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Linguistic uncertainty in qualitative risk assessment and how to minimize it
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Summary

Stakeholder deliberations and consensus are often significantly impeded by arbitrary confusion that arises because language is vague, ambiguous, context dependent or underspecified. The aim of this project was to develop methods to identify language-based misunderstandings in qualitative risk assessments. The project developed software created originally to teach graduate students techniques for dealing with language-based uncertainty in interactions with stakeholders.

The software and facilitation strategies that accompany it were further developed and then trialed during the ARC-funded round of meetings to identify and rank hazards confronting Victoria's marine parks and sanctuaries.

This publication summarizes the operation of the software in facilitated contexts and provides some examples of the problems it solves. An earlier version was presented to the New York Academy of Sciences workshop in New York in 2006.

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STRATEGIES FOR RISK COMMUNICATION

Evolution, Evidence, Experience

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Linguistic Uncertainty in Qualitative Risk Analysis and How to Minimize It

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Most risk assessments assume uncertainty may be decomposed into variability and incertitude. Language is often overlooked as a source of uncertainty, but linguistic uncertainty may be pervasive in workshops, committees, and other face-to-face language-based settings where it can result in misunderstanding and arbitrary disagreement. Here we present examples of linguistic uncertainty drawn from qualitative risk analysis undertaken in stakeholder workshops and describe how the uncertainties were treated. We used a process of iterative re-assessment of likelihoods and consequences, interspersed with facilitated discussion, to assist in the reduction of language-based uncertainty. The effects of this process were evident as changes in the level of agreement among groups of assessors in the ranking of hazards.

Key words: **risk analysis; linguistic uncertainty; ambiguity; vagueness; underspecificity; context dependence**

Introduction

Most risk assessments assume uncertainty may be decomposed into *variability* (naturally occurring, unpredictable change) and *incertitude* (lack of knowledge about parameters or models). Incertitude in model parameters and functional relationships may be reduced by acquiring additional data. Variability may be better understood and more precisely characterized but is not reduced by additional data. While useful, this taxonomy overlooks *linguistic uncertainty*, the uncertainty that arises because words have different or imprecise meanings.[1] Language-based uncertainty may be particularly pervasive in workshops, committees, and other face-to-face language-based settings where words and phrases used to describe hazards may be interpreted differently by participants, resulting in misunderstanding and arbitrary disagreement.[2] Resolving such disagreements is an important step if genuine differences of opinion are not to be obscured and meaningful consensus is to be achieved.

Regan and others[1] identified several types of linguistic uncertainty, including the following:

- Ambiguity—words have two or more meanings, and it is not clear which is meant. For example, terms applied to the general notion of a weed include exotic, invasive, noxious, naturalized, volunteer, and nonindigenous. Indiscriminate use of these terms means that it is now often unclear exactly what is meant.[3]
- Vagueness—words allow borderline cases. For instance, the words "low," "remote," and "endangered" are vague in the expressions "the chance of a ship collision is low," "the risk of gene transfer is remote," and "the species is endangered."
- Underspecificity—definitions include unwanted generality. For example, in the expression "there is a 70% chance of rain," the absence of a specified reference class allows for differing interpretations including rain during 70% of the day, rain over 70% of the area, or a 70% chance of at least some rain at a particular site within the area.[4]
- Context dependence—a failure to specify context. For example, imagine an oil spill of 300 L has occurred. The ecological consequences of such a spill in the open ocean would be quite different to those had it occurred within a small estuary.

Treatments for elements of linguistic uncertainty include specification of context, clarification of meaning, specifying data, and sharply delineating categories.[1]

Qualitative risk analysis provides a basis for comparing, ranking, and assessing hazards so that risk

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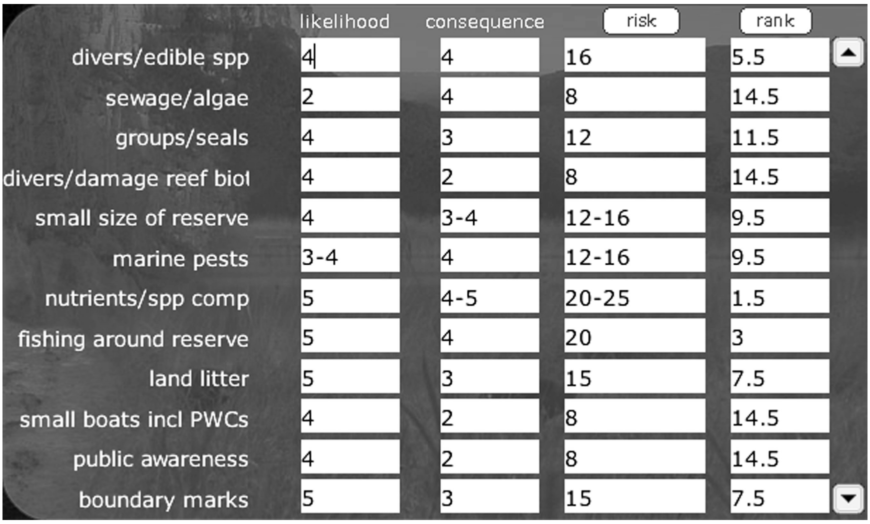

	likelihood	consequence	risk	rank
divers/edible spp	4	4	16	5.5
sewage/algae	2	4	8	14.5
groups/seals	4	3	12	11.5
divers/damage reef biol	4	2	8	14.5
small size of reserve	4	3-4	12-16	9.5
marine pests	3-4	4	12-16	9.5
nutrients/spp comp	5	4-5	20-25	1.5
fishing around reserve	5	4	20	3
land litter	5	3	15	7.5
small boats incl PWCs	4	2	8	14.5
public awareness	4	2	8	14.5
boundary marks	5	3	15	7.5

FIGURE 1. List of hazards, likelihood and consequence scores as point estimates or intervals, and calculated risk scores and risk ranks as displayed by a software tool[15] designed to assist in reduction of language-based misunderstandings.

managers can focus attention on the most severe risks. Frameworks for such analysis offer definitions of likelihood and consequence that depend on evaluations of extent and/or likelihood of exposure and the importance of the consequences.[5–7] The interpretations of these joint facets of each hazard determine the acceptability of the risks.

Qualitative risk analysis often involves subjective judgments by stakeholders, expert and otherwise, who are susceptible to a range of forces that have little to do with facts or data. Recognized frailties include anchoring, framing, context dependence, and motivational bias.[8–12] Linguistic uncertainty may contribute substantially to the uncertainty surrounding the analysis, yet it has received relatively little attention in risk analysis literature.

Arbitrary language-based differences in qualitative risk assessments may be minimized by using iterative re-assessment of likelihoods and consequences, interspersed with facilitated discussion to identify, describe, and resolve language-based misunderstandings.[13] The approach is applicable in qualitative risk analysis where ordinal values are assigned to likelihoods and consequences (sometimes called semiquantitative risk analysis[5]), resulting in risk scores for each hazard.

Here we briefly outline this approach, then present examples of linguistic uncertainty encountered in a series of stakeholder workshops and describe their treatment. Finally, we present evidence that the approach can have a measurable effect on workshop outcomes.

Workshop Approach

In workshop settings, the approach we advocate begins with the identification of a suite of hazards. For example, in a marine protected area, hazards might include divers removing edible species from the reserve, a nearby sewage discharge affecting the algal assemblage, and groups of park visitors disturbing seals.[14] Assessors complete an initial ranking of the hazards using an ordinal scoring system for likelihood and consequence to generate a risk score for each hazard (FIG. 1). The level of agreement in risk scores between pairs of assessors is measured using Spearman's rank correlation. This is a simple statistical procedure in which a correlation coefficient of +1 indicates perfect agreement in rank order, −1 perfect disagreement, and values around 0 indicate no particular pattern between the two sets of ranks.[16] The correlations make it possible to identify assessors between whom disagreement is the greatest (FIG. 2), while examination of the likelihood and consequence scores distinguishes hazards that contribute most to this disagreement.[a]

In the workshop setting, assessors discuss disagreements in detail. Sometimes, the discussion results in

[a]A software tool, *Subjective Risk Assessment*,[15] designed to facilitate the style of qualitative risk assessment described, is available for download from the Australian Centre of Excellence for Risk Analysis at http://www.acera.unimelb.edu.au/materials/software.html.

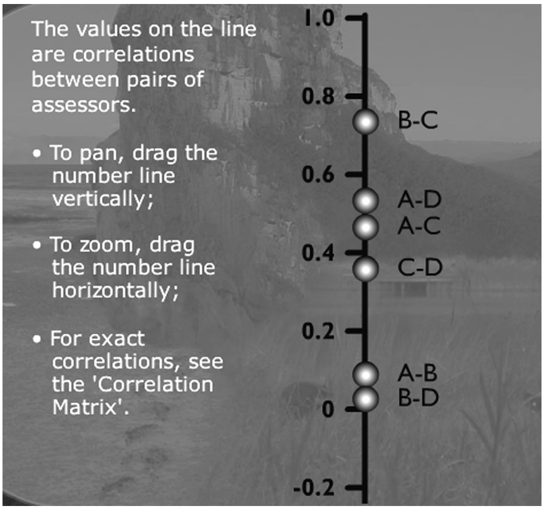

FIGURE 2. Correlations between pairs of assessors as displayed by a software tool[15] designed to assist in reduction of language-based misunderstandings. Agreement is highest between Assessors B and C and lowest between Assessors B and D.

the sharing of additional information that may not have been available to everyone. Often discussion results in more specific definitions of the hazards, which resolve some, but not all, differences of opinion.

Following identification of disagreements and discussion, assessors revise their definitions of terms and meanings. They then are given the opportunity to revise their likelihood and consequence scores. Risk scores and hazard ranks are recalculated. Any change in the level of agreement is reflected in the rank correlation coefficients. The assessors may then go through additional cycles of assessment, scoring, discussion, and reassessment.

Examples of Linguistic Uncertainty and Their Treatment

In 2004 and 2005, a series of stakeholder workshops was held to identify threats to valued natural attributes of marine environments in Victoria, Australia. The following examples of linguistic uncertainty are drawn from those workshops, the majority of which concerned marine protected areas.[14]

Example 1: Ambiguity

Hazard: Nutrient loads from rural and urban runoff causing algal blooms.

Problem: Stakeholders did not share a common understanding of what type of algal bloom the hazard entailed. Some assumed the bloom was one of phytoplankton, while others assumed mats of epiphytic macroalgae.

Treatment: *Clarify meaning*. Once the problem was recognized, the hazard was defined more precisely as an unacceptably high concentration of phytoplankton cells. (Note that the subsequent question of *how high* a concentration was unacceptable [e.g., more than 5000 phytoplankton cells per mL] would be a problem of vagueness, which is addressed in the next example.)

Example 2: Vagueness

Hazard: Oil spill with sanctuary-wide effects on flora and fauna.

Problem: The effects of an oil spill would depend on, among other things, the size of the spill. Furthermore, the frequency with which spills occur might also be expected to vary with the size of the spill.

Treatment: *Delineate categories*. While quantities of oil could have been used to delineate categories, in this case workshop participants opted to use type of vessel as a broad descriptor for both quantity and frequency of spill. Spills from recreational boats would tend to be small (i.e., tens of liters) and might occur several times a year. Commercial fishing vessels could carry larger quantities of oil but are obliged to comply with more rigorous regulatory standards in terms of equipment and operation. Commercial shipping may carry thousands of tonnes of oil. There have been three spills of more than 1000 tonnes on or near the Australian coast since 1970, two of which were greater than 10,000 tonnes.[17]

Example 3: Context Dependence

Hazard: Dogs not under effective control disturbing (i.e., causing a change in behavior of) native shorebirds and seabirds, including migratory waders.

Problem: This hazard related to a popular urban beach and was contentious from the outset. Stakeholders were sharply divided on the issue of whether or not dogs should be permitted on the beach, part of which forms part of a small marine sanctuary. During extensive discussion, it became apparent that pro-dog participants were considering the offshore rocky reefs, where many birds roost but few dogs venture. Anti-dog stakeholders, on the other hand, were concerned primarily with sandy areas close to or above the high water mark, where disturbance is apparently less even though dog activity is greater.

Treatment: *Specify context*. The use of a conceptual model helped to clarify that participants in this debate were referring to different parts of the intertidal region where the levels of bird disturbance also differed. Nonetheless, the entrenched difference of

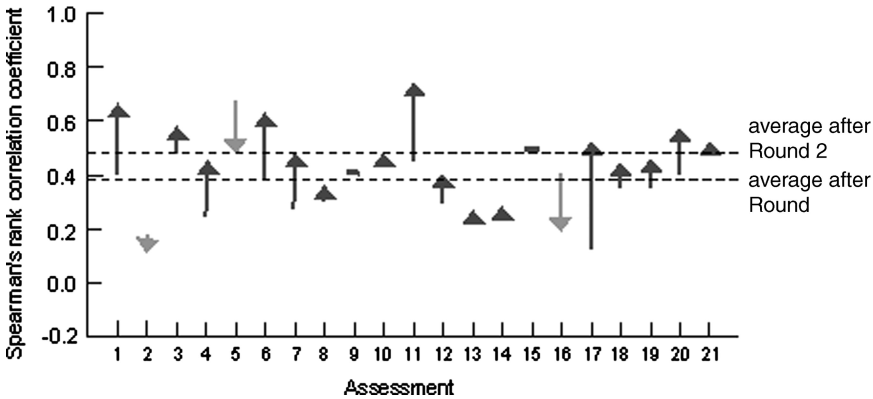

FIGURE 3. Change in the median level of agreement between assessors or groups of assessors after software analysis of language-based misunderstandings. The majority of assessments concerned marine protected areas,[14] two related to terrestrial national parks (number 2 and 3),[19,20] two addressed the concerns of a coastal catchment management authority (number 9 and 11), and one was a class exercise for risk assessment students (number 1).[13] Arrows indicate magnitude and direction of change in the correlation coefficient.

opinion about dogs being present on the beach, irrespective of any disturbance to birds, was not resolved and is unlikely to be.

Example 4: Underspecificity

Hazard: Marine debris from beyond the marine national parks resulting in smothering of, entanglement with, or ingestion by marine organisms.

Problem: Some stakeholders took the generic term "marine debris" to mean only items of litter, such as discarded plastics, while others assumed it also included lost fishing gear. This created difficulties when scoring the hazard because participants were scoring different types of litter.

Treatment: *Clarify the definition*. After some discussion, the consensus was to consider both general litter and lost fishing gear in the hazard. A point not raised during the workshop was that such a definition could also be taken to include other items, such as wreckage from vessels.

Example 5: Underspecificity, Compounded by Vagueness and Context Dependence

Hazard: Pollution, groundings, and anchoring from recreational boating affecting marine communities and habitats.

Problem: The initial problem was one of underspecificity in that there were no data on the extent of recreational boating activity in the area of concern. The number of recreational boats operating along this regional coastline was clearly an issue that would affect the likelihood of the hazard eventuating.

Treatment: Discussion to address underspecificity centered on estimating the extent of recreational boating activity. However, this process generated further linguistic uncertainty. Descriptors like "few" and "many" were used extensively. As well as the problem with the use of inherently vague terms, it gradually became apparent that individual perceptions of how many boats constituted "few" or "many" depended on the frame of reference used. For a participant using as a baseline the number of boats in nearby Port Phillip Bay (the preferred destination of 48% of polled owners of the state's 158,000, registered, recreational boats[18]), 10 boats would seem to be "few," but if the frame of reference was locally based boats, 10 would constitute "many."

Effect of Reduced Linguistic Uncertainty

The iterative re-assessment approach described above was initially developed as a student exercise[13] and has since been used in environmental risk assessment workshops for both marine and terrestrial protected area management,[14,19,20] for the irrigation industry,[21] and in catchment management. Recorded changes in median correlation coefficients range from a decrease of 0.2 to an increase of 0.4, indicating substantial changes in the level of agreement between groups of assessors (FIG. 3). In 75% of cases, the change was an increase, indicating a greater level of agreement. In a few cases, apparent agreement in the initial ranking proved to be based on differences in interpretation of the hazards.[14] Once these were resolved, true differences of opinion became more evident.

Conclusions

Participants in workshops, committee meetings, and other face-to-face language-based settings should be aware of the potential for linguistic uncertainty to introduce misunderstanding into discussions and result in arbitrary disagreement. Facilitators of risk assessment workshops, in particular, are in a position to take positive steps to minimize such uncertainty by using the iterative re-assessment approach to risk ranking. They can improve the quality of their workshop outcomes by minimizing misunderstandings and thus presenting a relatively unobscured picture of stakeholder opinions, be that one of consensus or genuine difference of opinion.

Acknowledgments

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Conflicts of Interest

The authors declare no conflicts of interest.

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