COMMUNICATING EFFECTIVELY ABOUT UNCERTAINTY WITH EXPERTS AND PUBLICS

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DECISION RESEARCH

A first step in Effective Communication: Understanding the decision context

- What is the choice being addressed?
- Who are the decision makers?
- Who are the lead participants / stakeholders?
- What are key elements of the problem structure?
  - What are the key objectives?
  - How will these objectives be measured? (performance measures)
  - How will consequences of actions be compared over alternatives?
  - What are the key value tradeoffs?
  - What is the time frame for the decision?
  - What are the major constraints: Poor information? Lack of high-quality data? Political maneuvering? Lack of funding? Mistrust?

Many choices are "too complex" for more casual or less structured approaches

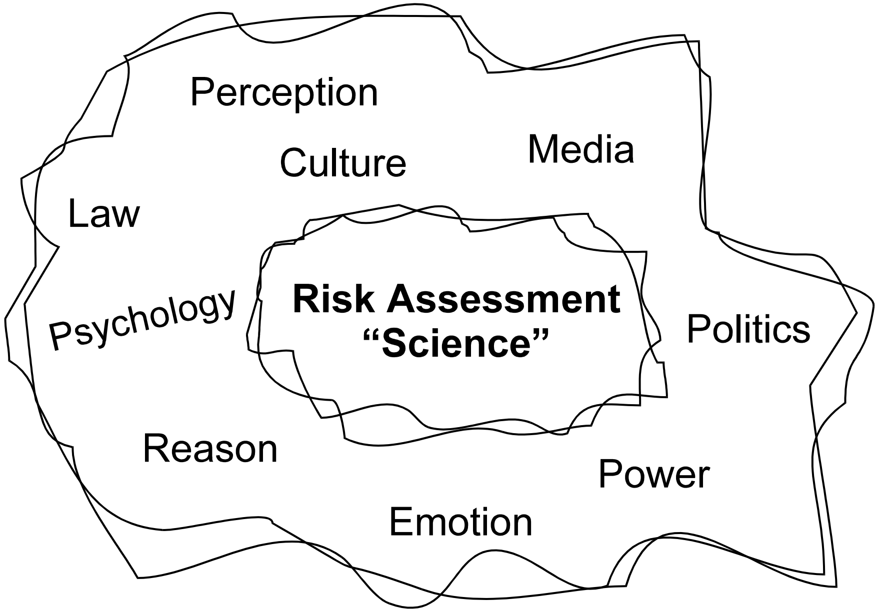
Decision-aiding methods are "a formalization of common sense for decision problems which are too complex for informal use of common sense."

– Ralph Keeney

How decisions are made – in addition to *What* decisions – is critical

Judgmental research emphasizes that it's difficult for people to:

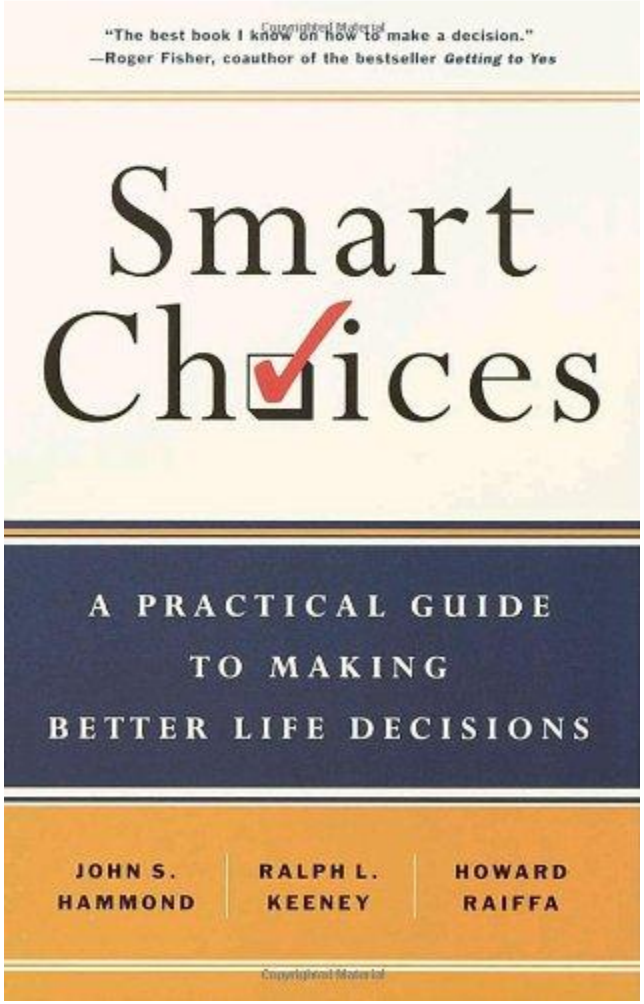
- Make tradeoffs across objectives
  - Anchor on one objective
  - Anchor on one alternative
- Incorporate probabilities
- Overcome overconfidence: too much faith placed in our own experience & knowledge
- Recognize the role of external factors
- Recognize the role of luck in what typically is referred to as "good" or "bad" decision making
- Integrate more intuitive (S1) and more thoughtful (S2) modes of decision making
- Integrate choices across risks and benefits



How to think about all this? Decisions that involve risk and uncertainty are complex, and involve intuition and emotions as well as "science" -- many interests, many stakeholders, tough choices.

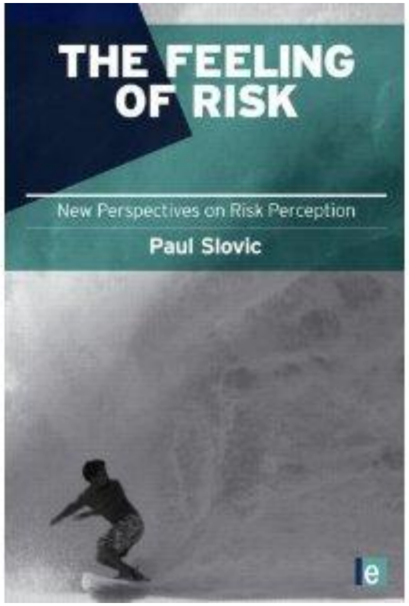
Adopting a defensible decision-making process

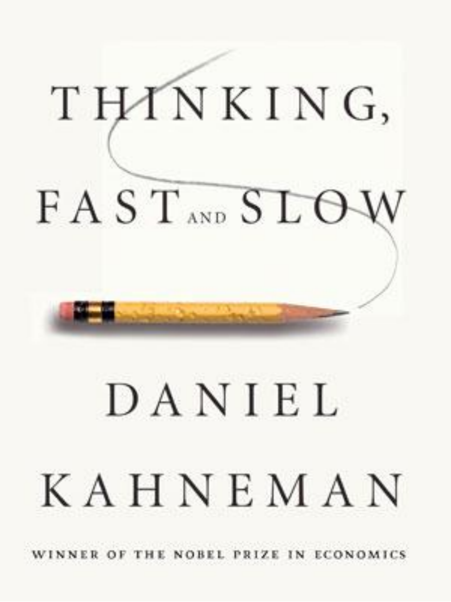
Hammond, J. S., Keeney, R. L., & Raiffa, H. (1999). *Smart choices: A practical guide to making better decisions. Cambridge, MA: Harvard Business School Press.*

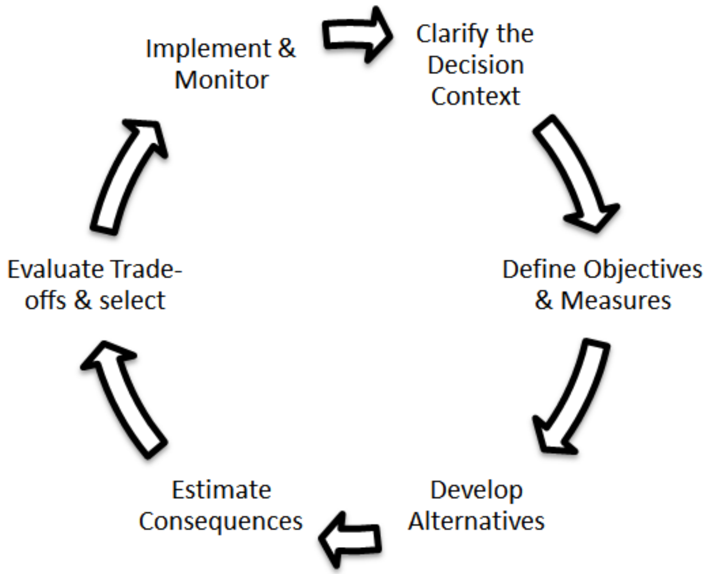


Understanding and integrating information – about values and perceptions as well as facts -- as part of a decision-making process

- Slovic, P. (Ed.). (2010). *The feeling of risk: New perspectives on risk perception*. London, UK: Earthscan.
- Kahneman, D. (2011). *Thinking, fast and slow.* New York: Farrar, Straus and Giroux.



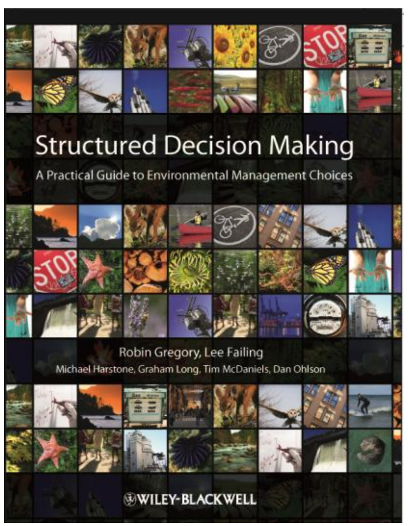




Structured Decision Making

A step-by-step approach to generating and evaluating policy strategies marked by

- Multiple interests
- Multiple participants
- Conflicting information
- Uncertainty



Gregory, R., Failing, L., Harstone, M., Long, G., McDaniels, T., & Ohlson, D. (2012). *Structured decision making: A practical guide to environmental management choices.* Chichester, West Sussex, UK: Wiley-Blackwell.

A second step in Effective Communication: Dealing with Uncertainty

- Bottom line: With due respect to science and good intentions, how effective will management actions be?

  [Good intentions – Implementation – Uncertainty – Outcomes]
- Multiple sources of uncertainty
  - Natural variation
  - Measurement error
  - Model uncertainty
  - Biased judgments
  - Linguistic uncertainty: vagueness, lack of specificity
- Some sources of uncertainty are within managers' control, some are not

Expressions of Uncertainty Link Factual Information (What is) with Values (What matters)

Anticipate multiple perspectives – different people will have different opinions about what is going on and what matters

Bringing uncertainty into multi-stakeholder deliberative contexts

Good scientific analysis is necessary but not sufficient:

- Insufficient attention paid to communication of uncertainty
- Commonly assumed that we know more about future effects than we do (overconfidence, seduction of numbers)
- Emphasis on complex studies and models rather than how well people understand them
- Non-expert, non-science stakeholders can be/feel marginalized
- Dialogue and understanding are discouraged, leading to a loss of trust and – often – difficulties in implementing plans

Communicating Uncertainty Effectively

Bottom line: Experts need to provide clear assessments of what they do and do not know to end users:

- Uncertainty in estimates of outcomes
- Degree of confidence in assessments

Unwillingness to communicate uncertainty?

- Need to overcome bias on the part of many scientists that uncertainty is "too difficult" for laypersons. However…
  - If uncertainty is ignored or understated, end users will lack important information, be overconfident, and may select an inferior option
  - If uncertainty is overstated, end users may ignore or overweight some alternatives and make poor choice (inconsistent w values)

Communicating Uncertainty Effectively

- Effective communication should facilitate:
  - Thoughtful deliberation about the risks and benefits of different options.
  - Informed, value-consistent choices.
- Find balance between completeness and understandability.
  - Not overly complicated, yet sufficiently detailed to be useful for decision making.
  - Present uncertainty to the level of detail that is useful for the decision context.

Expressions of Uncertainty

Binary questions

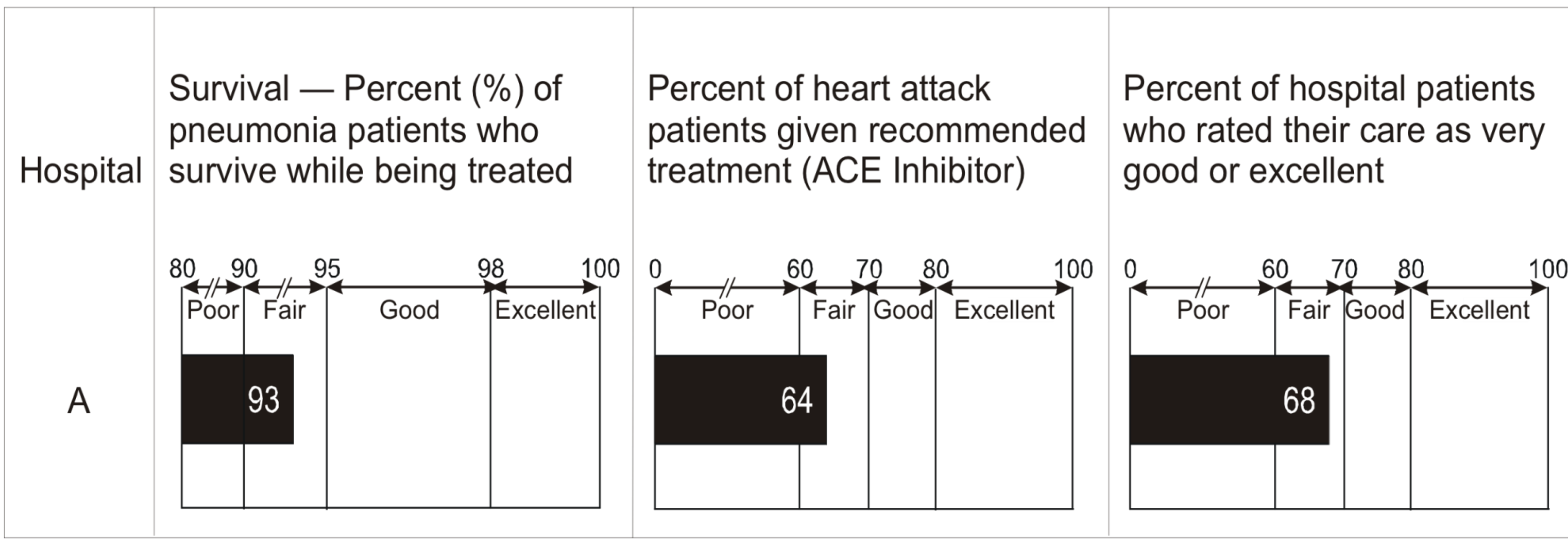
- Will this action reduce emissions?
- Will this increase in temperature cause more than 1/3 meter sea level rise at location X?

Expressions

- Verbal probabilities & evaluative labels
- Numerical probabilities: frequencies, percentages
- Numerical ranges: two-point (low-high), three point (low-high plus best estimate)
- Box-whisker diagrams (low-25%-median-75%-high)
- Probability distributions (density functions, cumulative)
- Other approaches (e.g., belief functions).

Evaluative labels

- Evaluative labels have been shown to facilitate the use of unfamiliar numerical information (Peters, Dieckmann, et al. 2009).



Ranges

- Show low and high estimates:
  - Two point

“The Intergovernmental Panel on Climate Change, which includes more than 1300 scientists from the United States and other countries, forecasts a temperature rise of 2.5 – 10.0 degrees Fahrenheit over the next century.”

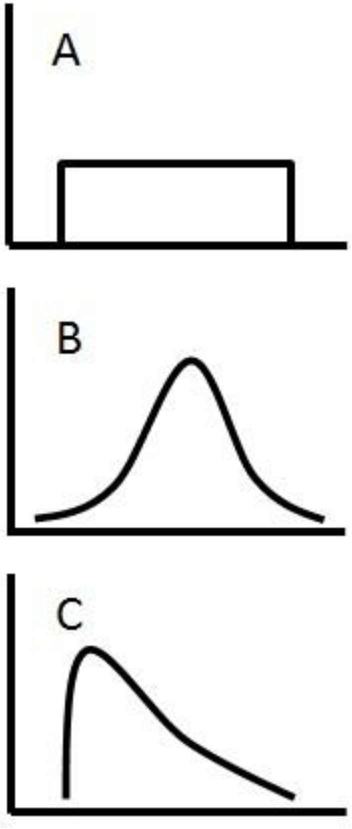
Three point

5.5 (low-high plus best estimate)

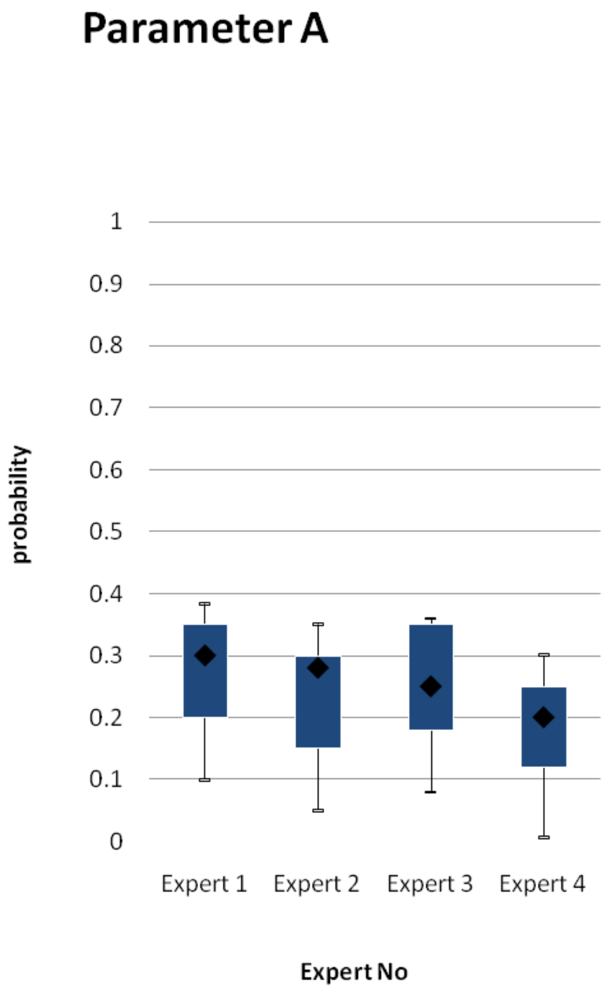
2.5 10.0

- *Research hypothesis: will people who differ in numeric abilities interpret ranges in different ways? What about experts vs public?*

Related question: Will different uncertainty formats affect understanding of the probability distribution?

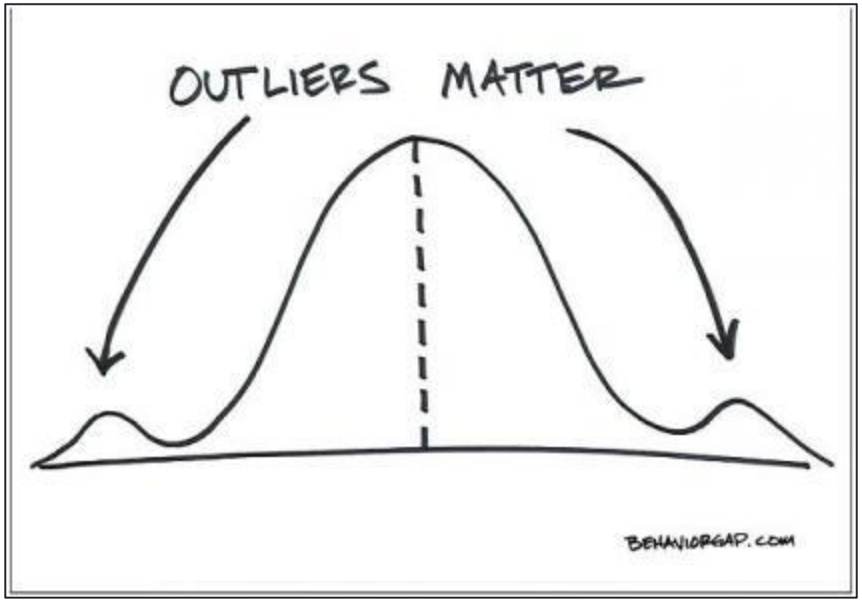


Boxplot: Mean/median and extremes(whiskers)



Common Finding: Expert Predictions of Uncertainty Display Overconfidence and Often Provide a Poor Guide to Outcomes

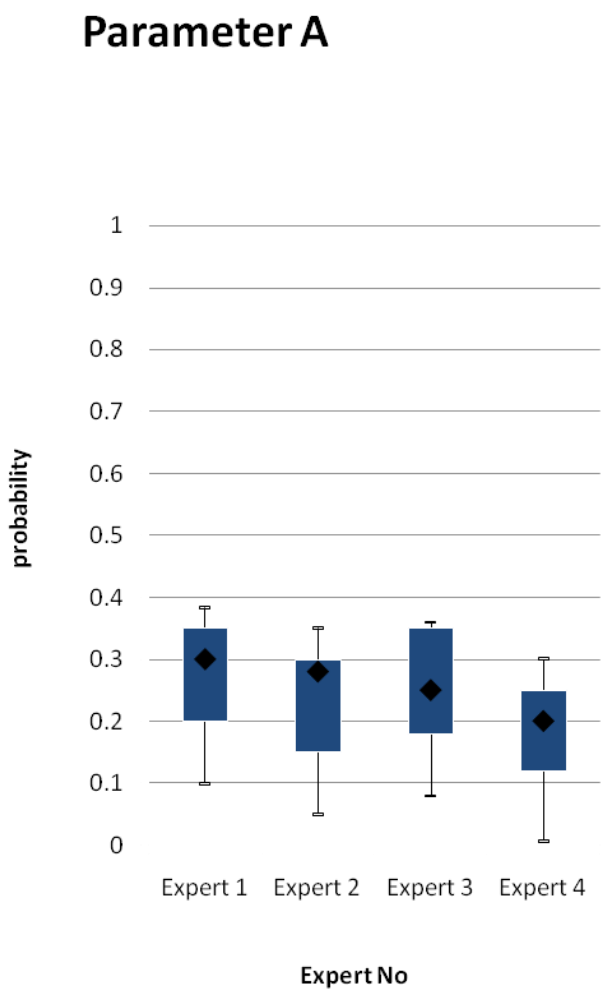
- Uncertainties may look well-characterized when they're not
- Averages from past events may poorly characterize the future
- The "fat tails" associated with extreme events are important when designing responses – do important thresholds exist?
- Actual values far too often lie outside even the "extreme range" predicted by experts – need for debiasing training

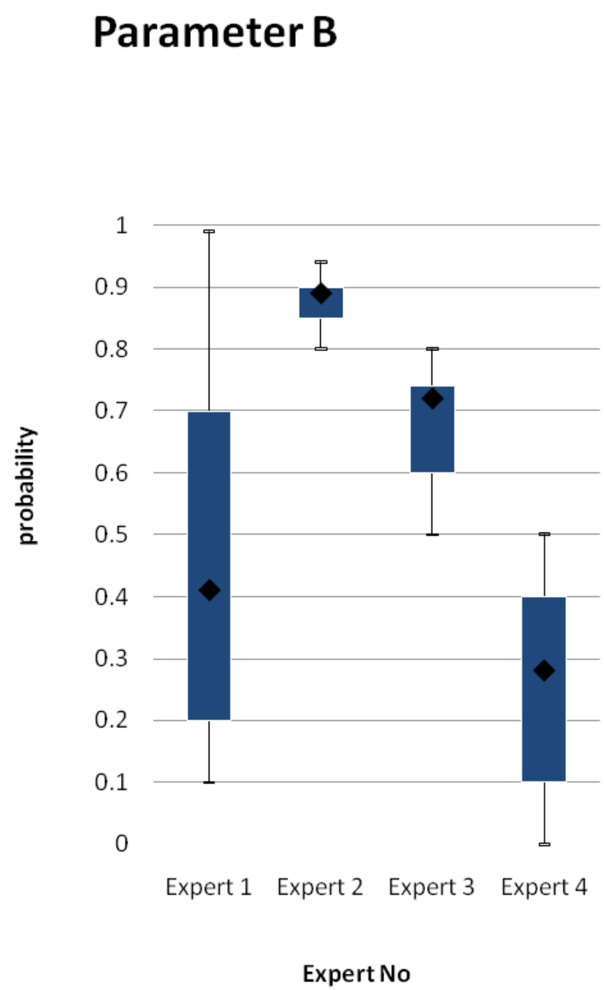


Uncertainty Communication with Experts: Use of Expert Judgment Elicitations

- If working with experts (e.g. on technical committees), many useful EJ techniques:
  - Expose fundamental assumptions regarding how a problem is thought about (mental models)
  - Encourage experts to reach agreement
  - Facilitate learning and use of knowledge from different sources
- EJ elicitations improved by training (biases, JDM)
- Expect that experts may be skeptical of EJ:
  - Undercutting science by merely stating “opinions”
  - Creating dissention by demonstrating disagreements
  - Initiating competition: who is right and who is wrong?

Expert judgment elicitations with experts: two examples





Wide range of judgements…

– priority for research?

- improved info on stakeholder risk tolerance?

Bottom line: even for “experts” it is difficult to predict consequences

“How am I supposed to think about consequences before they happen?”

NSF Award Experiments: Uncertainty Communication with Publics and Experts

- Main research goal: Explore the effectiveness of ranges, evaluative labels, and box plots to increase the comprehension and use of expressions of outcome uncertainty.
- Related research questions:
  - What assumptions are triggered about underlying uncertainty distributions?
  - Will systematic differences be observed between experts and publics in their responses to uncertainty formats?
  - Will the importance (weight) of a concern vary with changes in the uncertainty presentation format?

Study 1: Overview:

- Lay participants (N=367) were randomly drawn from a web panel.
  - Mean age was 40.35 years (range 19-76) and was 65.1% female.
- Expert Risk managers drawn from US Fish and Wildlife service (N=67).
  - Mean age was 45.48 years and was 38.8% female.
- Experts older, more educated, and more numerate.

Study 1: Comprehension and Choice

Research Questions:

- 1: How well can people draw meaning from uncertainty (comprehension)?
- 2: How sensitive are laypeople and experts to evaluative labels in terms of choices.

Manipulated uncertainty formats:

- Numerical range only
- Evaluative label only
- Combined condition

Source: Gregory, Dieckmann, Peters, Failing, Long & Tusler, *Risk Analysis* 2012

Study 1: Scenario

Forests in the northeast of the US 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 and their impacts cannot be predicted as precisely …

	Option 1:	Option 2:	Option 3:
Best estimate of saved moose population	5,500	2,000	2,800
Confidence range in saved moose population [*In condition with labels*]	1,500-9,000 [*Low*]	1,800-2,300 [*High*]	2,200-4,000 [*Medium*]
Average Cost ($ per moose)	$100	$100	$100

Study 1:Example Comprehension Results (% correct)

In which option do scientists have the least amount of confidence in the estimated saved moose population?

	Lay group	Expert group
Range	47%	100%
Label	83%	100%
Combined	80%	100%

- **Range worse than label only or combined for lay group**

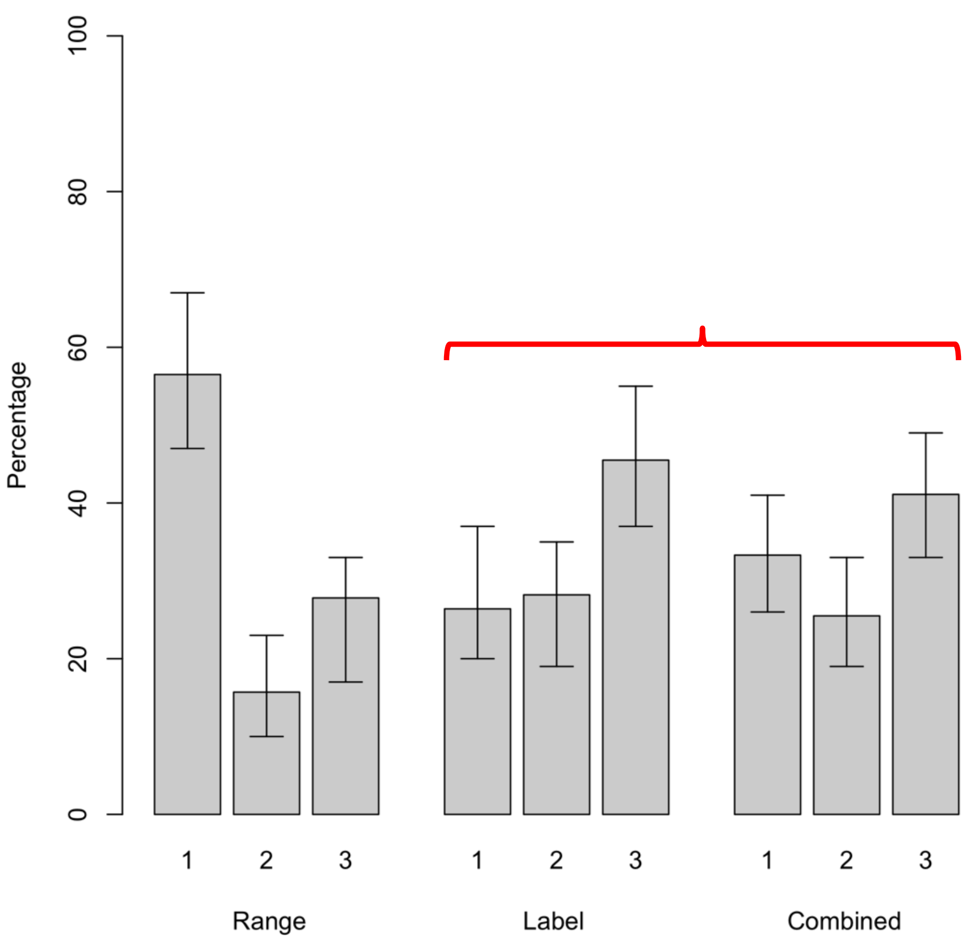
Study 1: Example Comprehension Results (% correct)

For which option is a final saved moose population of xxxx most likely?

	Lay group	Expert group
Range	92%	100%
Label	52%	82%
Combined	83%	93%

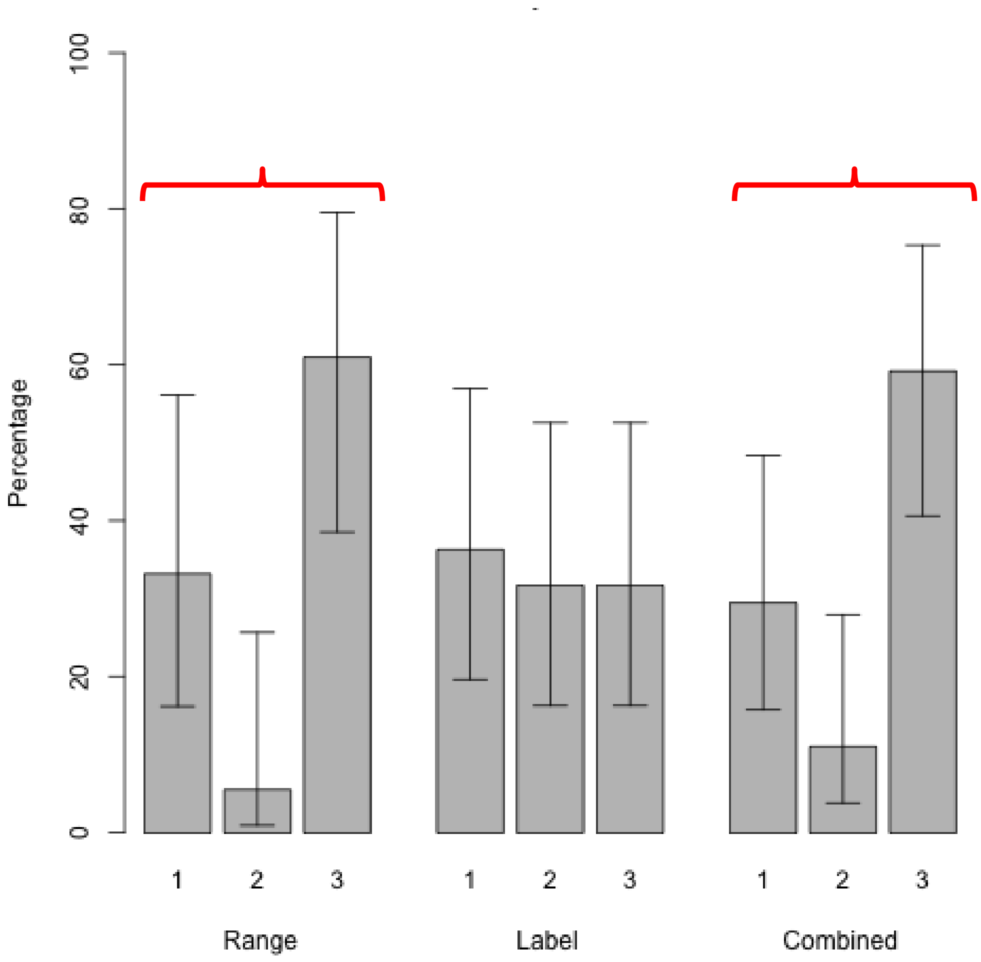
- **Range better than label only and combined for lay group, label only also worse for experts**

Study 1: Public Choice Results



Choice results very similar in labels only and combined conditions implying that labels are the focus even in the presence of ranges.

Study 1: Expert Choice Results



Choice results very similar in range and combined conditions implying that ranges are the focus in the presence of evaluative labels.

Study 1: Conclusion

- With multiple presentations of uncertainty, different audiences can focus on different formats and may reach very different conclusions.

Study 2: Value-consistent choices

RQ: Could the salience of evaluative labels lead laypeople into choices that are inconsistent with personal values?

Manipulated uncertainty format:

- Numerical range only
- Combined condition

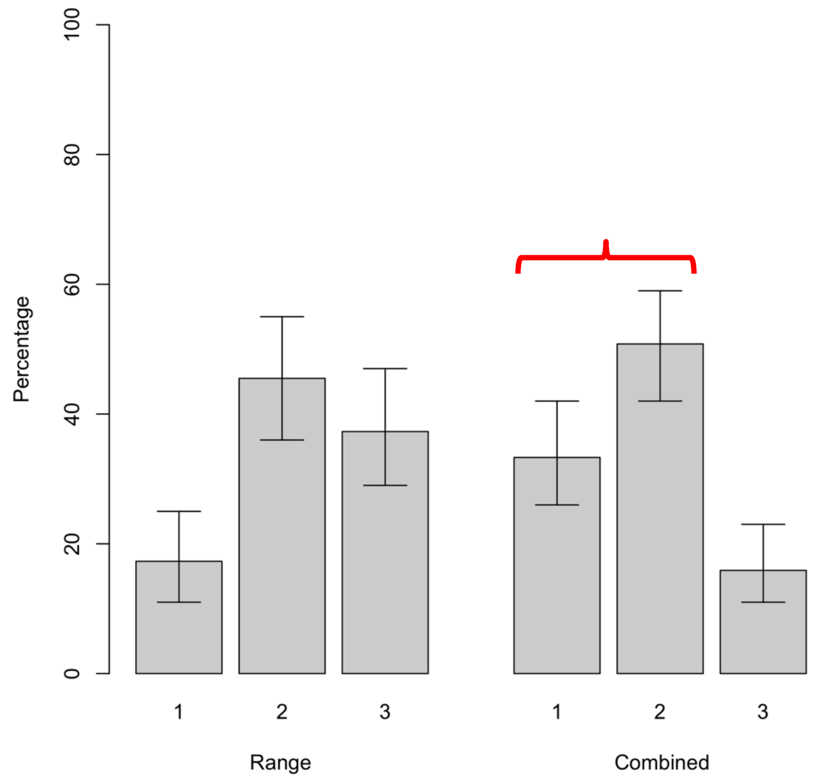
Source: Dieckmann, Peters,Gregory & Tusler
Journal of Risk Research 2013

Study 2: Scenario

The Seshon river in Washington State, which empties into the Pacific Ocean, is well-known for its annual spring run of Chinook salmon. However, fish populations in the river have declined dramatically over the past 75 years, so much so that historical annual runs of nearly 500,000 salmon have been reduced to runs of only about 20,000 fish, although this number is uncertain due to the difficulty of getting accurate fish counts. There is agreement that fish losses are the result of habitat destruction and the building of dams to create reservoirs, used for irrigation by local farmers and to supply electricity to neighbouring communities …

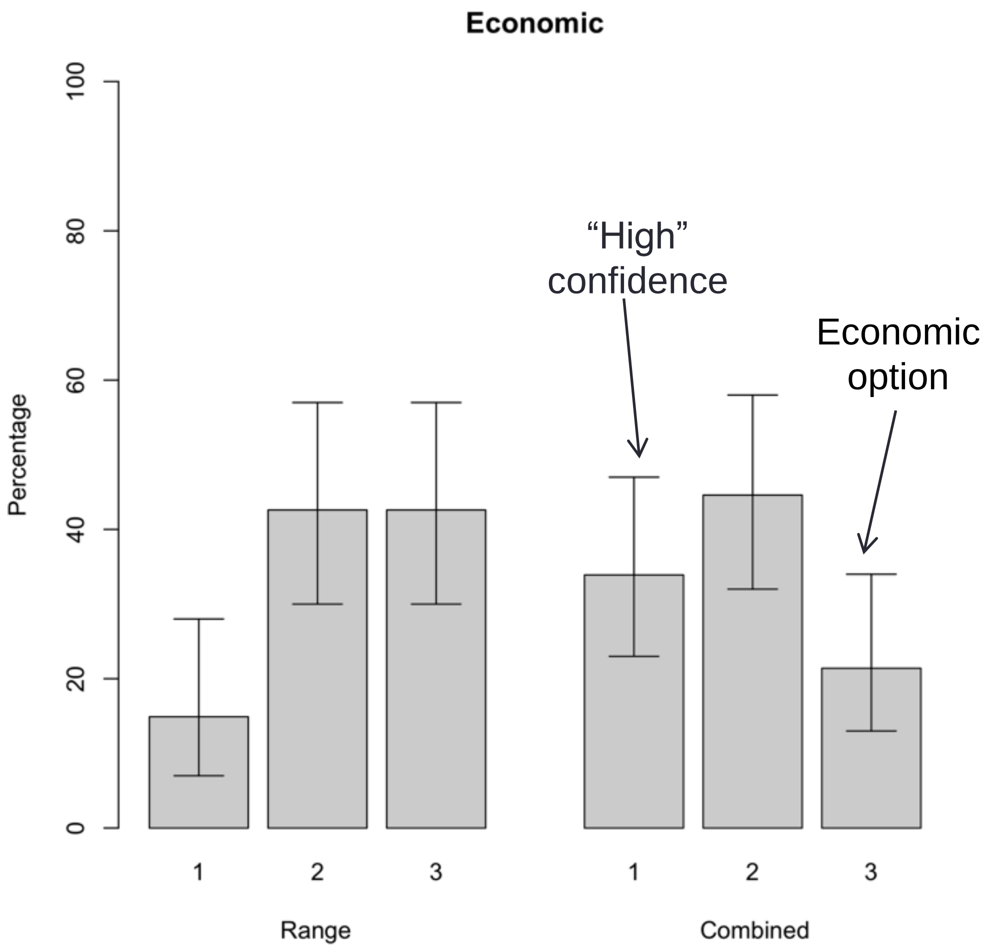
	Option 1	Option 2	Option 3
Best estimate of Salmon Population	20,000	20,000	20,000
Confidence Range in Salmon Population [*In combined condition*]	18,000 –22,000 [*High*]	14,000 – 26,000 [*Medium*]	8,000 – 32,000 [*Low*]
Cost increases ($ per year per household)	$350	$200	$100

Study 2: Lay Choice Results



As in Study 1, the presence of labels increased choices of highest confidence and compromise options.

Study 2: Choices by economically leaning participants



People with strong economic values should choose option #3 (lowest cost).

The presence of the labels decreased choices of #3 and increased choices of #1 (highest confidence).

Thus, labels produced more value-inconsistent choices in this group.

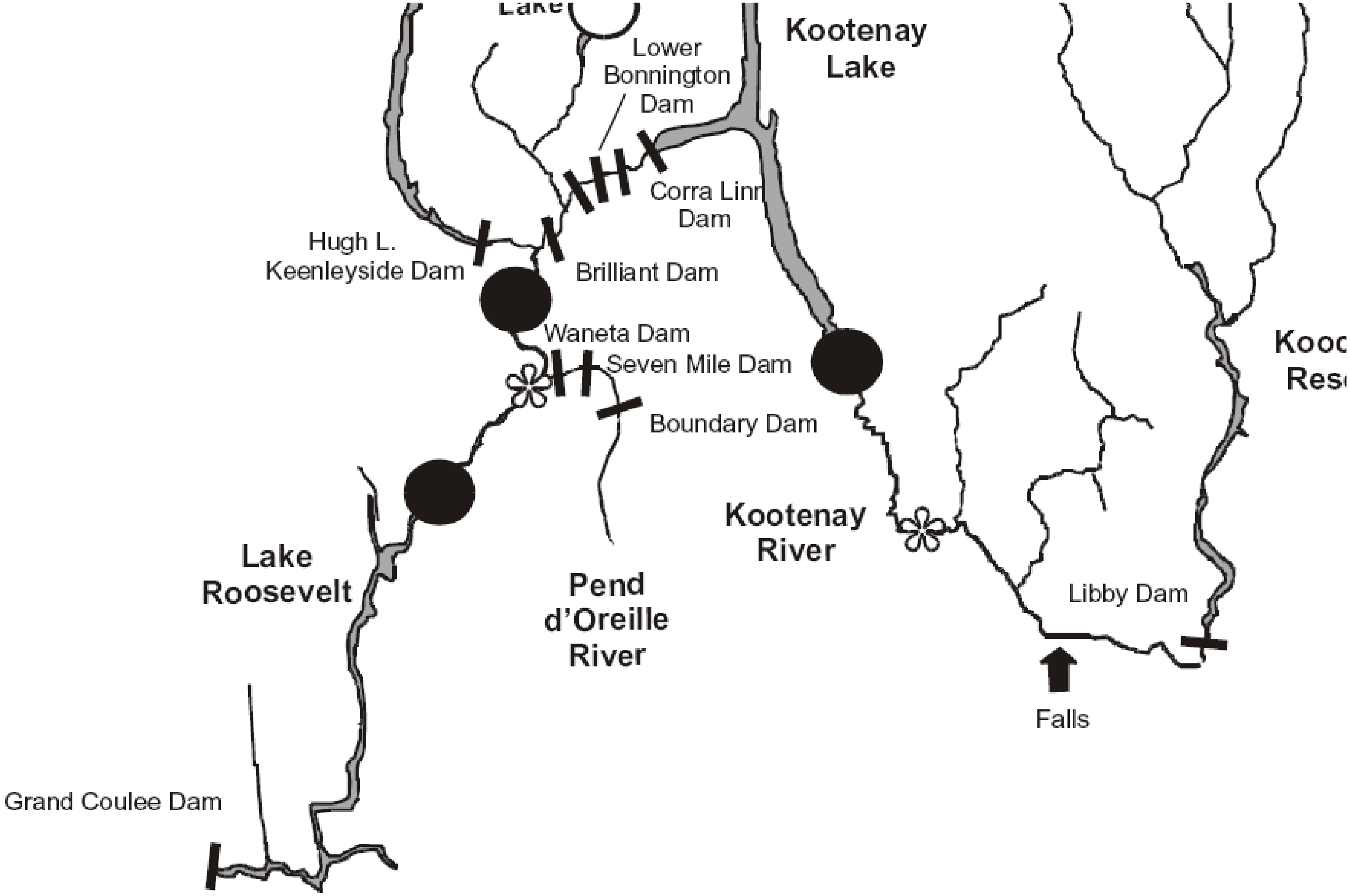
Example 1: Recovery planning for Endangered Upper Columbia River White Sturgeon

Used DA / EJ methods to clarify uncertainty among experts, through development of “science court”

- Expose differences across technical experts
- Explore reasons for these differences
- Consensus position or agreement to disagree?
- Use influence diagrams to clarify “hypothesis pathways”
- Explore degree of confidence that experts hold in their assessments

- Source: Gregory, Failing, Harstone, Long, McDaneils & Ohlson (2012). Structured Decision Making: A Practical Guide to Environmental Management Choices. Wiley-Blackwell.

UPPER COLUMBIA WHITE STURGEON



Upper Columbia River White Sturgeon Recruitment Failure – TECHNICAL EXPERTS

Upper Columbia River White Sturgeon

– Features

- Iconic endangered species (listed)
  - No recruitment in last 40 years
  - Functional extinction within 25 years
- Overlapping jurisdictions
  - Canadian Federal, Provincial, USFWS, State of Washington
- Major industrial interests
  - Mining corporation, hydroelectric utility corporation
- Serious scientific uncertainties
- Recovery plan with too many ‘priority actions’ produced in 2002
- Little activity for several years on Action Plan – why?

UPPER COLUMBIA WHITE STURGEON

- Problem: Apparent failure of White Sturgeon to recruit in Upper Columbia River following construction of hydroelectric dams in 1960s and 1970s

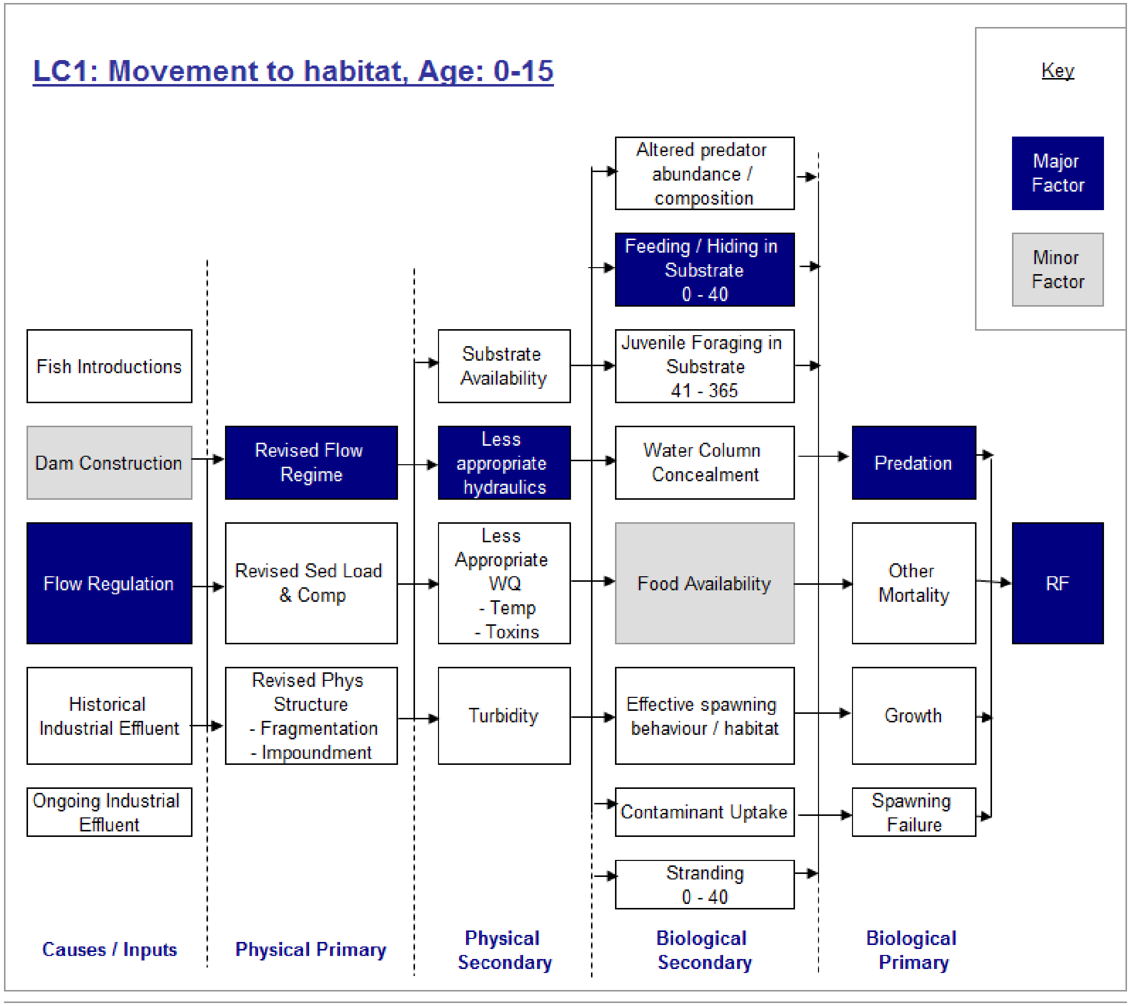
- How to aid recruitment through
  - altering flows (volume, temperature, turbidity, timing);
  - restoring habitat (food availability, substrate for spawning, rearing, feeding);
  - removing predators
  - other means?

UPPER COLUMBIA WHITE STURGEON

Our work, using SDM techniques:

- Organize and group (“bin”) competing hypotheses
- Develop precise meaning for each hypothesis
- Help experts reach a common understanding of relative importance of hypotheses via “science court” arguments, for and against (presentation plus discussion)
- Clarify ties between hypotheses and management actions
- Link management actions to existing and proposed research
- Prioritize and sequence management and research actions (in progress)
- Clarify extent to which new work would reduce uncertainty

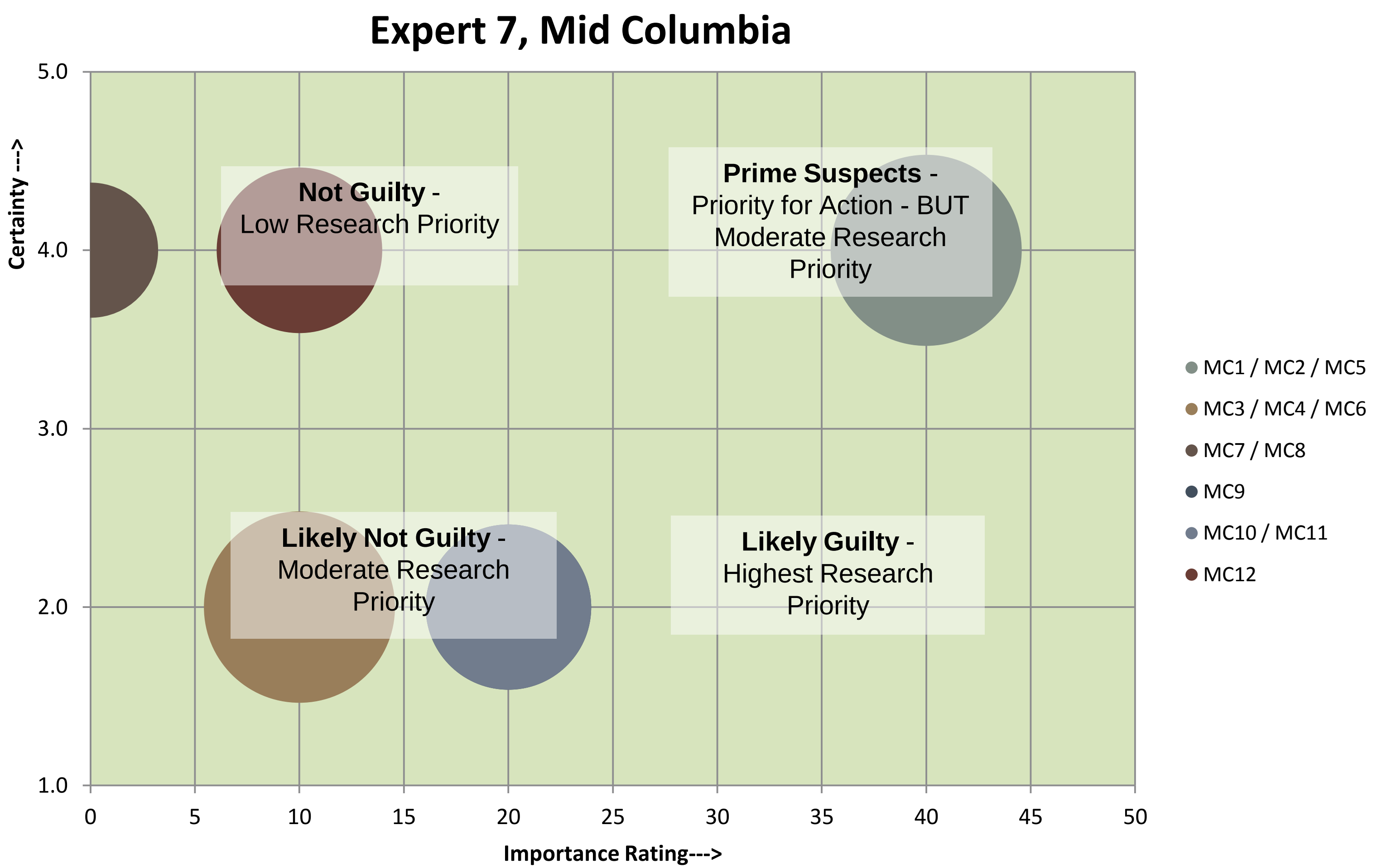
UPPER COLUMBIA WHITE STURGEON



UPPER COLUMBIA WHITE STURGEON

Q1	Q2	Q3
What % of ongoing RF is attributed to this H, based on current knowledge?	**How certain are you in your assessment for Q1?**	**How likely is it that further research could 'confirm' that this H accounts for at least 20% of ongoing RF?**
Distribute 100% points	5 = I expect I could be wrong by up to ±10% points	1 = Very unlikely (<20% chance)
	4 = I expect I could be wrong by up to ±20% points	2= Unlikely (20-40% chance)
	3 = I expect I could be wrong by up to ±30% points	3= As likely as not (40-60% chance)
	2 = I expect I could be wrong by up to ±40% points	4 = Likely (60-80% chance)
	1 = I expect I could be wrong by more than ±40% points	5 = Very likely (>80% probability)

UPPER COLUMBIA WHITE STURGEON



Example 2: Flow 2015 survey responses

Focused on three major topics:

1. Comparison of 3 conditions: effects on choice
   - No uncertainty
   - Three-point range uncertainty (90% CI) – narrow vs. wide
   - Two point range plus evaluative label – high vs. low unc levels
2. Effect of *uncertainty* on importance weight of objectives
3. Descriptions of the role of uncertainty in your work:
   - How often uncertainty is associated with actions
   - How uncertainty generally is communicated
   - Importance of different sources of uncertainty

Following slides based on preliminary analysis only (n = 76)

Flow2015: Scenario 1, Choice percentages by condition

	10cms	20 cms	40 cms
No uncertainty	14.3%	21.4%	64.3%
Low uncertainty	25%	41.7%	33.3%
High uncertainty	13.0%	60.9%	26.1%

Flow2015: Scenario 2, Choice percentages by condition

	Mix A	Mix B	Mix C
No uncertainty	50.0%	42.9%	7.1%
Low uncertainty	54.1%	32.4%	13.5%
High uncertainty	25.0%	58.3%	16.7%

Flow2015: Talking Uncertainty with Different Audiences

Audience	< 25% of time	25-75% of time	>75% of time
Technical experts	8%	52%	40%
Public	36%	51%	13%
Officials & other DMs	34%	54%	10%

Flow2015: Formats used for Presenting Uncertainty

Format	Mean weight	% who ranked highest
Evaluative label 3-point interval	7.14 4.84	32.0 18.7
Box plot Certainty equivalent	3.79 3.73	12.0 10.7
2-point interval Full prob distribution	3.65 2.20	8.0. 8.0

Flow2015: Sources of Uncertainty in Typical Projects

- Complexity is big winner (63% ranked highest)
- Randomness (11% ranked highest)
- Lack of knowledge (9.3%)
- Expert disagreement (6.7%)
- Expert bias, unwillingness to admit uncertainty, and expert incompetence all rankedvbery low (<3% ranked highest)

Results in sharp contrast to public samples, which rate expert bias, unwillingness to admit uncertainty, and expert incompetence as among the highest

(Tentative) Guidelines: Evaluative Labels

- Advantages of evaluative labels
  1) Can help (laypeople especially) evaluate the meaning of numerical uncertainty expressions.
  2) Can highlight particular aspects of uncertainty that are important for the decision context.
- Disadvantages of evaluative labels
  1) People may think less with simple yet salient representations; leads to value-inconsistent choices.
  2) Not trivial to define evaluative structure: What defines high or low, good or bad? How many categories are needed?

(Tentative) Guidelines: Numeric Ranges

- Advantages
  - Commonly understood (although not CI – 80% vs 95?)
  - Careful EJ elicitation leads to more accurate endpoints
- Disadvantages
  - Can lead to systematic differences in how people perceive the distribution underlying the ranges. Relates to numerical ability: more numerate individuals are more likely to perceive distribution as normal
  - Assumption of normal distribution enhanced with inclusion of best estimate (3-point distribution)

(Tentative) Guidelines: Boxplots & Graphic Displays

- More precise depictions of uncertainty can enhance understanding and clarity with some audiences
- But other audiences may be confused and "tune out"
  - Boxplot representations of uncertainty may be seen as too complex so uncertainty is ignored(i.e., reliance on single-point best estimate)
  - Accuracy depends on quality of expert elicitations
- Use depends on context: is middle of range (25-75) the focus or are endpoints more important – e.g., cumulative distributions allow direct reading of prob associated with crossing important threshold (species viability)

(Tentative) Guidelines: Multiple Uncertainty Formats

- Multiple presentations of uncertainty
  - Common recommendation so people can use what is best for them.
  - Be aware that different groups may focus on different representations and come to different conclusions.
    - Experts versus laypeople
    - Higher versus lower numerate
  - Need to consider the communication context and whether a focus on different formats could lead to different choices and conclusions.

Bottom-line Guidance for uncertainty communications

- No representation of uncertainty works best in all contexts.
- Both numerical representations and non-numerical evaluative structures are important techniques.
- Simple graphical representations can be very helpful.
- Basic training in understanding probabilities and making decisions (for everyone!) can make a big difference.
- Be clear about the aspects of uncertainty that you want to make most salient – all objectives not equally important.
- Think about how the communication might go wrong as well as how it might go right.
- More learning still to come ….

But uncertainty continues to fascinate and interest us…

"Those once-in-a-lifetime events are beginning to add up."

THANK YOU

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