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ARTICLE

An Expert Panel Approach to Assessing Potential Effects of Bull Trout Reintroduction on Federally Listed Salmonids in the Clackamas River, Oregon

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Abstract
The bull trout *Salvelinus confluentus* is an apex predator in native fish communities in the western USA and is listed as threatened under the U.S. Endangered Species Act (ESA). Restoration of this species has raised concerns over its potential predatory impacts on native fish fauna. We held a five-person expert panel to help determine potential impacts of reintroducing bull trout into the Clackamas River, northwest Oregon, on the viability of four anadromous salmonid populations that are listed as threatened under the ESA: spring and fall Chinook salmon *Oncorhynchus tshawytscha*, coho salmon *O. kisutch*, and winter steelhead *O. mykiss*. The panel session was rigorously structured and used a modified Delphi process with structured expert elicitation, disclosure, discussion, and brainstorming. Each panelist distributed 100 score points among seven categories of potential bull trout impact (from no impact to very high impact) on extinction probabilities for the anadromous salmonids. Results were provided by individual panelists rather than as a group consensus and were summarized as means and variations in scores to express the panelists' individual uncertainty, variability among the panelists, and expected differences among the affected salmonids. Score results suggested that panelists viewed the potential impact of bull trout as very low or moderately low for spring Chinook salmon, coho salmon, and winter steelhead and mostly none to very low for fall Chinook salmon. Panelists also provided 19 possible monitoring activities and 21 possible management actions for assessing potential impacts and taking remedial action if bull trout are found to have unacceptable adverse effects. Results of the panel were used by the U.S. Fish and Wildlife Service to help craft and execute a plan to reintroduce bull trout into the Clackamas River system under the ESA. This rigorous expert panel process can be used for a wide range of evaluations in situations where empirical data are sparse or ecological interactions are too complex for explicit analytic solution.

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Conflicts between federally protected species are increasingly common due in part to the rising number of species listings under statutes such as the U.S. Endangered Species Act (ESA; Roemer and Wayne 2003) and species-specific recovery actions that may compromise one species' recovery for another. In the U.S. Pacific Northwest, recent examples include predation on ESA-listed anadromous salmonids in the Columbia River by California sea lions *Zalophus californianus* (Fryer 1998), which are protected under the Marine Mammal Protection Act, and by Caspian terns *Hydroprogne caspia* and other waterbirds, which are protected by the Migratory Bird Treaty Act (Roby et al. 2003; Wiese et al. 2008). Conflicts between native and nonnative aquatic species are even more common; in the case of freshwater fishes, such conflicts often pit the conservation of protected species against that of nonnative fishes deemed to be of higher value by sport anglers (Clarkson et al. 2005). Managers that are faced with policy decisions regarding the management of species conflicts have limited tools to adequately address scenarios characterized by a lack of empirical information and by uncertainty, often resulting in inaction or actions that may be overly precautionary in nature (Prato 2005; Gregory and Long 2009). In this paper, we describe one such tool—an expert panel process—that was used to address the concerns and uncertainty associated with the reintroduction of threatened bull trout *Salvelinus confluentus* into the Clackamas River, Oregon, particularly with regard to the potential impacts on several species of threatened anadromous salmonids.

Bull Trout Status

Bull trout are found in coastal and inland systems of western North America. During the last century, populations have declined or become locally extirpated due to habitat degradation, blockage of stream passage, and exploitation, in combination with other stressors such as hybridization and competition with other fish species (Rieman and McIntyre 1993). In 1999, the U.S. Fish and Wildlife Service (USFWS) listed the bull trout as threatened throughout its range in the lower 48 states. As a step to recovering bull trout populations, the USFWS and the Oregon Department of Fish and Wildlife proposed the reintroduction of bull trout into the Clackamas River, northwest Oregon, where they were last observed in 1963. Using an expert-judgment scoring approach, Dunham et al. (2011) determined that the Clackamas River system is capable of supporting a self-sustaining population of bull trout, and evaluated the potential effects on donor populations.

Whereas reestablishment of bull trout into the Clackamas River would represent a major success for the species' recovery, concerns have also arisen about the possible impact of bull trout on four other ESA-listed threatened anadromous salmonid populations occurring in the same river system: spring Chinook salmon *Oncorhynchus tshawytscha*, fall Chinook salmon, coho salmon *O. kisutch*, and winter steelhead *O. mykiss* (anadromous rainbow trout). These salmonids historically existed in sympatry in the Clackamas River and currently co-occur in many watersheds in the Pacific Northwest. However, there is concern that the Clackamas River salmonid populations are much reduced from historic levels and may not be able to recover in the stressors of reintroduced bull trout and anthropogenic changes in the basin—namely the development of the hydropower system, which increases predation risk to salmonid juveniles that concentrate in project reservoirs and fish bypass systems. There are no available field studies that describe the effects of bull trout reintroduction on the viability of this specific assemblage of anadromous salmonids, although bull trout studies elsewhere in Oregon have shown that bull trout can be particularly voracious piscivores (Beauchamp and Van Tassell 2001). Thus, we organized an expert panel workshop to provide management agencies with rigorous professional judgment regarding the possible impacts on these salmon and steelhead populations, and advice on areas of key uncertainty, potential monitoring activities, and possible management actions in the face of adverse impacts.

Expert Knowledge and Expert Panels

Expert judgment often has been used for interpreting difficult or otherwise intractable problems in natural resource modeling, management, planning, and impact assessment. Some examples include evaluation of a habitat model for elk *Cervus canadensis* (Holthausen et al. 1994), development of general faunal distribution models (Pearce et al. 2001), modeling of the potential occurrence of rare species (Marcot 2006), and evaluation of adaptive management options (Failing et al. 2004). Expert knowledge also has been used to develop computer programs for advising on species and habitat conservation. For example, Converse et al. (2011) elicited expert judgments to optimize allocation of resources for endangered species consultation; Cheung et al. (2005) incorporated expert knowledge in an expert system to predict extinction probabilities of marine fishes; Crist et al. (2000) used an expert systems tool to evaluate effects of land use on biodiversity; and O'Keefe et al. (1987) developed an expert system approach for evaluating the conservation status of rivers.

One critical step in all of these examples is the solicitation and representation of expert knowledge in a reliable, rigorous, and unbiased fashion, especially from multiple experts. One major approach to this involves conducting expert panels. Expert panels have been used extensively by natural resource and land management agencies for a wide variety of problems. Examples include evaluating potential effects on species viability from an array of forest and land management planning options (FEMAT 1993; Lehmkuhl et al. 1997), determining the appropriate conservation status for a wide variety of potentially at-risk species under the Northwest Forest Plan (Marcot et al. 2006), and developing a management plan for a national forest in Alaska (Shaw 1999).

We chose an expert panel format and refined paneling procedures to help ensure rigor and transparency in capturing expert judgment on the difficult assessment problems of potential bull trout reintroduction. The objectives of the Bull Trout Expert

Panel workshop were to (1) provide a scientific assessment of potential impacts to existing salmon and steelhead populations from bull trout reintroduction into the Clackamas River and (2) outline monitoring and management strategies that could reduce uncertainty and risk after a possible bull trout reintroduction.

The purpose of this paper is to present the results of the Bull Trout Expert Panel workshop and, more broadly, to explain the specific structure and methods of our expert paneling approach, which could be adapted for other projects that require rigorous polling of expert judgment. We also provide insights on application and use of the expert panel results for developing the reintroduction project and the associated interagency administrative documentation.

Study Site

Located in northwest Oregon, the Clackamas River is a tributary to the Willamette River, which in turn flows north into the Columbia River (Figure 1). Within the Clackamas River system, the area that has been deemed suitable for bull trout reintroduction includes the main stem, the upper Clackamas River, and four tributary watersheds (USFWS 2011a). Bull trout extirpation from the Clackamas River was probably caused by harvest, habitat degradation, and migration barriers presented by dams (USFWS 2011a). All of these stressors have likely been greatly reduced or eliminated, leaving open an opportunity for the reintroduction of bull trout.

METHODS

Overall Expert Panel Approach

We structured the Bull Trout Expert Panel as a modified Delphi paneling process (e.g., Vose 1996). The Delphi paneling process entails a structured querying, disclosure, discussion, and revisiting of expert judgment on some focused problem of interest (e.g., MacMillan and Marshall 2006; Hsu and Sandford 2007). In addition to some of the above-cited expert paneling projects, the Delphi process has been used in assessing life stage ratios of Devils Hole pupfish *Cyprinodon diabolis* (Barrett 2009), assessing the status of wildlife species (Clark et al. 2006), prioritizing urban improvement strategies in India (Gokhale 2001), developing habitat suitability index curves (Crance 1987), and in other ecological projects.

In the standard Delphi process, the panel of experts must eventually reach a consensus (e.g., Weisberg et al. 2008). The modification used here (and in many previous expert panels) omits the consensus step because we desired to obtain individual experts' input, in part to discover their range of judgment and interpretation. A consensus approach would not provide this, as it might entail potential bias from group-think, would mask any expression of uncertainty among panelists, and may exclude outlier opinions (i.e., those that differ from the majority views), thus masking important individual knowledge and interpretations. We developed the specific paneling methods presented here to help ensure scientific credibility and rigor in capturing individual and collective expert judgment.

Specific Expert Panel Steps for Scoring Bull Trout Impact

The Bull Trout Expert Panel consisted of five members chosen by us and by agency managers; panelists were selected on the basis of their individual expertise in bull trout and salmonid biology and ecology. The specific modified Delphi method we used with the Bull Trout Expert Panel for determining potential impacts of bull trout on the four listed salmon and steelhead populations entailed the seven steps described below.

Step 1: premeeting material.—Prior to the workshop, each expert panelist was sent a letter of explanation along with premeeting reading material. The purpose was to ensure that the panelists studied the same background information and understood the overall purpose of the panel, the nature of the questions to be asked of them, and the general paneling methods to be used in the meeting. Specifically, the premeeting reading material included a statement of the goal, objectives, and expected products of the expert panel workshop; a detailed workshop agenda; a set of general questions and answers about the project; and several key technical publications on bull trout and salmonid ecology and native fish reintroduction (e.g., Beauchamp and Van Tassell 2001).

Step 2: structured presentations.—At the workshop meeting, after initial introductions of participants and a review of the agenda by the facilitators, a series of focused presentations was provided by various experts on key topics pertaining to the Clackamas River, including its hydroelectric dam management structure and the biology, ecology, and status of the salmon and steelhead populations of interest. As with the premeeting reading material, the purpose of these presentations was to ensure that all panelists were brought to a common level of understanding (i.e., parity) of these key topics so that in answering the questions posed, they would all be equally informed from the same background information (Zohar and Rosenschein 2008). The presentations included a brief description of the overall project to clarify the context, role, and expected use of the panel results (Figure 2) and a description of a working Bayesian network model of potential food web and species interaction dynamics (see Figure A.1.1 in Appendix 1). The network model depicted relationships among bull trout, anadromous salmonids, and other predator and prey species in the river system and was presented to help prompt panelists' thinking and discussion of trophic and food web dynamics, including identification of key areas of uncertainty.

Step 3: review of worksheet and terms.—Next, the format of the scoring worksheet and related key terms and definitions (Appendix 2) were presented and reviewed so that all panelists would understand and interpret the intent and terminology the same way.

The overall purpose of steps 1–3 was to reduce or eliminate bias from variation in the panelists' understanding of the ecological and environmental context and terminology and of

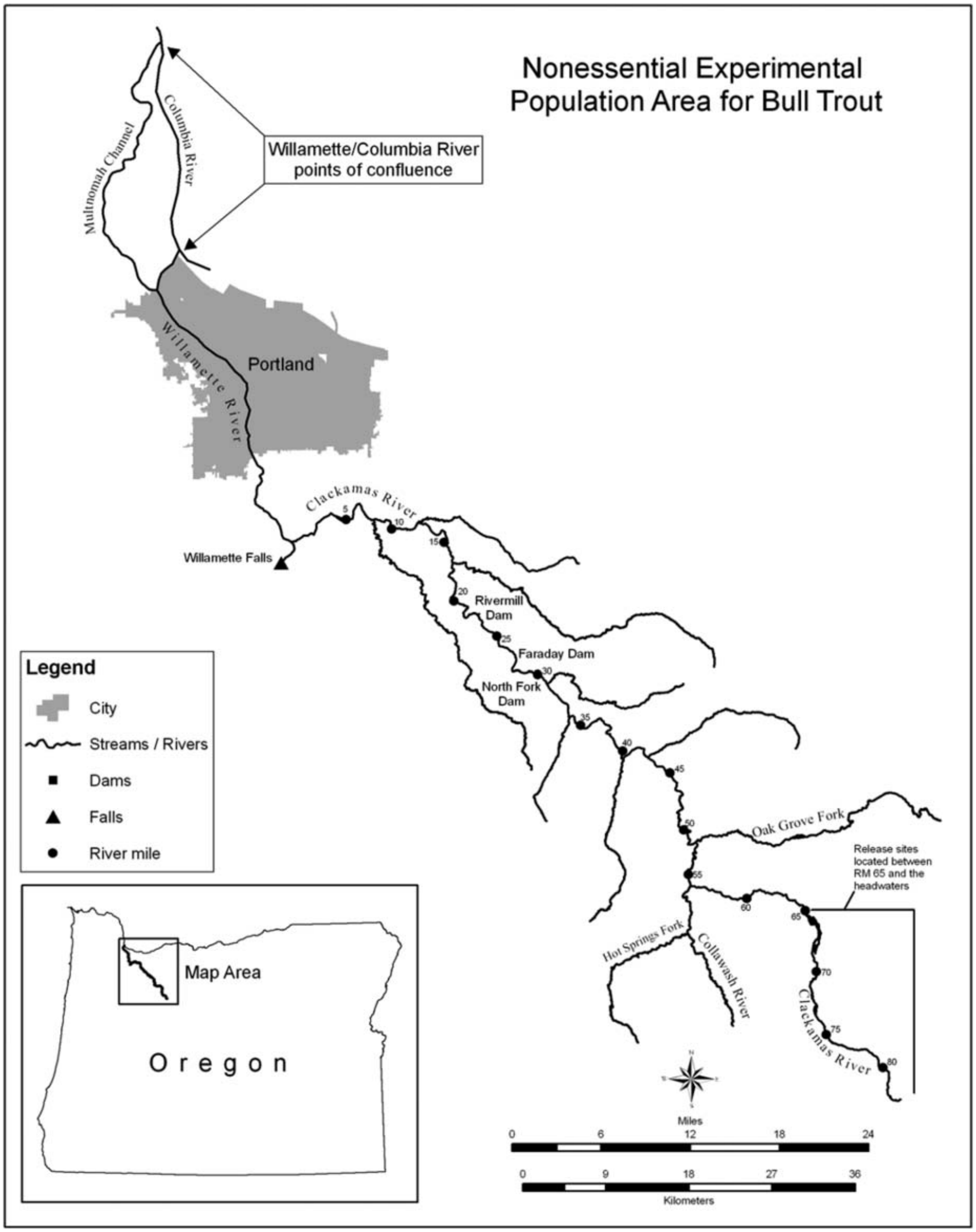

FIGURE 1. Location of the Clackamas River, northwest Oregon (source: U.S. Fish and Wildlife Service).

the scoring methodology. This ensured that the variation among panelists' scores would be principally contributed by their individual ecological interpretations and expertise rather than by differences in understanding of the paneling methods, terms, and concepts.

Step 4: initial scoring.—The panelists were asked to provide initial scores expressing their judgment about the potential degree of impact of bull trout on the salmon and steelhead populations (Appendix 2). Scoring was done by having each panelist allocate 100 points among one or more of the seven possible

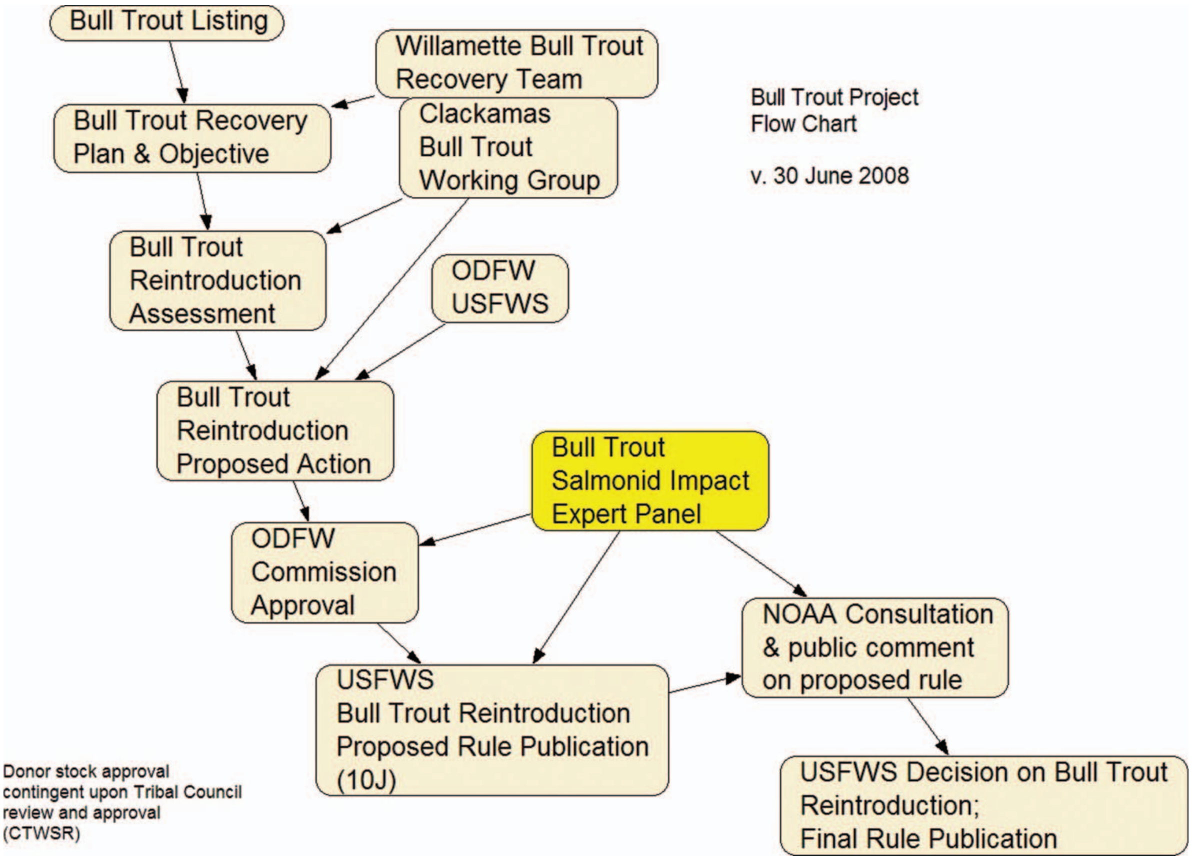

FIGURE 2. Flowchart presented to the Bull Trout Expert Panel, displaying the context and intended flow of their technical and scientific information (NOAA = National Oceanic and Atmospheric Administration; ODFW = Oregon Department of Fish and Wildlife; USFWS = U.S. Fish and Wildlife Service; CTWSR = Confederated Tribes of the Warm Springs Reservation). [Figure available in color online.]

impact outcome categories (ranging from none to very high impact; see Appendix 2) for each of the four salmonid populations; specifically, panelists assessed the degree of impact that bull trout would have on the extinction probability of each salmonid population over 100 years from the start of the reintroduction project. The 100-year time frame was chosen as a reasonable duration for evaluating the viability response of the salmonid populations, as this time frame is commonly used in analyses of population viability and recovery (e.g., McCarthy et al. 2003; Dunham et al. 2011; Wenger et al. 2011). Panelists were instructed to score only that portion of salmon and steelhead population extinction probabilities that would be caused by bull trout; thus, they were not asked to score overall extinction probabilities. In this way, the relative impact contributed specifically by bull trout would be represented.

The allocation of 100 points expressed the uncertainty of outcomes and displayed potential differences in outcome among the salmon and steelhead populations. The scoring was done explicitly on the assumption that bull trout reintroduction objectives are met: the objective as defined by the USFWS prior to the workshop was that at least 200–500 adult bull trout would be present in the Clackamas River by 2030. This first round of scoring (i.e., round 1 in Appendix 2) was done individually, in silence, without interaction or discussion among panelists or between panelists and the facilitators.

Step 5: structured disclosure and discussion.—One by one, each panelist was prompted by the facilitators to disclose the scoring they applied to each salmonid population and to explain their rationale. After this structured disclosure, panelists were allowed to engage in a guided discussion on their rationale, including how they considered and weighed various factors in their scores. The discussion was followed by allowing the panelists to ask questions of others attending the workshop (i.e., managers and other experts in the room). The overall purpose of structured disclosure and guided discussion was to allow panelists to learn from each other, thereby bringing out their best efforts and broadest judgments of all information and considerations. Guided discussions generally conformed to the semidirective interview approach (Huntington 1998) whereby discussions were allowed to address broadly identified topics without unduly constraining conversations but while averting digressions.

Step 6: final scoring.—The panelists then engaged in a second round of silent scoring (round 2 in Appendix 2), which constituted their final expert judgment on the degree of impact. They were given the opportunity to retain or change any of their initial scores based on what they may have learned from the structured disclosure and guided discussion. The panelists were also directed to denote, on their score sheets, the rationale for why they scored as they did—that is, the main environmental, biological, or ecological factors they considered and weighed in their scoring decisions. This provided explicit documentation and explanation of their judgments.

Step 7: review of results.—Results of the final scores were presented back to the panelists for their information. At this stage, the panelists were also given the opportunity to provide any further clarification or explanation of their scoring, but they were not allowed to change their final scores based on the knowledge of other panelists' scores.

The expert panel workshop portion (steps 2–7) was guided by two facilitators (D. Shively and B. G. Marcot) whose roles were to (1) ensure rigorous adherence to a scientific focus by the panelists, (2) ensure adherence to the paneling procedures and workshop schedule, and (3) record and present the results of the panelists' point scores. During the workshop, panelists' verbal comments and discussions were also recorded by a scribe. In addition, the workshop was attended by invited observers (selected managers and fish biologists).

Identification of Potential Monitoring Activities

By use of a structured brainstorming paneling procedure, the panelists were then quizzed to provide ideas on potential monitoring activities and metrics, again under the presumption that the bull trout reintroduction program would go forward. The structured brainstorming procedure entailed (1) asking each panelist in turn to suggest his or her "top-two" monitoring topics and metrics without repeating or critiquing what a previous panelist might have suggested and (2) rotating through the panel as many times as necessary to provide new ideas. Panelists were allowed to "pass" after their first suggestions if they felt that any new ideas had already been added to the list, which was presented cumulatively on screen. The panelists then engaged in an open discussion to refine their list of potential monitoring activities, specifically to clarify, combine, or split some suggestions but without criticizing others' suggestions. They also provided information on each monitoring activity's overall objective, theme, and duration or frequency.

The panelists were given printouts of the final list of monitoring activities and were asked to score each activity on a three-class priority scale (1 = essential to conduct; 2 = important but not necessarily essential; and 3 = worthwhile but of lower importance). They provided these scores individually in silence (just as they had done during the impact scoring in the previous exercise). The priority scores were entered by the facilitator into a previously prepared spreadsheet; means of the scores were calculated; and the monitoring activities were sorted by increasing mean score (decreasing priority). The resulting list was presented to the panel for final discussion and refinement.

Identification of Potential Management Response Activities

The expert panelists were next asked to provide ideas on potential management response activities that could be considered in the event that the bull trout were found to exert unacceptable adverse effects on the salmon and steelhead populations. The panelists provided ideas on such potential management activities again in a structured brainstorming process as described above. The panelists also specified the type and degree of adverse impact and the overall management theme to which each potential management activity pertained. The panel then engaged in a guided discussion to revise and refine their list of potential management activities (i.e., to exclude, combine, or split some suggestions). The final list was sorted based on management theme and was presented to the panel for final discussion and refinement.

Additional Panel Activities

The workshop agenda also provided, at the end of the sessions, an opportunity for each panelist to offer any comments of interpretation, caution, recommendation, or other statements and to interact more freely with all observers in the room. The observers were then given the opportunity to ask any final questions of the panelists and to provide comments on the workshop content and procedures. The panelists were also given an opportunity to review the content of the scribe's summary of each of their main comments to ensure that their statements were correctly captured.

Retention of Anonymity

A major part of documentation included allowing the panelists' individual input to remain anonymous on their score sheets, in their suggestions for monitoring and management activities, and in their structured disclosure and guided discussion periods. The five panelists were randomly assigned code letters A–E, which appeared on their name cards; only the code letters were used on their score sheets (Appendix 2) and in the transcriptions of their discussions. In this way, the panelists felt greater freedom to provide potentially controversial ideas than would have been possible if their scoring and statements had been individually attributed.

Focus on Science

One potential problem in using expert judgment is that of motivational bias (Morgan and Henrion 1990), wherein the expert may unconsciously (or deliberately) slant his or her scores or statements so as to adhere to an underlying mistrust of institutions or agencies. For example, an expert might be more apt to score population viability ratings lower if they did not trust a management agency to otherwise maintain higher viability levels and thus intended to force the agency to deal with viability issues. To help avoid such bias in the Bull Trout Expert Panel workshop, the panelists were reminded by the facilitators to (1) adhere to high standards of addressing the questions and issues strictly from technical and scientific perspectives, (2) avoid second-guessing the potential agency use of their information, and (3) be aware that their role was not to provide or recommend management decisions per se. Furthermore, parsing out the various technical and scientific questions in accordance with the above seven steps—and especially in the use of structured disclosure and guided discussion methods—helped to reduce or eliminate individual motivational bias.

RESULTS

Final Scoring of Bull Trout Impacts on Anadromous Salmonids

Scores averaged across all five expert panelists (from round 2; step 6 above) suggested that bull trout impact on the extinction probabilities of salmon and steelhead populations in the Clackamas River was generally rated as moderately low, very low, or even none (Figure 3). The mean scores also suggested that the panelists in general considered bull trout impacts on extinction probability to be lower for fall Chinook salmon than for the other three salmonid populations. However, some nonzero scores were suggested even at the moderately high and moderate degrees of impact for three of the populations.

It is instructive to view the individual panelists' degrees of uncertainty and variation among the four salmonid populations, across the various outcome categories, and among the panelists (Figure 4). These results suggested that (1) not surprisingly, each panelist expressed some degree of uncertainty over the possible impact of bull trout on extinction probability of each anadromous salmonid population, as denoted by the spread of scores across multiple outcomes; (2) panelists differed in their degree of uncertainty among salmonid populations (e.g., for three of the four populations, panelist C [Figure 4] leaned more to the "none" impact outcome than did the other panelists); and (3) although the panelists differed in their specific score values, they fully concurred by not scoring bull trout impact on any population as very high or high, and modes were mostly in the categories of "moderately low" to "none."

Possible Monitoring Activities

The expert panel identified a collective set of 19 possible monitoring activities, without regard to cost, that could follow bull trout reintroduction (see Table A.3.1 in Appendix 3). The activities variously pertained to general objectives for monitoring the overall aquatic environment, predator (bull trout) status, prey (anadromous salmonid population) status, and trophic interactions; such activities would address various aspects of predator age and growth, angler catch of bull trout, bull trout

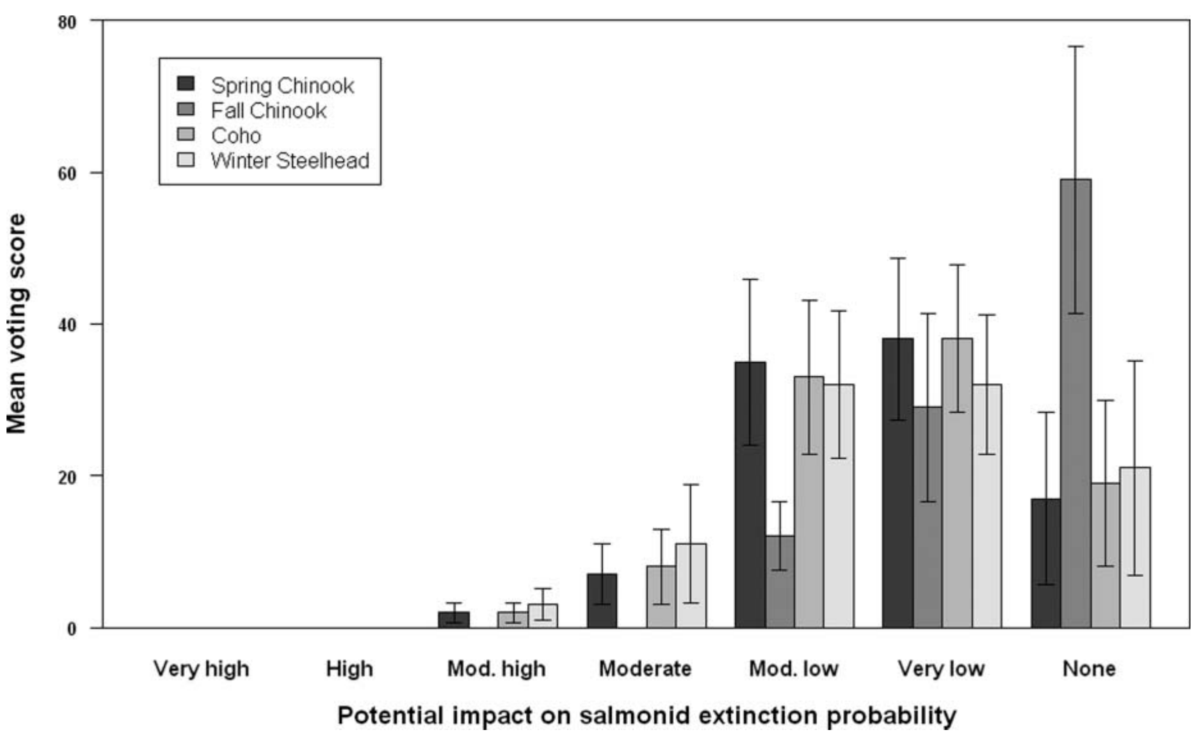

FIGURE 3. Mean and range of scores assigned by five expert panelists in assessing the potential impact of bull trout on extinction probability for spring Chinook salmon, fall Chinook salmon, coho salmon, and winter steelhead populations in the Clackamas River system after 100 years of bull trout reintroduction (Mod. = moderately).

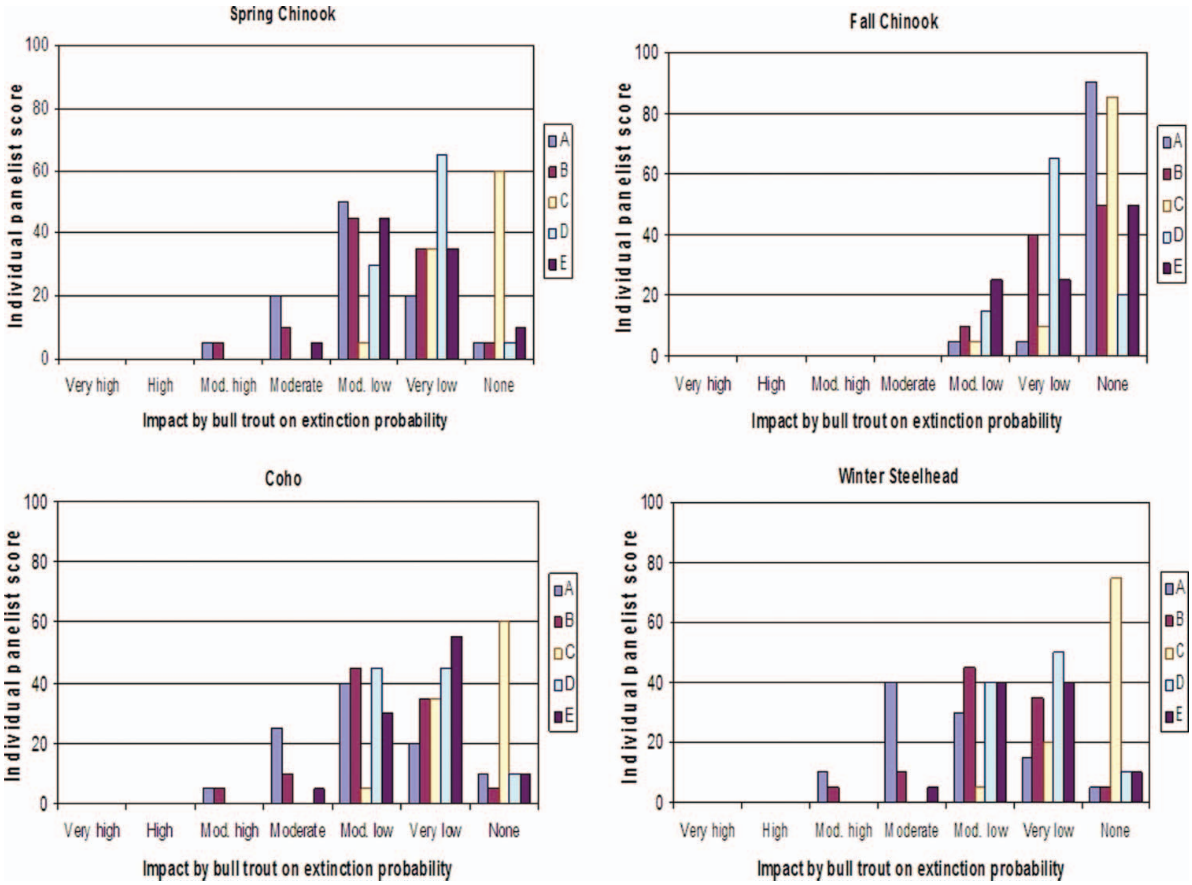

FIGURE 4. Individual scores assigned by five expert panelists (codes A–E) in assessing the potential impact of bull trout on extinction probability for spring Chinook salmon, fall Chinook salmon, coho salmon, and winter steelhead populations in the Clackamas River system after 100 years of bull trout reintroduction (Mod. = moderately). [Figure available in color online.]

movement, bull trout size structure, food web and predator consumption dynamics, predator and prey demography, predator and prey habitat selection, reservoir use by prey, predator and prey abundance and productivity, reservoir limnology, and other topics. The top activities ranked as essential to conduct by at least four of the five panelists pertained to the monitoring of

- bull trout reproduction and recruitment (e.g., spawning surveys, age, and size; annual);
- rates of food consumption by bull trout (baseline and periodic);
- size structure of bull trout in reservoir and river environments (periodic);
- abundance, size, and age of smolts and adults at North Fork Dam for each listed salmonid population (annual);
- abundance and size structure of juveniles and adults above North Fork Reservoir for each listed salmonid population (annual); and
- diet and stable isotopes of fish and key invertebrates, for use in identifying major predators (fish and others) of salmon, steelhead, and other fishes (i.e., to determine the food web; baseline and periodic).

Possible Management Response Activities

The expert panelists collectively identified 21 possible management activities that could be pursued if bull trout are found to have unacceptable impacts on the four salmon and steelhead populations (see Table A.4.1 in Appendix 4). The management activities were not prioritized because the type and degree of bull trout impact might vary considerably. Instead, the management activities were categorized by type and degree of impact and by overall management theme, as noted above.

As examples, if the degree of impact was high to very high, then possible management activities pertaining to predator (bull trout) control were identified as complete removal of the bull trout population or maintenance of the bull trout population at a specified lower level. If the type of impact was bull trout predation on juvenile fish in tributaries, then one possible management activity pertaining to prey (salmon and steelhead) management was identified as the addition of refuge cover in tributary habitat and other habitat enhancements to reduce predation levels.

DISCUSSION AND MANAGEMENT OUTCOME

Scoring Represents Outcome Probabilities and Uncertainties

The panelists' scores of potential impact by bull trout on salmon and steelhead in the Clackamas River are essentially statements of the certainty of outcomes and can be interpreted as how probable a given impact of bull trout might be. Presenting scores averaged across panelists (Figure 3) also provides the option to combine their scores across outcome categories. For example, if managers are concerned about any moderate or greater effects of bull trout reintroduction, they may want to know the scores in the top-five outcome categories (i.e., moderate to very high effects). In this case, the overall mean scores for spring Chinook salmon, fall Chinook salmon, coho salmon, and winter steelhead in the top-five outcome categories were 9, 0, 10, and 14, respectively, which suggests a low overall impact but perhaps identifies coho salmon as the most vulnerable population. However, to avoid selecting outcomes that match prior biases, it is important to identify such combinations of outcome categories before the final score results are presented.

The allocation of scores represents the degree of panelists' individual and collective uncertainty about the extinction probability classes. Comparing how individual panelists divided their scores among outcome categories for a given salmonid population (Figure 4) represents the degree of difference in uncertainty as well as individual differences in scoring among panelists. For example, relative to most of the other panelists, panelist C tended to assign a higher score to the "none" category for most species, and this panelist never provided nonzero scores for more than three outcome categories. Panelists A and B, on the other hand, provided nonzero scores for five of the outcome categories on most species and thereby spread their scores more evenly than did the other panelists, thus representing their greater uncertainty of outcomes. Such differences in judgment among experts are to be expected when projecting future outcomes, and in this case agreement was high among panelists in concluding that the influence of bull trout was likely to be minor.

Individual scoring also provided for identifying outlier positions that might be based on unique and useful insights. For example, panelist A scored 40 points on the moderate outcome for winter steelhead, which was a far higher score than that given by other panelists. The panel process required panelists to also record the basis for their scores; panelist A's rationale included some considerations that had not been suggested by other panelists, such as (1) relative availability of juvenile fish compared to forage fish among seasons and between habitats and (2) temporal patterns in thermal regimes of both streams and reservoirs, which might have put some salmonids at greater risk.

One can calculate measures of numerical dispersion to explore the degree of agreement among panelists for given outcome categories by species. A useful measure is the coefficient of variation (SD/mean), which normalizes for differences in score levels. Among the four salmonid populations, the coefficients of variation were lowest for very low and moderately low outcomes (ranging up to 0.84) and were higher for the remaining outcomes (ranging up to 1.52), suggesting greater concurrence among panelists for the former outcome sets.

Overall, use of the modified Delphi paneling process to prompt for equal, individual opinions provided greater openness of discussion and equality of input from all panelists than would have been obtained by requiring a consensus among the panelists. This approach also provided managers with a better understanding of the degree of agreement or uncertainty among the experts, including outliers, which in a risk management framework can be valuable information for use in making recovery decisions and judging the need for monitoring.

Value of Multiple Scoring Rounds

Multiple scoring rounds provided for the sharing of knowledge and insights among panelists and the opportunity for panelists to further query other experts and presenters (Hsu and Sandford 2007). Two scoring rounds were provided, although additional rounds could be allowed if further discussion is desired to reduce uncertainty or to ensure parity of knowledge among panelists; in the present case, the use of additional rounds was unnecessary.

One major change between scoring rounds 1 and 2—actually suggested by the panelists—was to expand the outcome categories from an initial set of five (none, low, moderate, high, and very high) to the final set of seven (Figure 3). The panelists wanted the opportunity to score outcomes on a finer scale across the range of possible outcomes. The effect of this change was most dramatic in scores of the initial "high" outcome category. For three of the salmonid populations, two of the five panelists initially provided some nonzero scores for the "high" category, thus indicating potentially dire outcomes albeit at low probability levels. Revamping the outcome categories to a set of seven allowed those panelists to better express their judgment by providing those scores in the "moderately high" category, thereby reducing the implication of possible dire results.

Other than this, the two scoring rounds were mostly similar in that the panelists weighted most of their scores in the "none" to "moderately low" categories. However, providing for multiple scoring rounds and guided discussions could result in major changes in some panelists' judgments (e.g., Marcot et al. 2006), although it is best to not conduct additional rounds when outcomes seem to have stabilized (Armstrong 2001).

Utility of the Impact Scoring Approach

Although commonly used (e.g., Steele and Shackleton 2010), point scoring is only one way of eliciting expert knowledge. More specifically, other approaches to codifying and modeling expert knowledge of bull trout populations have been developed, although not necessarily used in a panel workshop setting. For example, Lee (2000) presented a Bayesian network model to assess the potential impacts of land use on bull trout by combining cumulative effects of factors that might adversely affect bull trout population persistence.

Dunham et al. (2011) used a slightly different scoring approach than ours to evaluate potential of the recipient habitat for bull trout reintroduction. They scored reintroduction potential on a scale of -1 to $+1$, representing a gradient of responses (i.e., "no" to "yes") to specific questions regarding habitat and population conditions, with a score of 0 representing complete uncertainty. Their scoring approximates a fuzzy logic approach to representing knowledge (e.g., Fukuda and Hiramatsu 2008; Janssen et al. 2010), which worked well for their purpose. In our approach, spreading the 100 score points across categories of bull trout potential impact was used to represent each expert's degree of uncertainty. We used points that tallied to 100 to approximate probabilities instead of fuzzy logic values (fuzzy scores are not probabilities) because our experience suggests that the experts who provide the scores and the managers who ultimately interpret the scores are readily able to conceive of potential alternative outcomes in terms of exclusive probabilities. A probability structure also was conducive to comparing degrees of potential extinction influence among populations and panelists.

Panelist Selection and Panel Size

In consultation with other specialists and managers, we developed the following criteria for inviting and selecting the expert panelists: the person must have sufficient knowledge of the subject area; they must have conducted empirical research on bull trout, or the four listed salmonids, or any combination thereof; and they must be able to work well in a team setting. Furthermore, we wanted the panel as a whole to represent adequate geographic coverage of the project area and to represent (as much as possible) a diversity of experience in the academic, agency, research, and management realms. We successfully met all criteria.

In our experience, panels of five to seven participants usually provide an adequate range of expertise given that the purpose of the panel is well defined and focused. Larger panels can prove unwieldy at best, can degrade into unfocused discussion, and can become dominated by individuals. Others have suggested that panels of 8–10 are desirable (Hodgetts 1977; Crance 1987) depending on the purpose of the panel, although there is no consensus or absolute rule on the ideal panel size. Also, we have found that use of an uneven number of panelists (ideally 5 or 7) avoids tendencies to form separate camps of opinions.

Use of Panel Results for Bull Trout Recovery

Since the Bull Trout Expert Panel was held, the USFWS considered the results along with other information; released a final environmental assessment; developed a biological assessment for consultation with the National Oceanic and Atmospheric Administration (NOAA) Fisheries (i.e., National Marine Fisheries Service) under Section 7 of the ESA; negotiated a robust research, monitoring, and evaluation plan; and published a federal regulation designating that bull trout be reintroduced into the Clackamas River system as a "nonessential experimental population" under the ESA (USFWS 2011a, 2011b, 2011c). In considering potential effects of the proposed reintroduction on the threatened salmon and steelhead populations under their jurisdiction, staff biologists with NOAA–Fisheries considered the results of the Bull Trout Expert Panel workshop in their analysis, which contributed to their determining that the proposal could go forward without jeopardizing the continued existence of the listed anadromous salmonid populations. Ultimately, the USFWS and other partnering agencies executed the first of what will be many transfers of bull trout by releasing 60 adult and 58 juvenile bull trout into the Clackamas River during late June 2011.

Results of our workshop therefore provided key rationale for expecting low impacts on salmon and steelhead but with enough expressed uncertainty as to warrant monitoring of the priority themes, as identified by the workshop panelists, in an adaptive management context. Many of the monitoring recommendations made in the workshop appear in the final research, monitoring, and evaluation plan, albeit sometimes modified to reflect logistics, improved understanding of the issues, and other concerns. In some respects, the positive outcome of the larger proposal shows not only that the USFWS engaged a rigorous evaluation process but also that the workshop successfully helped to identify and address major uncertainties, thereby facilitating and supporting the reintroduction decision process.

Results of our workshop, however, did not resolve major concerns from (1) Portland General Electric (PGE), as its Federal Energy Regulatory Commission license allowing generation of hydroelectric power would potentially be impacted by bull trout reintroduction; and (2) NOAA–Fisheries, which in its ESA Section 7 (species impact consultation) capacity would need to provide the formal judgment on the effect of bull trout on the salmon and steelhead populations. Although the USFWS had hoped to submit the workshop report as evidence that predation risks were likely to be acceptably low, the reality was still a healthy dose of skepticism and risk aversion by PGE and NOAA–Fisheries. This is not surprising, as the differing frames of reference among the USFWS (as project proponent), NOAA–Fisheries (via its role in the ESA Section 7 consultation process), and PGE (in its stance as a potentially affected Federal Energy Regulatory Commission licensee) would reasonably cause each party to weigh the workshop results with different interests, concerns, and degrees of risk aversion. However, the workshop results did serve to change the nature and scope of remaining uncertainty about risks from bull trout predation on salmon and steelhead, allaying much of the concern expressed by PGE and NOAA–Fisheries. Put another way, while the workshop results did not eliminate all concerns, it significantly reduced the scope and range of perceived risk such that careful negotiations and expanded monitoring commitments provided an acceptable basis for implementing the bull trout reintroduction project.

Although we view the workshop as successful, one area that warrants mention is the importance of developing and articulating questions for the panel that can also be readily understood by observers, project partners, stakeholders, and, most importantly, decision makers. It was critical to clearly state the overall objective of the bull trout reintroduction project (i.e., that at least 200–500 adult bull trout would be present in the Clackamas River by 2030). Within this context, we asked the panel to evaluate the potential degree of bull trout impact on extinction probabilities of the four salmon and steelhead populations over 100 years; this question seemed logical to us, whereas the terminology ultimately proved confusing to some others. In hindsight, we could have further explained the question during the workshop and in subsequent documentation, which would have alleviated unnecessary confusion and strengthened acceptance of and provided greater support for subsequent application of the results to project development.

Overall Value of the Expert Panel Approach

Our approach entailed four major expert paneling methods: (1) the modified Delphi expert panel approach, in which panel consensus was not elicited and individual input was retained anonymously so as to help illustrate the variation in judgment among experts; (2) the structured impact scoring approach; (3) the guided discussion approach using the semidirective interview method; and (4) the structured brainstorming paneling procedures. Collectively, these methods provided for efficient use of time and helped ensure equality and thoroughness of panelists' contributions.

However, we emphasize that surveying expert judgment, even in such a rigorously structured workshop, cannot and should not substitute for empirical studies. At best, results of expert paneling should provide a clear depiction of the state of knowledge on a focused topic.

On the other hand, although this particular panel met the objectives well, it is our experience that panels in general can be subject to biases and errors, including group-think, the force of dominant personalities, and the undermining of procedures and failure to produce results from obstinate participants. Such problems, however, are usually avoided by selecting panelists who can work well in team settings and who can adapt to new procedures and ideas, as was the case with the current panel. It was also most important to provide time in the agenda to allow each panelist as well as the observers to fully express any caveats and advice that were not solicited during the more formal proceedings. We suggest that our expert panel methods could be adapted for use in other species conservation and reintroduction issues for which specific empirical studies are few and synthesis of knowledge from multiple experts is desired.

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REFERENCES

Armstrong, J. S. 2001. Principles of forecasting: a handbook for researchers and practitioners. Springer-Verlag, New York.

Barrett, P. J. 2009. Estimating Devils Hole pupfish lifestage ratios using the Delphi method. Fisheries 34:73–79.

Beauchamp, D. A., and J. J. Van Tassell. 2001. Modeling seasonal trophic interactions of adfluvial bull trout in Lake Billy Chinook, Oregon. Transactions of the American Fisheries Society 130:204–216.

Cheung, W. W. L., T. J. Pitcher, and D. Pauly. 2005. A fuzzy expert system to estimate intrinsic extinction probabilities of marine fishes to fishing. Biological Conservation 124:97–111.

Clark, K. E., J. E. Applegate, L. J. Niles, and D. S. Dobkin. 2006. An objective means of species status assessment: adapting the Delphi technique. Wildlife Society Bulletin 34:419–425.

Clarkson, R. W., P. C. Marsh, S. E. Stefferud, and J. A. Stefferud. 2005. Conflicts between native fish and nonnative sport fish management in the southwestern United States. Fisheries 30(9):20–27.

Converse, S. J., K. J. Shelly, S. Morey, J. Chan, A. LaTier, C. Scafidi, D. T. Crouse, and M. C. Runge. 2011. A decision-analytic approach to the optimal allocation of resources for endangered species consultation. Biological Conservation 144:319–329.

Crance, J. H. 1987. Guidelines for using the Delphi technique to develop habitat suitability index curves. U.S. Fish and Wildlife Service Biological Report 82(10.134).

Crist, P. J., T. W. Kohley, and J. Oakleaf. 2000. Assessing land-use impacts on biodiversity using an expert systems tool. Landscape Ecology 15:47–62.

Dunham, J., K. Gallo, D. Shively, C. Allen, and B. Goehring. 2011. Assessing the feasibility of native fish reintroductions: a framework applied to threatened bull trout. North American Journal of Fisheries Management 31:106–115.

Failing, L., G. Horn, and P. Higgins. 2004. Using expert judgment and stakeholder values to evaluate adaptive management options. Ecology and Society [online serial] 9(1): article 13. Available: www.ecologyandsociety.org/vol9/iss1/art13. (September 2011).

FEMAT (Forest Ecosystem Management Assessment Team). 1993. Forest ecosystem management: an ecological, economic, and social assessment. FEMAT, U.S. Government Printing Office, Washington, D.C.

Fryer, J. K. 1998. Frequency of pinniped-caused scars and wounds on adult spring-summer Chinook and sockeye salmon returning to the Columbia River. North American Journal of Fisheries Management 18:46–51.

Fukuda, S., and K. Hiramatsu. 2008. Prediction ability and sensitivity of artificial intelligence-based habitat preference models for predicting spatial distribution of Japanese medaka (*Oryzias latipes*). Ecological Modelling 215:301–313.

Gokhale, A. A. 2001. Environmental initiative prioritization with a Delphi approach: a case study. Environmental Management 28:187–193.

Gregory, R., and G. Long. 2009. Using structured decision making to help implement a precautionary approach to endangered species management. Risk Analysis 29:518–532.

Hodgetts, R. M. 1977. Applying the Delphi technique to management gaming. Simulation 29:209–212.

Holthausen, R. S., M. J. Wisdom, J. Pierce, D. K. Edwards, and M. M. Rowland. 1994. Using expert opinion to evaluate a habitat effectiveness model for elk in western Oregon and Washington. U.S. Forest Service Research Paper PNW-RP-479.

Hsu, C. C., and B. A. Sandford. 2007. The Delphi technique: making sense of consensus. Practical Assessment, Research and Evaluation [online serial] 12. Available: http://pareonline.net/getvn.asp?v=12&n=10. (September 2011).

Huntington, H. P. 1998. Observations on the utility of the semi-directive interview for documenting traditional ecological knowledge. Arctic 51:237–242.

Janssen, J. A. E. B., M. S. Krol, R. M. J. Schielen, A. Y. Hoekstra, and J. L. de Kok. 2010. Assessment of uncertainties in expert knowledge, illustrated in fuzzy rule-based models. Ecological Modelling 221:1245–1251.

Lee, D. C. 2000. Assessing land-use impacts on bull trout using Bayesian belief networks. Pages 127–147 *in* S. Ferson and M. Burgman, editors. Quantitative methods for conservation biology. Springer-Verlag, New York.

Lehmkuhl, J., M. Raphael, R. Holthausen, J. Hickenbottom, R. Naney, and J. Shelly. 1997. Historical and current status of terrestrial species and the effects of proposed alternatives. Pages 537–730 *in* T. Quigley, K. Lee, and S. Arbelbide, editors. Evaluation of EIS alternatives by the science integration team, 2 volumes. U.S. Forest Service General Technical Report PNW-GTR-406.

MacMillan, D. C., and K. Marshall. 2006. The Delphi process: an expert-based approach to ecological modelling in data-poor environments. Animal Conservation 9:11–20.

Marcot, B. G. 2006. Characterizing species at risk I: modeling rare species under the Northwest Forest Plan. Ecology and Society [online serial] 11(2): article 10. Available: www.ecologyandsociety.org/vol11/iss2/art10./ (September 2011).

Marcot, B. G., P. A. Hohenlohe, S. Morey, R. Holmes, R. Molina, M. Turley, M. Huff, and J. Laurence. 2006. Characterizing species at risk II: using Bayesian belief networks as decision support tools to determine species conservation categories under the Northwest Forest Plan. Ecology and Society [online serial] 11(2):article 12. Available: www.ecologyandsociety.org/vol11/iss2/art12./ (September 2011).

McCarthy, M. A., S. J. Andelman, and H. P. Possingham. 2003. Reliability of relative predictions in population viability analysis. Conservation Biology 17:982–989.

Morgan, M. G., and M. Henrion. 1990. Uncertainty: a guide to dealing with uncertainty in quantitative risk and policy analysis. Cambridge University Press, Cambridge, UK.

O'Keefe, J. H., D. B. Danilewitz, and J. A. Bradshaw. 1987. An "expert system" approach to the assessment of the conservation status of rivers. Biological Conservation 40:69–84.

Pearce, J. L., K. Cherry, M. Drielsma, S. Fierrier, and G. Whish. 2001. Incorporating expert opinion and fine-scale vegetation mapping into statistical models of faunal distribution. Journal of Applied Ecology 38:412–424.

Prato, T. 2005. Accounting for uncertainty in making species protection decisions. Conservation Biology 19:806–814.

Rieman, B. E., and J. D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. U.S. Forest Service General Technical Report INT-302.

Roby, D. D., D. E. Lyons, D. P. Craig, K. Collis, and G. H. Visser. 2003. Quantifying the effect of predators on endangered species using a bioenergetics approach: Caspian terns and juvenile salmonids in the Columbia River estuary. Canadian Journal of Zoology 81:250–265.

Roemer, G. W., and R. K. Wayne. 2003. Conservation in conflict: the tale of two endangered species. Conservation Biology 17: 1251–1260.

Shaw, C. G. 1999. Use of risk assessment panels during revision of the Tongass land and resource management plan. U.S. Forest Service General Technical Report PNW-GTR-460.

Steele, M. Z., and C. M. Shackleton. 2010. Using local experts as benchmarks for household local ecological knowledge: scoring in South African savannas. Journal of Environmental Management 91:1641–1646.

USFWS (U.S. Fish and Wildlife Service). 2011a. Reintroduction of bull trout to the Clackamas River, Oregon. USFWS, Oregon Fish and Wildlife Office, Environmental Assessment, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 2011b. Clackamas River bull trout reintroduction implementation, monitoring, and evaluation plan. USFWS, Oregon Fish and Wildlife Office, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 2011c. Endangered and threatened wildlife and plants: establishment of a nonessential experimental population of bull trout in the Clackamas River subbasin, OR. Federal Register 76:119(21 June 2011):35979–35995.

Vose, D. 1996. Quantitative risk analysis: a guide to Monte Carlo simulation modeling. Wiley, Chichester, UK.

Weisberg, S. B., B. Thompson, J. A. Ranasinghe, D. E. Montagne, D. B. Cadien, D. M. Dauer, D. Diener, J. Oliver, D. J. Reish, R. G. Velarde, and J. Q. Word. 2008. The level of agreement among experts applying best professional judgment to assess the condition of benthic infaunal communities. Ecological Indicators 8:389–394.

Wenger, S. J., D. J. Isaak, C. H. Luce, H. M. Neville, K. D. Fausch, J. B. Dunham, D. C. Dauwalter, M. K. Young, M. M. Elsner, B. E. Rieman, A. F. Hamlet, and J. E. Williams. 2011. Flow regime, temperature, and biotic interactions drive differential declines of trout species under climate change. Proceedings of the National Academy of Sciences of the USA 108:14175–14180.

Wiese, F. K., J. K. Parrish, C. W. Thompson, and C. Maranto. 2008. Ecosystem-based management of predator-prey relationships: piscivorous birds and salmonids. Ecological Applications 18:681–700.

Zohar, A., and J. S. Rosenschein. 2008. Mechanisms for information elicitation. Artificial Intelligence 172:1917–1939.

Appendix 1: Bayesian Network Model

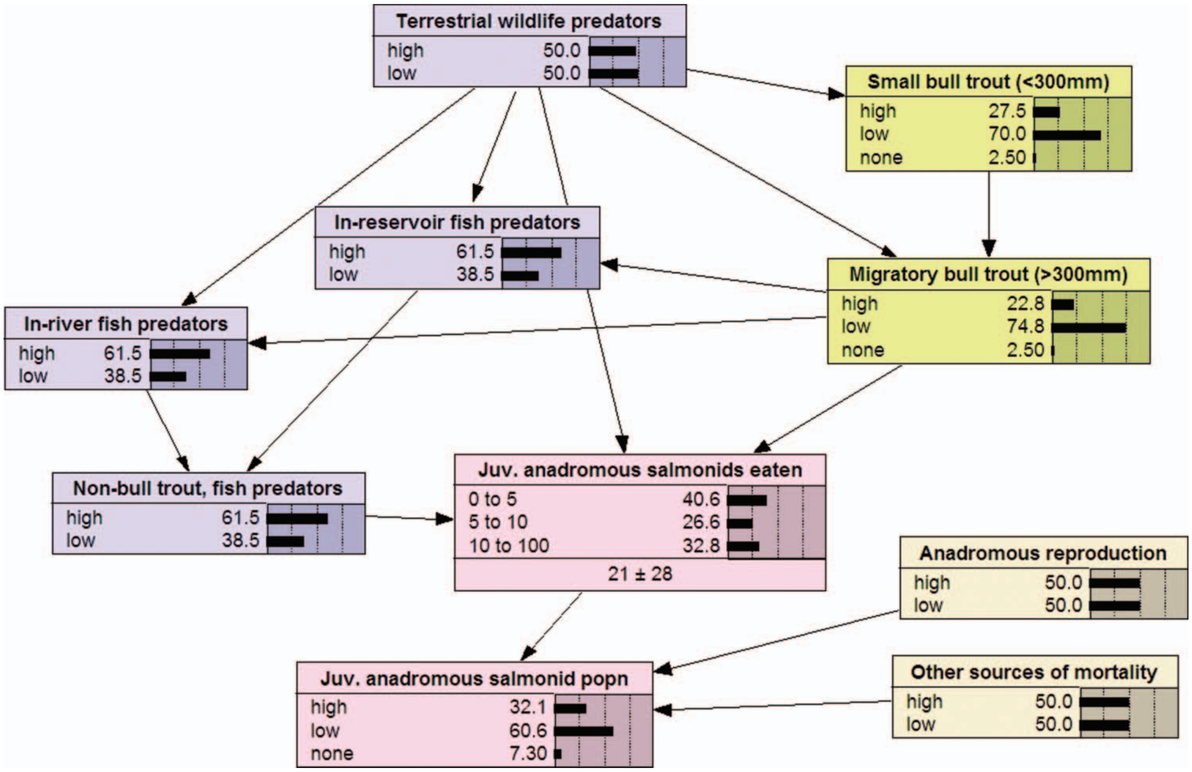

FIGURE A.1.1. Bayesian network model (J. Dunham, U.S. Geological Survey, C. S. Allen, and B. G. Marcot, unpublished data) developed to illustrate potential food web and species interaction dynamics related to bull trout–anadromous salmonid interactions (explanation of nodes: small bull trout = at least juveniles and possibly resident adults; terrestrial wildlife predators = some amphibians, reptiles, birds, and mammals; juvenile [juv.] anadromous salmonids eaten = average annual percentage of total juvenile anadromous salmonids that are consumed by fish and other predators; juvenile anadromous salmonids = parr to smolt stages, although some bull trout predation on eggs also occurs; popn = population; anadromous reproduction = number of offspring [embryos] produced by spawning adult salmonids; other sources of mortality = poor water quality, passage through reservoirs and past dams, natural disturbances, etc.). [Figure available in color online.]

Appendix 2: Scoring Worksheet

Worksheet used by expert panelists to score the potential impacts of bull trout on each of the four federally listed (Endangered Species Act [ESA]) anadromous salmonid populations (spring Chinook salmon, fall Chinook salmon, coho salmon, and winter steelhead) in the Clackamas River, Oregon.

Panelist code: ________________

Date: ________________

TASK 1: DEGREE OF IMPACT

Assume that bull trout reintroduction objectives are met (that is, at least 200–500 adult bull trout sustainable by 2030). Now, **what are the impacts from bull trout on ESA-listed salmon and steelhead populations?**

Spread 100 points among one or more cells in each column (the spread of points represents your degree of predictability for each species); score each species independently.

Key:

Round 1/Round 2

Degree of impact	Spring Chinook	Fall Chinook	Coho	Winter Steelhead
Very High	/	/	/	/
High	/	/	/	/
Moderately High	/	/	/	/
Moderate	/	/	/	/
Moderately Low	/	/	/	/
Very Low	/	/	/	/
None	/	/	/	/
Total	100/100	100/100	100/100	100/100

Very High = bull trout influence contributes to 100% of the extinction probability
High = bull trout influence contributes to about 95% of the extinction probability
Moderately High = bull trout influence contributes to about 75% of the extinction probability
Moderate = bull trout influence contributes to about 50% of the extinction probability
Moderately Low = bull trout influence contributes to about 25% of the extinction probability
Very Low = bull trout influence contributes to about 5% of the extinction probability
None = bull trout influence has no contribution to the extinction probability

Overall rationale for your scoring across all species – ***denote only for Round 2***

Check all that apply to your scoring:

- Refer to food web diagram
- Role of reservoirs in juvenile rearing of salmonids
- Migratory timing of salmonids
- Spatial and temporal habitat use by predatory bull trout
- Predator aggregations caused by in-stream structures
- Current abundance and recent trend of each salmonid species
- Other: ________________

Appendix 3: Potential Monitoring Activities

Table A.3.1. List of 19 potential monitoring activities identified by the five members of the Bull Trout Expert Panel, sorted in decreasing order of mean priority scores averaged across panelists. Panelists scored each activity as follows: 1 = essential to conduct; 2 = important but not necessarily essential; and 3 = worthwhile but of lower importance. See Figure 1 for locations. "Predator" refers to bull trout; "prey" refers to the Endangered Species Act-listed anadromous salmonid populations (spring Chinook salmon, fall Chinook salmon, coho salmon, and winter steelhead) in the Clackamas River.

Monitoring theme	Monitoring parameter	Brief description and metric	Mean score
Predator abundance and reproduction	Predator status	Bull trout reproduction and recruitment (e.g., spawning surveys, age, and size)	1
Consumption	Trophic interactions	Estimate rates of food consumption by bull trout	1
Bull trout size structure	Predator status	Monitor size structure of bull trout in reservoir and river environments	1.2
Prey abundance and productivity	Prey status	Smolt and adult abundance, size, and age at North Fork Dam for the listed salmonid populations	1.2
Prey abundance and productivity	Prey status	Juvenile and adult abundance and size structure of the listed populations above the North Fork Reservoir	1.2
Trophic interactions	Trophic interactions	Monitor diet and stable isotopes of fish and key invertebrates to identify major predators (fish and others) of salmonines and other fishes (determine food web)	1.2
Demography	Predator status	Estimation of life-stage- and habitat-specific survival of bull trout	1.6
Fish habitat selection	Predator status	Habitat selection by predator; probability of habitat use	1.6
Species abundance	Prey status	Monitor coho salmon, Chinook salmon, and winter steelhead abundance in nearby, adjacent basins for determining; both marine and other common freshwater effects	1.6
Spatial and temporal variation in distribution of species	Trophic interactions	General surveys; over time for temporal variation; seasonally; all aquatic species	1.6
Reservoir limnology	Environment	Monitor temperature and zooplankton	1.8
Age and growth	Predator status	Age and growth of all predators	1.8
Demography	Prey status	Estimation of life-stage- and habitat-specific survival of all prey species	1.8
Fish habitat selection	Prey status	Habitat selection by prey, probability of habitat use	2
Fish use of reservoir	Prey status	Hydroacoustic survey in the reservoir to determine fish species abundance and distribution	2
Bull trout movement	Trophic interactions	Tracking of bull trout movement through the basin, especially if below the dam, to better understand interaction with prey species	2
Habitat	Environment	Monitor habitat to determine environmental correlates for a better understanding of potential species interaction	2.6
Prey behavior	Prey status	Monitor the behavior of prey species, microhabitat selection, and diel activity	2.6
Angler catch of bull trout	Predator status	Monitor angler catch of bull trout	3

Appendix 4: Potential Management Responses

Table A.4.1. List of 21 potential management response activities (sorted by management theme) for reducing or eliminating adverse impacts of bull trout on the four anadromous salmonid populations in the Clackamas River (see Table A.3.1), as identified by the five members of the Bull Trout Expert Panel.

Management theme	Type and degree of impact	Brief description of activity
Monitoring	High to very high impact of bull trout on other listed salmonids	Confirm type and degree of impact by collecting better data and by improved or more intensive monitoring to determine whether there is indeed an impact so stated
Offset impacts of bull trout	Other threats	Deal with the lower Clackamas River; mitigate threats to anadromous salmonids in the lower river
	All impact levels of bull trout predation on salmonids	Greater management emphasis to address other native and nonnative fish species' impacts to listed salmonids in the Clackamas River to offset possible bull trout predation effects
Predator control	High to very high impact of bull trout on other listed salmonids	Removal of bull trout in toto or maintaining the bull trout population at a lower specified level
	Moderate to high bull trout predation on salmonids	Targeted eradication of particular size-classes of bull trout through public angling or fisheries management
	Moderate to high bull trout predation on salmonids	Targeted eradication of bull trout redds to reduce the population
	Predation on fall Chinook salmon and chum salmon *Oncorhynchus keta* in the lower river	Control downstream movement of bull trout at North Fork Dam
	Moderate to high bull trout predation on salmonids	Stop introductions of bull trout and observe the effects (passive)
Prey enhancement	All impact levels of bull trout predation on salmonids	Enhance the listed salmonid populations by increasing habitat capacity throughout the range of the populations (including areas below North Fork Dam) and increasing survival of these populations
	All impact levels of bull trout predation on salmonids	Ensure healthy populations of mountain whitefish *Prosopium williamsoni* and other native resident fish species by increasing habitat capacity throughout the range of the populations and increasing their survival; the purpose is to provide a stable alternative prey base for bull trout
Prey management	Predation by bull trout on juvenile salmonids in tributary habitats	Add refuge cover in tributary habitat; habitat enhancements to reduce predation
	Predation in reservoir	Trap out-migrating smolts and physically move them below the reservoir
	All impact levels of bull trout predation on salmonids	Reservoir management to increase populations of other non-salmonid prey taxa
	All impact levels of bull trout predation on salmonids	Hatchery rainbow trout management in North Fork Reservoir: increase or decrease stocking levels or sizes of fish (depending on results of baseline food web monitoring)
	All impact levels of bull trout predation on salmonids	Focused supplementation of salmon carcasses in areas known to be forage "hot spots" if determined
	All impact levels of bull trout predation on salmonids	Facilitate upstream passage of Pacific lamprey *Lampetra tridentata* at North Fork Dam
	All impact levels of bull trout predation on salmonids	Add wood or structure to the reservoir and inlet channel as refuge habitat for prey species
Public management	Noncompliance with fishing regulations	Enhance law enforcement controls on enforcing fishing regulations in the upper basin
Public perception	Social impact	Public conservation education about bull trout reintroduction objectives
Reservoir management	Time and area of acute predation	Adjust flow regime or engineering to guide smolts to the bypass system more quickly
	Thermal impacts on trophic interactions	Water management to adjust the thermal structure and productivity of reservoirs