and the x_f = (1- $p_{l,f}$) quantile of U_f. Then, any informal Project arriving with a potential value greater than x_i and any formal Project arriving with a potential value greater than x_f would go into the long bin, and be handled in a total time of $H_{l,i}$ or $H_{l,f}$ days, respectively. Remaining Projects would go into the short bin and be handled in a total time of $H_{s,i}$ for informal Projects and $H_{s,f}$ for formal Projects.

The final component of the model is the potential value submodel. This submodel derives the potential value of a Project from identifiable characteristics of the Project. Thus, the submodel allows staff to predict the potential value of a Project based on certain attributes of a given Project identified during the intake process. The "potential value" model is used in 2 ways. First, it allows for the development of vectors U_i and U_f based on characteristics of Projects that have arrived at the WWFWO in the past (see further discussion below). Second, it allows each incoming Project to have a potential value assigned to it, so that the decision rule can then be applied.

Decision Analysis

We used simulation to develop an optimal decision rule by manipulating handling times ($H_{l,i}$, $H_{l,f}$, $H_{s,i}$, $H_{s,f}$) and the proportion of informal Projects in the long bin ($p_{l,i}$). In fact, of most interest for manipulation amongst the handling time parameters were $H_{l,i}$ and $H_{l,f}$ because there is probably little flexibility for changing the minimal investment of time needed to complete a Project as quickly as possible (i.e., short bin Projects). We simulated the process of Project arrival (i.e., N_i and N_f Projects arriving, each of which has a potential value randomly drawn from U_i and U_f, respectively. We then applied a given decision rule, and calculated the total value achieved (V_{tot}). V_{tot} is calculated as the potential value of each Project in the long bin, multiplied by the proportions of the total potential value achieved given handling times $H_{l,i}$ and $H_{l,f}$ (see input 1 above).

Through iterative simulation, we will be able to develop outputs such as those illustrated in Figure 3 – the total value achieved as a function of $H_{l,f}$ and the total value as a function of $p_{l,i}$. The use of simulation to derive the levels of these variables that maximize total value will provide a decision rule that is maximally efficient for allocating the workload for the WWFWO.

Uncertainty

Stochastic uncertainty is represented in the model through the random draw of Projects from the "universe" of possible Projects. This is the only uncertainty formally addressed in the model. A currently unresolved structural uncertainty is in the calculation of potential value – this is a component of the model that is currently in development (see below). In addition, while we are developing a workload allocation model to be implemented at the WWFWO, the ultimate success of the model will depend on implementation of the model by the staff; the inability to perfectly direct the outcome of management is known as partial controllability.

Discussion

Value of decision structuring

The Structured Decision Making process exposed the specific elements (objectives, alternatives, constraints, and tradeoffs) inherent to the decision problem. Prior to decomposing the decision problem, attempts to address the problem resulted in a focus on treating symptoms of the overall problem rather than the problem itself. In other words, the biological elements of the objective had tended to dominate past approaches to developing a solution to what is foremost an operational problem.

The step that was critical to this insight was when the group agreed to simplify the most critical part of the framework – the potential value of a Project. Once this was done, the effects of the constraints and insights to the solution were revealed.

Prototyping process

A critical component of the model, the potential value submodel, had to be developed with the use of hypothetical values for the rapid prototype model. The next version of the model will focus on the development of a more detailed potential value submodel. However, the process of developing a prototype provided the following insights:

- The use of a decision-rule resulted in an overall higher conservation value (V_{tot}) when compared to a random management approach to allocating effort (i.e., essentially the current approach);

- The proportion of projects assigned to the long-term bin depends only on handling time ($H_{s,i}$, $H_{s,f}$, $H_{l,i}$, $H_{l,f}$), the number of projects (N_i, N_f), and total available staff time (K) and not on the potential value of a project.; and

- Optimal handling time may be dependent on the law of diminishing returns, such that, as $H_{l,i}$, $H_{l,f}$ increase past some threshold, the total combined value may decline.

Further development required
Intentional simplification of the potential value of a Project points to the importance of developing an approach for estimating potential value (i.e., a potential value submodel). In addition, several other model inputs were approximated, and need to be developed further. Thus, the next steps involve generating estimates for several important model parameters in addition to the potential value submodel.

Estimates of needed inputs will be derived as follows:

- Input 1 – the percent of a Project's potential value as a function of handling time. These functions (one for formal, on for informal consultations) will be developed through expert elicitation methods, where experts are staff biologists in the WWFWO. The expert elicitation process will involve having experts critique candidate functions developed by the authors.

- Input 2 – the total number of informal and formal Projects arriving in 135 days. This can be calculated by examining Project arrival statistics in past, randomly selected, 135-day periods and calculating averages.

- Input 3 – the universe of possible Projects, in terms of potential value, will be calculated by applying the potential value model to a random sample of past Projects.

- Input 4 – while we included handling time in the manipulable parameters, we imagine that minimum handling times (i.e., handling times for short Projects, $H_{s,i}$ and $H_{s,f}$ will not be highly manipulable. We will use expert elicitation methods to estimate these parameters. Again, the expert elicitation process will involve having experts critique candidate handling time parameters developed by the authors.

- The potential value submodel – first, the authors will identify parameters that could influence potential value (e.g., the overall risk to the species in the affected area, the scale of the Project, etc.). Simultaneously, experts will be asked to identify the potential value of a sample of projects based on a description of the concept supplied by the authors. Then, the identified parameters will be used as independent parameters, and the potential value rankings as dependent parameters, in a model selection exercise. Once a candidate model is developed, this model will be critiqued by the experts in an expert elicitation process – additional independent parameters may be identified, as needed, and a refined potential value submodel will be finalized.

It will be necessary to assess the overall model performance after the initial field testing. In addition, we expect that model input parameters may be adjusted on a regular basis to reflect changes in the number of full time equivalent (FTEs) employees or other conditions.

Recommendations

We recommend that the decision structure described here be used to develop a decision rule for allocating incoming Section 7 consultations to long-term and short-term bins. We assume that by maximizing the value of Section 7 consultations, we will achieve the greatest conservation value for the species. Expert elicitation processes and data analyses to provide for the information needs identified above should be conducted in the near future so that this decision framework can be used in initial field-testing during FY 2008.

Literature Cited

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U.S. Fish and Wildlife Service. 1999. Determination of Threatened Status for Bull Trout in the Coterminous United States; Final Rule. 50 CFR Part 17, Vol. 64: No.210, November 1, 1999.

Figures

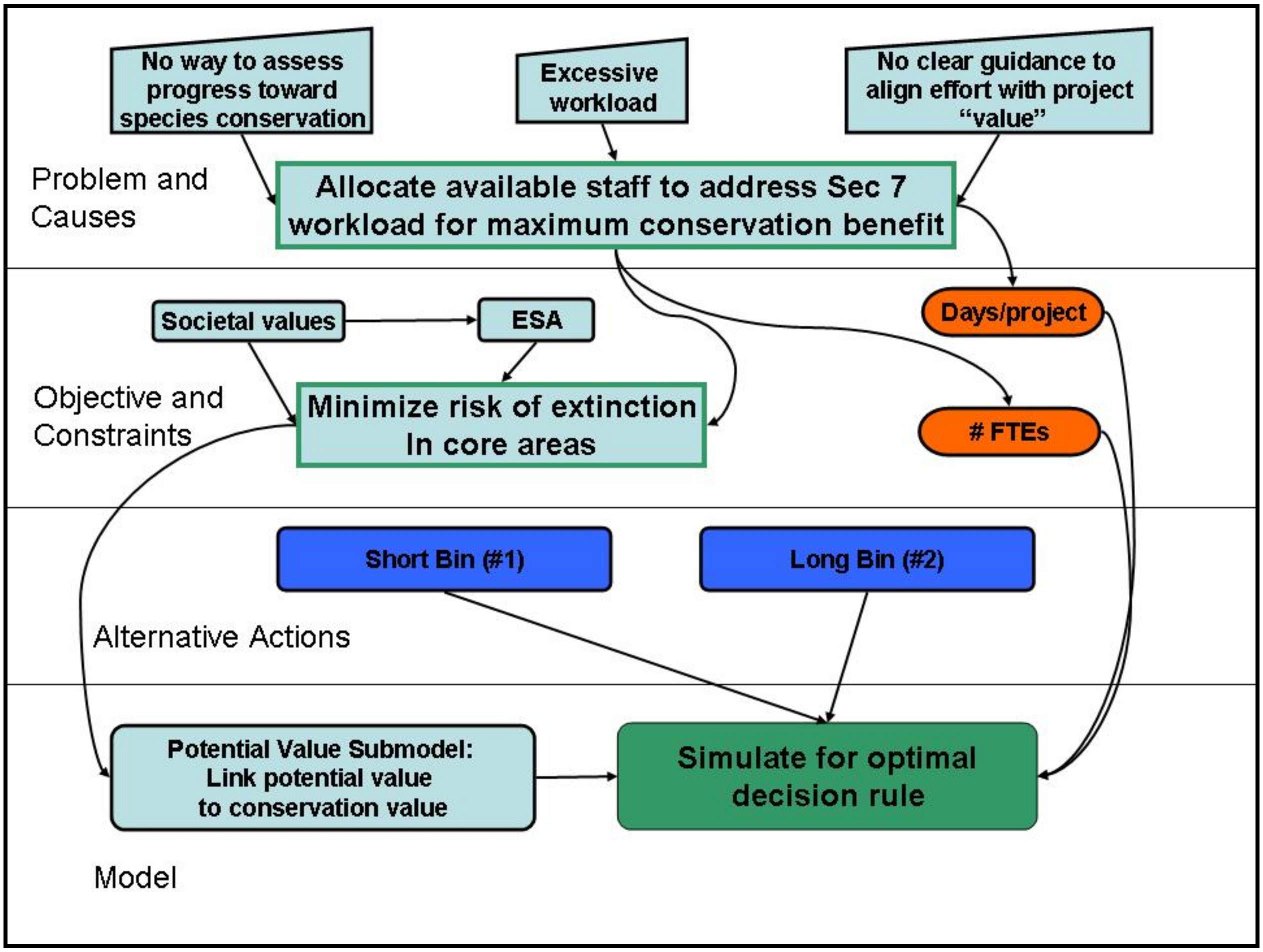

Figure 1. Overall Structure of the Section 7 Workload Allocation Decision Analysis.

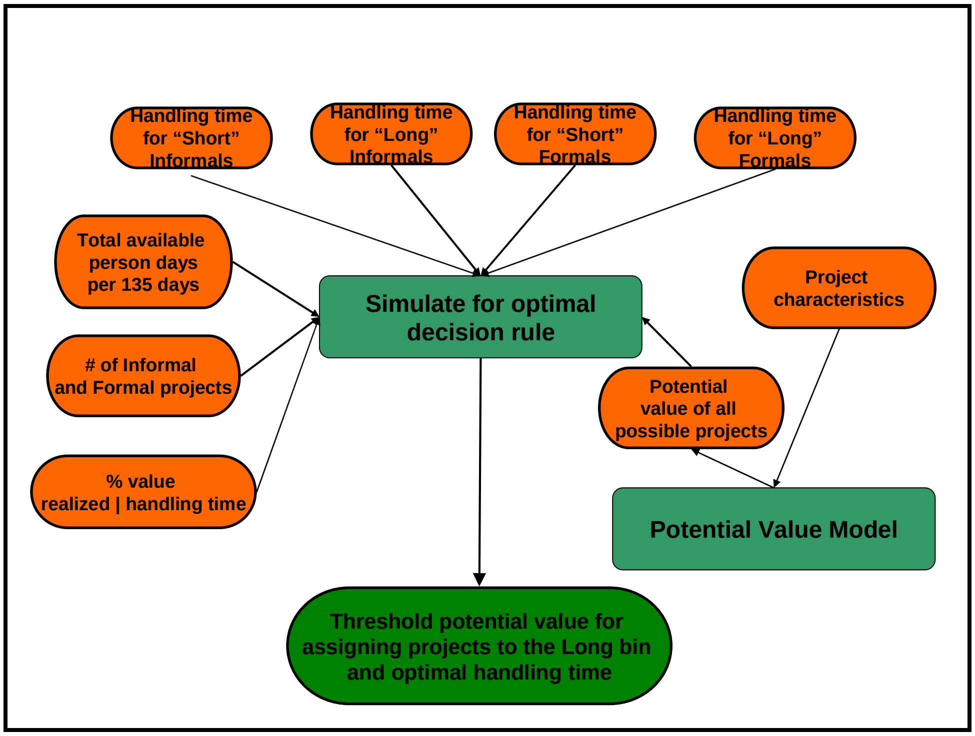

Figure 2. Schematic diagram of the predictive model.

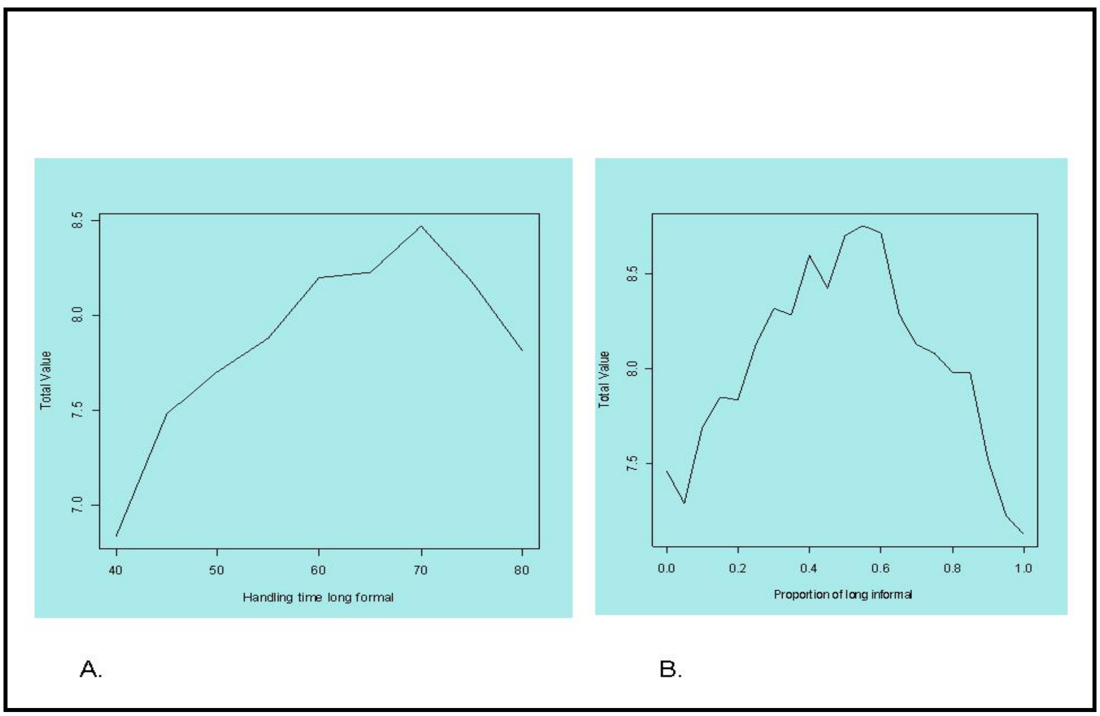

Figure 3. Examples of results for the cumulative value (V_{tot}) as a function of handling time for formal consultations (A) and the proportion of formal|informal consultations in the long bin (1,000 runs).