Deliberative Disjunction: Expert and Public Understanding of Outcome Uncertainty

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ABSTRACT

Many environmental and risk management decisions are made jointly by technical experts and members of the public. Frequently their task is to select from among management alternatives whose outcomes are subject to varying degrees of uncertainty. Although it is recognized that how this uncertainty is interpreted can significantly affect decision-making processes and choices, little research has examined similarities and differences between expert and public understandings of uncertainty. We present results from a web-based survey that directly compares expert and lay interpretations and understandings of different expressions of uncertainty in the context of evaluating the consequences of proposed environmental management actions. Participants responded to two hypothetical but realistic scenarios involving trade-offs between environmental and other objectives and were asked a series of questions about their comprehension of the uncertainty information, their preferred choice among the alternatives, and the associated difficulty and amount of effort. Results demonstrate that experts and laypersons tend to use presentations of numerical ranges and evaluative labels differently; interestingly, the observed differences between the two groups were not explained by differences in numeracy or concerns for the predicted environmental losses. These findings question many of the usual presumptions about how uncertainty should be presented as part of deliberative risk- and environmental-management processes.

Key words: uncertainty, deliberation, experts, risk management, environment
1. INTRODUCTION

1.1 Environmental Management Deliberations and Uncertainty

Environmental risk managers and decision makers frequently need to make choices despite the existence of substantial uncertainty about the anticipated outcomes of proposed actions. Much of the literature focuses on technical or statistical analyses intended to assist experts in developing effective methods for characterizing and evaluating the uncertain consequences of proposed actions.\(^{(1,2)}\) A quite different interest in the treatment of uncertainty has arisen over the past two decades because many environmental decision making processes now involve both expert and lay participants, drawn from a variety of backgrounds and representing a variety of interests.\(^{(3-6)}\) This increased role of deliberative processes in risk management decisions is encouraged by legal mandates for increased public participation, which require risk managers and environmental decision makers to engage and communicate effectively with stakeholders about the implications of the uncertainty associated with proposed actions.\(^{(7)}\)

Risk managers engaged in multi-stakeholder processes can make use of a variety of different uncertainty presentation formats, hoping to assist participants in comprehending the implications of uncertainty as part of making informed decisions.\(^{(8)}\) One common representation of uncertainty is to present a range of numerical values showing the estimated consequences of a proposed management action: the removal of a predator species from a lake is expected to increase populations of a desired sport fish by 15% over the next ten years, but (with 90% confidence) managers acknowledge that the resulting population increase could be as small as 5% or as large as 30%. Alternatively, graphs or visual presentations of various types can be used to convey this information.\(^{(9)}\) Natural language expressions also are frequently used to communicate outcome uncertainty (e.g., high, medium, low uncertainty). In the example above, the uncertainty in the sport fish population could be communicated by neutral language or by an evaluative label (e.g., uncertainty is poor, good, or excellent) instead of, or in addition to, a numerical range or graph. Using evaluative labels to communicate uncertainty could have advantages in that they are simple and make salient the comparisons of different options based on uncertainty,\(^{(10)}\) although they also are imprecise and thus have some of the same disadvantages as other natural language expressions of outcome uncertainty.\(^{(11,12)}\)

Unfortunately, little guidance is available to risk managers as to how uncertainty should be depicted in specific problem or stakeholder contexts. Yet if differences arise in how uncertainty is interpreted across different presentation formats, particularly in ways that are neither anticipated nor fully understood, then individuals’ preferences may be obscured and misunderstandings or conflicts may be encouraged. As noted in the National Research Council’s *Understanding Risk* report:

> . . . uncertainty analysis should be conducted with care and in conjunction with deliberation and in full awareness of its limitations . . . The users of uncertainty analysis should remember that both the analysis and people’s interpretation of it can be strongly affected by the social, cultural, and institutional context of the decision.\(^{(1)}\)

In some cases, the failure to predict or to interpret specific responses to different presentations of uncertainty may lead to the selection of an inferior management alternative, one that would not be preferred were the influence of the associated uncertainties better understood.\(^{(13)}\)
1.2 How Might Experts and Laypeople Differ in the Interpretation and Use of Uncertainty?

In this paper we examine how technical experts and members of the public understand and respond to different presentations of uncertainty with respect to the outcomes of management actions. Although this expert–public distinction is widely considered to be important to deliberative environmental processes,\(^{14}\) it rarely has been tested empirically. Nor is it straightforward. The typical assumption is that expert participants will better understand, and be more comfortable with, presentations of outcome uncertainty; this group includes environmental managers from government resource-based and regulatory agencies (often with advanced training in fisheries, wildlife management, ecology, forestry, or risk management), academics, consultants, and many industry or NGO stakeholders. Public or lay participants, on the other hand, are expected to have lower levels of understanding and to experience greater difficulty in dealing with uncertainty; this group includes members of potentially affected communities, resource users, some members of NGOs and other interest groups, and often Aboriginal populations (e.g., Native Americans in the United States; First Nations, Metis or Inuit in Canada).

Given the lack of clear guidance for matching contexts with methods when communicating about uncertainty, it’s not surprising that a common approach when working with multi-stakeholder groups is to employ a variety of different metrics: numbers, words, graphs, and/or labels. Both Ibrekk and Morgan\(^{15}\) and Fishchoff et. al.,\(^{16}\) for example, conclude that if the goal is to have individuals understand an uncertain quantity, often it helps to present the result using multiple methods. A recent review completed for the Intergovernmental Panel on Climate Change (IPCC) also recommends a dual approach for communicating uncertainty, pairing a seven-step verbal classification system with a range of numerical probabilities\(^{17}\). The assumption seems to be that people will either integrate multiple uncertainty representations to achieve a better understanding of uncertainty, or choose to focus on the representation that is easiest for them to use. However, rarely are these assumptions tested, and even more rarely is careful attention given to ways in which participants’—either experts or laypersons—understanding of uncertainty could be improved as a result of incorporating the most appropriate presentation format.

Differences in the numerical ability of experts and laypeople may partially explain why these groups perceive and use uncertainty in different ways. Studies of numeric ability show that people differ substantially in their ability to process and make sense of numbers.\(^ {18,19}\) In the context of deliberations about the uncertain consequences of management alternatives, even careful presentations of numeric consequences might fail to be interpreted correctly.\(^ {20}\) If less-numerate people are either uncomfortable with using quantitative information or do not understand a numeric presentation of uncertainty, this may cause them to focus on other more easily evaluated information such as evaluative labels or, if nothing else is available, they may base their decisions on incorrect interpretations of the expressed outcome uncertainty or fail to take uncertainty into account.\(^ {21}\)

However, experts may also differ in a variety of other ways from laypeople, unrelated to numeracy.\(^ {22}\) For instance, their greater experience in choosing among management options or a greater concern for making a “good” decision may affect either how they interpret uncertainty as part of their deliberations or the effort they will expend. In the context of environmental management choices, experts employed as resource managers also may (on average) care more about protecting threatened species than would members of the public, which could influence their choices under uncertainty.
Overall, we find it surprising that, despite the significant role that uncertainty plays in the development and evaluation of risk management options as part of multi-stakeholder deliberations, and despite the increased attention given to the evaluability of information as part of choice tasks, little research has been conducted that directly compares the understanding of uncertainty among different stakeholders. In particular, the lack of direct comparisons between expert and public participants means that the choice of an approach to articulating and identifying uncertainty typically is largely left to the experience of the analyst responsible for conducting an evaluation or to the resource manager charged with leading the group making a decision.

2.0. OVERVIEW OF STUDY DESIGN & METHODS

If experts and laypeople respond differently to representations of uncertainty, this could affect their decision strategies and the eventual choices that are made. We present results from a web-based survey that directly compares expert and lay participants on how they interpret and use different expressions of uncertainty to understand and to evaluate the consequences of proposed environmental management actions. All participants responded to two hypothetical but realistic scenarios, emphasizing decision contexts that directly affect environmental considerations but that also influence economic, social, or health concerns.

2.1 Subjects

Subjects were drawn from two different groups, one composed of members of the U. S. public and the other composed of professionals (technical experts) employed by the U. S. Fish and Wildlife Service (USFWS). Participants in the nationally representative public panel were randomly drawn from a larger pool of subjects (N = 1500) who have participated as paid subjects in numerous previous web surveys undertaken by Decision Research. Demographically, public panel members generally are similar to the national U. S. population but differ in three areas: they are younger, better educated, and have a higher proportion of females than the U. S. population as a whole.

Of the 393 subjects invited for the public survey, 374 responded (95% response rate). Responses were anonymous and participants were paid for their time. The expert survey was administered through a website organized by the U. S. Fish and Wildlife Service for employees who have undertaken some previous training in resource management and decision making. Of the approximately 250 subjects invited, 67 responded with fully completed surveys (27% response rate); all responses were coded anonymously. The experts (all U. S. government employees) were not paid, but were promised a summary of study results. Both public and expert participants were encouraged to write in any additional remarks they might want to include; selections from these comments are reported in the following sections.

2.2 Survey Design

The expert and public panels were given identical surveys, with the exception of some of the demographic questions asked at the end. Both scenarios reviewed by participants were hypothetical but modelled closely on real environmental management problems that would easily be understandable and familiar to most participants. Importantly (and in contrast to many of the stimuli used in other studies to test uncertainty presentations), the scenarios and supporting information were presented in a format that closely mirrors how information about the consequences of proposed actions is often presented to laypersons and to experts participating in a deliberative process convened to provide policy direction decision makers about an
environmental or risk management issue. All subjects worked through the scenarios in the same order, and all subjects were provided with information about the consequences of actions that showed the same impact measures and the same three management alternatives.

2.2.1 Presentation of Information: Objectives, Alternatives, and Consequences

Following a brief (one paragraph) written description, the key elements of each scenario were summarized for participants in a table. The format of this table was based on methods drawn from decision analysis and structured decision making that are widely employed in working with groups of diverse backgrounds to develop solutions to risk and environmental management problems. The specific format used to present the anticipated consequences of management actions under various strategies makes use of what is often termed a “consequence table” or “facts box,” showing the primary objectives (i.e., key issues of concern) in rows and the leading management alternatives in columns. Objectives are further defined in terms of a specified metric or unit of measure (e.g., costs are measured in dollars, temperature in degrees F). Each cell of the table therefore provides information about one of the anticipated outcomes of one of the alternatives.

An example consequence table, included as part of the introduction to the surveys shown to both groups, is shown in Table I. It presents three concerns (cost, temperature, and travel time) that may be relevant to the illustrative choice of “where should I go for my one week winter vacation” and three alternative destinations: Mexico, Hawaii, and Montreal. As discussed in the survey introduction, this type of table summarizes much of the factual information needed to make a decision when alternatives are discrete. Individuals could review this information and come to different conclusions about the best vacation choice for themselves, depending on what criteria matter most to them and the information shown for each of the destinations.

[Table I about here]

Subjects were informed that the environmental management scenarios would have the added feature that “sometimes there is uncertainty about what will happen if the actions are taken.” This uncertainty could be about the biology or some other aspect of the environmental problem, such as how much an action will cost. Subjects also were reminded that “some actions are more uncertain than others.”

2.2.2 Manipulations of Outcome Uncertainty

The uncertainty presentation was manipulated in a six-level single factor between-subjects design. The six uncertainty presentations used in this study are summarized in Table II.

[Table II about here]

The six presentations selected for this study include some of the approaches most frequently used as part of deliberative processes whose outcomes depend in part on experts’ and laypersons’ understanding of uncertainty presentations. Several other formats were considered but rejected, either because they would require an extensive parallel set of studies (e.g., various graphical presentations) or because they require levels of understanding of the rules of probability that exceed those typically held by many stakeholders. This choice (informed by experience and pre-tests) means that a variety of other presentation options, including so-called “box and whisker” diagrams to present range information or the introduction of cumulative
distribution functions to help participants visualize probabilistic information,\(^{(29)}\) were rejected for consideration as part of this initial study\(^2\) even though at least in some cases they can effectively be used in deliberative processes after suitable training is given to participants.\(^{(27)}\)

2.2.3 Scenarios

The first scenario focused on a plan to manage forest vegetation in the north-eastern United States, using either conventional methods involving aerial spraying of herbicides or more expensive hand spraying methods intended to reduce adverse impacts on local moose populations. This scenario included the following narrative:

Forests in the northeast of the United States have been managed intensively for decades. An important issue is how to encourage the growth of young trees that are replanted after mature trees are harvested. Several different vegetation management methods are now being used. All of them cost about the same and are equally effective, according to scientists. However, their effects on moose and other animals living in forested areas are very different. Conventional replanting methods, which involve aerial spraying of herbicides, damage animal habitat and reduce survival but their impacts are predictable. Newer methods, involving hand cutting of weeds or spraying of unwanted vegetation from the ground, are thought to be better for populations of moose and other animals, but because they are experimental, their impacts cannot be predicted as precisely. Federal managers and industry therefore face a tough decision across these different vegetation management strategies.

An example consequence table (using the second uncertainty format) for this scenario is presented in Table I\(^{II}\). The average cost for saving each moose was constant across the alternatives, while the best estimate and confidence in the saved moose populations varied. As the best estimate of saved moose increases, the confidence in this estimate decreases. Thus, the primary trade off facing participants (and, in turn, the decision makers asked to make a recommendation) is between the best estimate of moose that would be saved and the confidence held in this estimate.

[Table III about here]

The second scenario focused on a proposal to build a new windfarm in a western state, which would lower electricity rates to local communities but could have negative effects on resident songbird populations. Participants were provided with a one-page written description that began:

A proposal has been received from a private company to build a new windfarm in a western state. The development would involve construction of 250 large wind turbines, capable of producing enough electricity to meet the needs of a city of 25,000 people, along with a new transmission line to link the windfarm to the existing power grid. The area is sparsely populated and contains open rangeland. Because of lower costs to transmit the electricity, the project will result in reduced electricity rates to local communities. The main drawback of the windfarm is its potential negative effects on resident birds, including several types of songbirds. Initial studies have shown an increase in birds’ risk of death, both from flying into the turbines and from disruption of their on-ground food supplies. None of the species are nationally threatened or at risk of extinction.
An example consequence table for this scenario, again using uncertainty format 2, is presented in Table IV. The best estimate of the bird population was constant across the options, while the confidence range in the best estimate and the cost savings per household varied. As the cost savings increased, the confidence in the best estimate decreased, shown by the dramatic increase in the range of estimated effects on local birds. Thus, the primary trade off for participants is between the estimated cost of management actions and the uncertainty (i.e., confidence range) associated with the anticipated effects on bird populations.

[Table IV about here]

2.2.4 Dependent Variables

Following each scenario, participants answered a series of questions. These included questions about their comprehension of the information (“In which option do scientists have the least amount of confidence . . . ”) and their preferred choice among the different alternatives. We also asked participants to rate the amount of effort it took to make a choice (1 = little to 4 = a lot) and how difficult it was to use the uncertainty information provided to them (1 = easy to 4 = hard). The full survey also included several other questions that are not reported here.

2.2.5 Individual Difference Measures

Numeracy was measured with an eight-item scale adapted from other numeracy measures (Cronbach’s $\alpha$ was .59 and .69 for the expert and lay samples, respectively). The numeracy scale consists of short math problems that test the ability to comprehend and manipulate numeric information. The emphasis of the test is on the comprehension and use of proportions and probabilities, but it also includes several more general numerical reasoning problems. We also asked participants two specific questions concerning how they felt about saving songbirds (moose) (-2 = very negative to 2 = very positive).

2.3 Research Questions

Experts are likely to differ from lay people is several important ways. Experts may differ because they have a richer understanding of the complexities in environmental management, they may be more familiar with numerical presentations of uncertainty and use different decision strategies because of this familiarity, they may have more experience dealing with the compromises inherent in many environmental management decisions, or because they are more numerate (which would facilitate the understanding of numeric presentations of uncertainty). Expert and public responses to different presentations of uncertainty could affect a large number of considerations that might be important to the discussion, evaluation, and selection of environmental management alternatives. In this experiment we focused on the following three considerations that, in our experience, are likely to be particularly important for the decisions with uncertainty in predicted outcomes that are made by risk or resource managers as part of a deliberative environmental management process.

i. Comprehension. We hypothesized that lay participants would have more difficulty understanding the uncertainty information, especially when it is presented as a numerical range. We expect that this is primarily due to experience with uncertainty presentations and numerical skill.

ii. Choice. The bottom line for risk managers is whether different uncertainty presentations affect the choice of management alternatives by either expert or lay participants:
Do experts and laypeople show the same pattern of choices when presented with the same uncertainty formats? We expected that experts would use different decision strategies, and that these might result in different choices from those of the lay sample. The considerations discussed above lead to two predictions relating to choice:

- When presented with multiple presentations of uncertainty, lay participants would tend to focus on the evaluative labels and experts would tend to focus on the numerical ranges, and
- Experts and laypeople would show more divergent choice patterns in the condition showing only a numerical range as compared to the condition showing only evaluative labels.

iii. Effort and difficulty. In addition to knowing which of several management alternatives is preferred, it is helpful for managers to know about the effects of uncertainty on related process indicators because these can significantly influence the course and success of stakeholder deliberations.(1) These indicators include the level of effort required to make a decision and the level of difficulty in using any uncertainty information; the relation of these issues to cognitive loads and emotions and their effects on decisions involving trade-offs have been the subject of numerous previous studies. In these studies, we are interested in learning whether lay and expert participants differ in their perceived effort and level of difficulty when interpreting uncertainty information. We hypothesized that the experts would be familiar with numerical presentations of uncertainty and have a more difficult time when relying on uncertainty descriptions that make use of the evaluative labels alone. In contrast, we expected that lay people will need to work harder to understand the numerical ranges and will perceive the labels to be easier to use.

3.0. RESULTS

3.1 Sample Comparisons

The lay sample was slightly younger (mean age = 40.35, sd = 12.32) than the expert sample (mean age = 45.48, sd = 7.90) and consisted of more females (lay = 65.1%, expert = 38.8%). The expert sample (college grad = 18.5%, graduate school = 81.5%) was also more educated than the lay sample (high school or less = 22.3%, some college/vocational = 31.9%, college grad = 30.0%, grad school = 15.8%). A comparison of numeracy showed the expected result: the older and better-educated expert group (mean = 6.20, sd = 1.24) was also significantly more numerate than the lay group (mean = 4.29, sd = 1.79, p < .001). It is not surprising that participants in the expert group of government risk and resource managers were, on average, older, more highly educated, and consisted of a higher percentage of males. In addition, the resource managers who comprised the expert group felt more positive about the importance of protecting both songbirds (Expert: mean = 1.70, sd = 0.63; Lay: mean = 0.89, sd = 0.86; p < .001) and moose (Expert: mean = 1.63, sd = 0.67; Lay: 0.98, sd = 0.85; p < .001).

For the purpose of comparing results between the lay and expert groups, the six between-subject uncertainty conditions (summarized in Table II) were collapsed into three, showing numeric ranges only, verbal labels only, or both ranges and labels. This was done for two reasons. First, there were few differences between the two range-only conditions, the two evaluative labels-only conditions, and the two combined conditions using both ranges and labels. Second, this aggregation across conditions was helpful in light of the relatively small sample of experts; merging the two range-only, evaluative labels-only, and combined conditions
helped increase sample sizes for statistical comparisons. This issue was anticipated at the start of the study, in that gaining access to expert participants who will take the time to answer quite detailed study questions is more difficult; nevertheless, some measures of statistical significance undoubtedly were affected by the relatively smaller sample size in the expert group. Although p-values are reported in the following discussion, we focus on effect sizes and replication across the two scenarios in our interpretation of results.

3.2 Comprehension

As predicted (see Table V), the expert group was better able to comprehend the information presented in the scenarios and to correctly identify the option with the lowest expressed confidence, particularly in the range only condition. Without an evaluative label, a participant must use the width of the stated ranges to infer relative confidence, making this a more difficult question. Given the significantly higher numerical skills of the expert group, these results are not surprising.

[Table V about here]

3.3 Choice

A fundamental comparison between expert and public participants in a deliberative risk management process is choice: given information about the uncertainty associated with key elements of the decision, do expert and public participants make the same choices among the proposed management options and are their respective choices motivated by a similar reliance on the uncertainty information that is presented to them? The choice proportions across the Forest and Windfarm scenarios for the lay and expert groups are presented in Figures 1 and 2.

We first examined what sources of uncertainty information participants tended to use when presented with both ranges and evaluative labels. If participants primarily focus on the evaluative labels when presented with both ranges and labels, then we would expect the choice proportions in the labels only condition to closely match the proportions for the combined (both ranges and labels) condition. If participants instead tend to focus on the numerical range, we would expect similarities between the range only conditions and the combined conditions. Chi-square tests of independence were conducted separately for experts and lay people comparing choice proportions in the labels and range conditions with the combined condition.

[Figure 1 about here]

For lay participants we expected the choice pattern in the labels condition to be more similar to the combined condition than in the range only condition. This hypothesis was confirmed in both scenarios. In the Forest scenario, choice patterns in the combined and labels only conditions were more similar, $\chi^2(2) = 1.42, p = .49, \phi_c = .08$, than the patterns in the combined and range only conditions, $\chi^2(2) = 13.91, p = .001, \phi_c = .23$. The same pattern of results was observed in the Windfarm scenario, where the choice patterns in the combined condition were more similar to the labels only, $\chi^2(2) = 2.97, p = .23, \phi_c = .11$, than to the range only condition $\chi^2(2) = 11.89, p = .003, \phi_c = .22$.

[Figure 2 about here]

In the expert group we expected the opposite pattern of results, with choices being more similar between the range only and the combined condition. This hypothesis was again
confirmed. For the Forest scenario, the choice patterns in the combined and range only conditions were more similar, $\chi^2(2) = 0.43, p = .81, \phi_c = .10$, than the patterns in the combined and labels only conditions, $\chi^2(2) = 4.66, p = .10, \phi_c = .31$. The same pattern of results was observed in the Windfarm scenario, with the choice patterns in the combined condition being more similar to the range only, $\chi^2(2) = 1.73, p = .42, \phi_c = .20$, than to the labels only condition, $\chi^2(2) = 2.99, p = .23, \phi_c = .25$. These results suggest that, when presented with both types of uncertainty information, lay people will tend to focus on the labels and experts will tend to focus on the numerical range. We return to this finding in the discussion section.

Our second prediction was that experts and lay people would show more divergent responses in the range only as compared to the labels only condition. Chi-square tests of independence were used to examine the pattern of choices for experts and lay people in the range only and labels only condition separately. In the Forest scenario, the pattern of choices were significantly different between the groups in the range only condition, $\chi^2(2) = 8.01, p = .02, \phi_c = .25$, but not in the labels only condition, $\chi^2(2) = 1.53, p = .47, \phi_c = .11$. In the range only condition, lay people were more likely to choose the lowest confidence option as compared to experts (56.5% versus 33.3%), and less likely to choose the compromise option (27.8% versus 61.1%).

Next, we examined whether these observed differences between the groups could be explained by differences in numeracy or concern for the predicted losses in moose, which were plausible explanations given that the experts and lay people differed on these variables. A multinomial logistic regression model (choice of the lowest confidence option used as the reference category) was used because traditional chi-square tests of independence are not flexible enough to explore the effect of covariates. Sample (lay versus expert), condition (contrast between range only and labels only), numeracy, and concern for moose (birds) were entered as predictor variables. The primary effect of interest was the interaction between condition and sample, which would indicate that the difference between the samples was larger for one condition or the other. Specifically, the goal was to assess whether this interaction effect held after controlling for numeracy and concern for moose. As expected, based on the chi-square analysis above, there was a significant interaction between sample and condition, $\chi^2(2) = 8.23, p = .02$. Adding numeracy, $\chi^2(2) = 3.03, p = .22$, and concern for moose, $\chi^2(2) = 13.17, p = .001$, did not substantially change the magnitude of the interaction effect, $\chi^2(2) = 8.31, p = .02$.

These results were generally replicated in the Windfarm scenario (although the effects were not as robust), with a larger difference between the groups in the range only condition, $\chi^2(2) = 3.73, p = .15, \phi_c = .17$, as compared to the labels only condition, $\chi^2(2) = 1.14, p = .57, \phi_c = .09$. In the range only condition, lay people were more likely to choose the lowest confidence option and less likely to choose the compromise option. As above, a multinomial logistic regression model (choice of the lowest confidence option as the reference category) was run to examine the effects of numeracy and concern for birds. As expected from the chi-square analyses above, the effects were in the same direction but not as robust as in the Forest scenario, resulting in a nonsignificant interaction between sample and condition, $\chi^2(2) = 3.93, p = .14$. Adding numeracy, $\chi^2(2) = 7.23, p = .03$, and concern for birds, $\chi^2(2) = 3.02, p = .22$, did not substantially change the nature of the interaction effect, $\chi^2(2) = 4.10, p = .13$.

These results broadly support our prediction that experts and lay people would show more divergent responses in the range only as compared to the evaluative label condition. When presented with a numerical range, experts tended to choose the compromise option more often than the lay participants, whereas the lay people tended to choose the option that had the
most favorable best estimate/costs but the lowest amount of confidence. This suggests that the groups are using quite different decision strategies when presented with numerical ranges. In addition, these results do not seem to be explained by higher numeracy or by the greater concern for animals in the expert group.

3.4 Effort and Difficulty

In the range only and combined conditions, lay participants reported expending much more effort in choosing between the options (see Table VI for means). These effects were strong and consistent across the scenarios. When presented with the labels only, however, there was little difference between the groups in terms of effort. Differences in numerical ability between the groups may account for the group differences. Numeracy was related to perceived effort, in that more highly numerate participants reported expending less effort when making the decision. The effects are attenuated but remain significant after controlling for numeracy (Range: Forest, \(d = .47, p = .06\); Windfarm, \(d = .18, p = .22\). Combined: Forest, \(d = .55, p = .001\); Windfarm, \(d = .58 p = .005\)). Thus, differences in numeracy explain some of the group difference but not all of it.

With respect to difficulty, in the range only and combined conditions lay participants found it substantially harder to use information about uncertainty. In the label only condition, it is the experts who report that using the confidence information was more challenging. These effects are consistent across the scenarios. However, differences in numerical ability between the groups may account for the group differences. Numeracy was related to perceived difficulty, in that higher numerate participants reported that it was less difficult to use the confidence information. The effects are attenuated (except for in the labels only condition where they are stronger) but remained after controlling for numeracy (Range: Forest, \(d = .51, p = .05\); Windfarm, \(d = .31, p = .22\). Labels: Forest, \(d = .44, p = .06\), Windfarm, \(d = 1.10 p < .001\). Both: Forest, \(d = .30, p = .15\); Windfarm, \(d = .25 p = .40\)). Thus, differences in numeracy explain some of the group difference but not all of it.

4.0 DISCUSSION

These results suggest several important insights relevant to the presentation of uncertainty as part of risk management and environmental planning deliberations. The choice results suggest that the decision made by experts and lay people are most different when presented with numerical range information only. This may be a consequence of the variety of strategies that could be applied when using a numerical uncertainty range. For instance, one could focus on the width of the range as a measure of overall uncertainty in the attribute, or instead focus on the ends of the range as plausible best and worst-case outcomes. Alternatively, some lay people may be ignoring the numerical uncertainty range altogether. Lay people had more difficulty answering a simple comprehension question and reported having more difficulty and expending more effort in choosing when presented with the range. The difficulty in dealing with this information may have led many lay participants to choose based on other sources of information. Whatever the cause, experts leading deliberative groups should be mindful of the variety of ways in which numerical ranges can be interpreted.\(^5\)

Interestingly, when presented with both a numerical range and an evaluative label, experts appeared more likely to rely on the numerical range and lay people to use the evaluative labels when choosing between options. In addition, lay participants found it
substantially harder to use the confidence information when the range was present. In the label only condition, it was the experts who found the confidence information more challenging to use.\(^6\)

These results raise questions about the logic of the usual presumption to employ multiple sources of information about uncertainty when working with multiple groups of stakeholders with diverse experience and training. What is hoped for is a magical kind of convergence: by providing multiple presentations of information, participants will somehow be able to draw an element of truth from each perspective and combine them to arrive at a more true, or at least less biased, understanding. Yet these preliminary experimental results – in line with experimental evidence showing that individuals tend to overestimate what others know and how well they themselves communicate or can judge others’ knowledge\(^{33}\) – suggest that convergence may not necessarily be achieved. Instead, processing and choice strategies may diverge, with each group focusing on their favorite sources of information: experts will continue to rely on numbers and laypeople will continue to rely on labels.

Differences between expert and public groups in the use of uncertain information are often explained by differences in their respective abilities to understand and interpret numeric presentations. Interestingly, although we did find significant differences between public and expert respondents, numeracy did not account for these effects. We also tested an alternative explanation, that differences in responses to the presentations of uncertainty reflected the two groups’ different levels of concern for the specified animals; this explanation also was not supported. It may be that the observed differences between experts and laypersons are accounted for by their experience with environmental decisions, or perhaps by components of numeracy or other predictors (e.g., affect or worldviews) that are not well captured by existing measures. Further research will continue to explore this question and its implications for risk management deliberative processes; for example, whether some types of training or deliberation might be useful to facilitate a shared understanding of uncertainty on the part of expert and public participants.

There are several limitations of this study that should be noted. The results are based on relatively small sample sizes, particularly for the experts group, and involve scenarios that focus on only one set of concerns (i.e., environmental management issues). The size of the uncertainty ranges were all fairly narrow, at least when compared to the high levels of uncertainty (e.g., the severe uncertainty that typically characterizes what have been referred to as “wicked” management problems) that often are encountered as part of environmental management policy deliberations. Responses in the face of wider ranges, or problems where uncertainty is so severe that ranges cannot meaningfully be used, may be different and merit further study. In addition, these results rely on a simplified presentation of the key considerations that typically would need to be considered by a risk or environmental manager. Several of the comments we received, from both public and expert participants, picked up on this point and noted that the real world is often far messier—and the associated uncertainties less clearly stated—than the simplified scenarios we present here. Finally, in interpreting these results we have tended to assume that ease of use is a good thing with respect to subjects’ understanding of the different uncertainty presentations—in other words, that compatibility between how people appear to think about uncertainty and the presentation format will assist understanding. Yet we recognize that this might not be true: cognitively matching an uncertainty presentation format may encourage participants to not give it sufficient attention, whereas perhaps a more unsettling or unfamiliar presentation context would initially prove more difficult but, in the long run, encourage greater understanding.
The bottom line is that the choice of format for communicating about outcome uncertainty depends on (a) who your audience is and (b) what you want people to pay most attention to. This conclusion is consistent with an active process of preference construction reflecting evaluability: people tend to rely on those aspects of the uncertainty presentation that are most readily evaluable. As a result, it also appears that the usual explanations guiding presentations of uncertainty as part of deliberative processes—use multiple presentation methods, seek to overcome the relatively lower numeracy levels of public participants—are overly simple and may lead to unintended results, including an increase (rather than the intended decrease) in conflicts across expert and public participants.

FOOTNOTES

1. As noted by a reviewer, presenting an outcome as both a point estimate and a range provides two sources of information to respondents (e.g., as compared to a range-only condition). We tested several minor variations in presentation (e.g., using hyphens vs. no hyphens, bolding the best estimate) and found no significant differences, but we acknowledge that this issue merits further examination as it could influence either participants’ choices or level of effort.

2. Additional experimental results, including deliberative participants’ responses to methods using graphical and other formats for communicating uncertainty, will be presented in separate papers.

3. Undoubtedly, one of the reasons why so much of the prior experimental work on uncertainty has involved lay participants is that it is difficult to gain access to large numbers of technical experts. In this case, we focused on a particular problem domain, risk and environmental management, and a particular uncertainty presentation and communication context, that of multi-stakeholder deliberations. Although we were therefore pleased to have participation from as large a sample of experts as we did, some creativity was required in making statistical comparisons between the relatively smaller expert and the relatively larger public samples.

4. One lay participant expressed his comprehension difficulties by commenting: “If you have an estimate of 10, but feel that it could be anywhere from 1–20, how can you be 90 percent certain of that?”

5. It is also true that the lay participants are likely to have found the problem context—choosing among different environmental management options, based in part of the associated uncertainty—to be more difficult than did the experts, for whom this type of decision would be more familiar. Several of the lay participants provided written comments stating that they found the surveys “very interesting and thought provoking” or “these surveys really make you think.”

6. More information about this latter point can be found in a companion paper.\(^{10}\)
ACKNOWLEDGEMENTS

We acknowledge the generous support of the Decision Risk and Management Science Program, U. S. National Science Foundation that made this work possible: NSF Award #0725025 to Decision Research (Robin Gregory, PI) and NSF Award #0925008 to Decision Research (Nathan Dieckmann, PI). When the research project began Ellen Peters worked with Decision Research in Eugene, Oregon; she is now affiliated with Ohio State University in Columbus, Ohio. We also thank the U. S. Fish and Wildlife Service, and in particular Donna Brewer, for cooperation in helping to pre-test and implement the expert group surveys. All views expressed in this paper are those of the authors alone.

5.0 REFERENCES


### Table I. Illustrative Consequence Table

<table>
<thead>
<tr>
<th>Units</th>
<th>Option 1: Mexico</th>
<th>Option 2: Hawaii</th>
<th>Option 3: Montreal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost (hotel, meals, airfare)</td>
<td>$</td>
<td>1,500</td>
<td>2,500</td>
</tr>
<tr>
<td>Average temperature</td>
<td>Degree (F)</td>
<td>75</td>
<td>85</td>
</tr>
<tr>
<td>Travel time (one-way)</td>
<td>Hours</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>

### Table II. Uncertainty Presentations for Scenarios 1 and 2

<table>
<thead>
<tr>
<th>Uncertainty Presentation</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Best estimate plus range</td>
<td>Best estimate and a range of numeric values, with a hyphen</td>
<td>5,000 4,500–5,500</td>
</tr>
<tr>
<td>2 Best estimate plus range</td>
<td>Best estimate (in large font) and a range of numeric values, without hyphen</td>
<td>5,000 4,500 5,500</td>
</tr>
<tr>
<td>3 Best estimate plus neutral evaluative labels</td>
<td>Best estimate (in large font) and verbally describes confidence as high, medium, or low</td>
<td>5,000 High</td>
</tr>
<tr>
<td>4 Best estimate plus affective evaluative labels</td>
<td>Best estimate (in large font) and verbally describes confidence as excellent, good, or poor</td>
<td>5,000 Excellent</td>
</tr>
<tr>
<td>5 Best estimate plus range and evaluative labels</td>
<td>Best estimate (in large font) and a range of values with verbal description of confidence as high, medium, or low</td>
<td>5,000 4,500 5,500 High</td>
</tr>
<tr>
<td>6 Best estimate plus affective evaluative labels</td>
<td>Best estimate (in large font) and a range of values with verbal description of confidence as excellent, good or poor</td>
<td>5,000 4,500 5,500 Excellent</td>
</tr>
</tbody>
</table>
### Table III. Consequence Table for the Forest Scenario

<table>
<thead>
<tr>
<th></th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best estimate of saved moose population</td>
<td>5,500</td>
<td>2,000</td>
<td>2,800</td>
</tr>
<tr>
<td>Confidence range in saved moose population</td>
<td>1,500–9,000</td>
<td>1,800–2,300</td>
<td>2,200–4,000</td>
</tr>
<tr>
<td>Average cost ($ per moose saved)</td>
<td>$100</td>
<td>$100</td>
<td>$100</td>
</tr>
</tbody>
</table>

### Table IV. Consequence Table for Windfarm Scenario

<table>
<thead>
<tr>
<th></th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best estimate of bird population</td>
<td>5,000</td>
<td>5,000</td>
<td>5,000</td>
</tr>
<tr>
<td>Confidence range of bird population</td>
<td>4,500–5,500</td>
<td>3,500–8,000</td>
<td>250–10,000</td>
</tr>
<tr>
<td>Cost savings ($ per household per year)</td>
<td>$150</td>
<td>$400</td>
<td>$575</td>
</tr>
<tr>
<td>New employment (# additional year-round jobs)</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

### Table V. Comprehension, Showing Percentage Correct for Experts and Laypeople by Condition

<table>
<thead>
<tr>
<th></th>
<th>Forest Scenario</th>
<th>Windfarm Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lay people</td>
<td>Experts</td>
</tr>
<tr>
<td>Range only</td>
<td>47.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Labels only</td>
<td>83.8%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Combined</td>
<td>79.4%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Note: $\phi_c$ is the Cramer’s V effect index for nominal cross-tabulation tables. Cramer’s V varies from $-1$ to $1$, with values closer to $-1$ or $1$ indicating stronger effects. The comprehension question asked participants to identify the option in which scientists had the least amount of confidence (“In which option do scientists have the least amount of confidence...”).
Table VI. Mean Effort and Difficulty for Lay and Expert Samples by Condition and Scenario

<table>
<thead>
<tr>
<th></th>
<th>Forest Scenario</th>
<th>Windfarm Scenario</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lay people</td>
<td>Experts</td>
<td>Effect</td>
<td>Lay people</td>
<td>Experts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effort</td>
<td>2.66 (.83)</td>
<td>2.17 (.62)</td>
<td>$d = .60, p = .02$</td>
<td>2.40 (.81)</td>
<td>2.00 (.69)</td>
</tr>
<tr>
<td>Difficulty</td>
<td>2.38 (.84)</td>
<td>1.83 (.71)</td>
<td>$d = .67, p &lt; .01$</td>
<td>2.22 (.87)</td>
<td>1.83 (.79)</td>
</tr>
<tr>
<td>Labels only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effort</td>
<td>2.43 (.80)</td>
<td>2.45 (.91)</td>
<td>$d = -.04, p = .88$</td>
<td>2.25 (.81)</td>
<td>2.09 (.75)</td>
</tr>
<tr>
<td>Difficulty</td>
<td>2.15 (.84)</td>
<td>2.36 (1.29)</td>
<td>$d = -.21, p = .27$</td>
<td>1.89 (.81)</td>
<td>2.64 (1.18)</td>
</tr>
<tr>
<td>Combined</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effort</td>
<td>2.71 (.83)</td>
<td>2.15 (.91)</td>
<td>$d = .65, p &lt; .01$</td>
<td>2.48 (.76)</td>
<td>1.85 (.81)</td>
</tr>
<tr>
<td>Difficulty</td>
<td>2.49 (.77)</td>
<td>2.11 (.80)</td>
<td>$d = .49, p = .03$</td>
<td>2.26 (.79)</td>
<td>1.96 (.94)</td>
</tr>
</tbody>
</table>

*Note.* Descriptive statistics reported as Mean (sd). Higher mean values indicates greater effort (difficulty).
Figure 1. Choice proportions for the lay (n = 367) and expert (67) samples in the Forest scenario. Confidence intervals for the proportions were calculated using Wilson’s method. Option #1 = Lowest confidence; Option #2 = Highest confidence; Option #3 = Compromise.
Figure 2. Choice proportions for the lay \((n = 367)\) and expert \((67)\) samples in the Windfarm scenario. Confidence intervals for the proportions were calculated using Wilson’s method.\(^{(34)}\) Option #1 = Highest confidence; Option #2 = Compromise; Option #3 = Lowest Confidence.