Fisheries Management and Ecology

Fisheries Management and Ecology, 2010, 17, 501–512

Categorising the risks in fisheries management

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Abstract The many risks associated with fisheries management can be attributed to the substantial uncertainties that exist within fishery systems and their numerous possible consequences for fishers and fish stocks. Compounding these risks are the possible disparities between different fisheries professionals on the nature and source of these risks. This paper attempts to categorise the risks as reported by fishery scientists and managers in Australia and along the US Atlantic Coast. Through the use of semi-structured interview data, this paper attempts to provide a categorisation of the risks identified by fisheries professionals; and to compare the identified risks by professional group and by country. The analysis yields three broad categories and 12 subcategories of risk found in both nations. Results indicate that: (1) fisheries management risks can be broadly categorised through interview data; (2) the frequency of identification of a particular risk category reflects the management system in which they operate; and (3) risk categorisation could be useful from a risk management perspective as risks in different categories may be evaluated and managed using different risk management approaches.

KEYWORDS: Atlantic coast fisheries, Australian fisheries, political risk, risk management, semi-structured interviews, uncertainty.

Introduction

Research into risk in fisheries management has grown, possibly with the increasing realisation that exploitation of marine resources has led to lower productivity and, in some cases, stock collapses (Walters & Maguire 1996; Charles 1998; Roberts & Hawkins 1999; Hutchings & Reynolds 2000; Dulvy *et al*. 2003). Although risk within fishery systems has been widely acknowledged by researchers (Francis & Shotton 1997; Charles 1998; Harwood & Stokes 2003; Peterman 2004), a comprehensive understanding of the risks identified by the different professional groups involved in fisheries management is not available (Smith 1988). Methods of risk management are contingent on the types of risks being identified, which can change over temporal and spatial scales and vary between individuals and groups (Harms & Sylvia 2001; Peterman 2004; Althaus 2005; Delaney & Hastie 2007). Research has highlighted the importance of articulating definitions of potential risks within fisheries management. For example, Peterman (2004) stressed that 'to avoid misunderstandings, fisheries scientists, managers, and stakeholders should always clearly state what they mean by the term risk' (p. 1332). Francis and Shotton (1997) stressed the informal, non-quantitative, undocumented and loosely linked way in which risk management is connected to risk assessment in fisheries management. They attributed the lack of explicit direction for managers and scientists on how to deal with different risks to the

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doi: 10.1111/j.1365-2400.2010.00749.x

often conflicting (but rarely articulated) way in which risks are managed.

A number of quantitative (Walters 1986; Hilborn *et al.* 1993, 2001; Rosenberg & Restrepo 1994; Punt & Hilborn 1997; Punt & Walker 1998; Pearsons & Hopley 1999; Touzeau *et al.* 2000; Puga *et al.* 2005; Groger *et al.* 2007) and qualitative (Francis 1992; Hobday *et al.* 2004; Fletcher 2005; Astles *et al.* 2006; Astles 2008) risk-based methods have been used in fisheries management as a way to mitigate potential undesirable outcomes associated with harvesting activities and extreme events, and as a means to prioritise research and management. Each of these methods are, at their core, an attempt to identify and rank the risks associated with the different uncertainties found within fisheries and articulate the consequences of these uncertainties for the associated human and environmental systems. Previous research has organised the various sources of uncertainty common to fisheries systems, ecology and conservation biology (Francis & Shotton 1997; Charles 1998; Regan *et al.* 2002; Harwood & Stokes 2003; Peterman 2004). Categorising uncertainty in this way has proven useful in the development of strategies for management as it has allowed separate fields of expertise to develop to consider different forms of uncertainty. A similar 'divide and conquer' approach may be employed to understand the various sources of risk in fisheries management and thus provide the groundwork for the development of a comprehensive risk management framework for fisheries.

A key problem in any such categorisation of 'risk' lies in the ambiguity associated with the differing usage of this term across the multiple disciplines that fisheries professionals may be associated with (Adams 1995; Althaus 2005; Hokstad & Steiro 2006). Any categorisation of risks in fisheries management must therefore take into account the risks identified by fisheries professionals that are involved with on-the-ground management of marine fisheries and should examine the extent to which these identified risks vary between fisheries professionals. This paper investigates such 'on-the-ground' categorisation of the risks in fisheries by examining the most commonly identified risks in responses from semi-structured interviews with fisheries professionals in Australia and USA.

Fisheries management in Australia and USA

Modern industrial countries manage marine fisheries in similar ways, usually by limiting fishing activities through a top-down approach, with overall control given to a central governing institution (Acheson & Wilson 1996; McCay & Jentoft 1996). Fisheries management in both Australia and USA is a hybrid of federal and state-level management, guided by legislation but integrating various aspects of stakeholder participation or co-management throughout the process. This strategy raises the possibility that risk becomes a much broader and more complex issue given the diversity of the groups involved. Additionally, both the US and Australian systems place emphasis on the scientific assessment of the resource and the use of harvest regulations and limits to control fishing pressure – both requiring extensive cooperative interaction between scientists and managers. The interpretation and role of risk within fishery management is expected to differ among management participants because the goals, priorities and values of the players differ (Adam *et al.* 2000).

Materials and methods

A qualitative research design based on in-depth personal interviews and grounded theory data analysis (Strauss & Corbin 1990) was chosen to capture the various ideas of risk held by fishery professionals in the two countries. Exploratory qualitative research methods like those used in this study are appropriate when exploring phenomena like risk (Marshall & Rossman 1998) and have been used routinely as a measure for complex social issues in natural resource management such as trust (Davenport *et al.* 2007). Further, grounded theory is an inductive method that allows for complexity in the interview data to be maintained while still allowing for distinct categories to be developed.

Study participants were chosen from publically funded fishery management institutions on the Atlantic Coast of USA (15 states from Maine to Florida, including Pennsylvania) and in all six Australian states as well as the Northern Territory and the Commonwealth (ACT). While the sample size is not intended to be statistically representative of the entire population in either country, it does represent a cross-section of fishery professionals as all state and federal institutions along the Atlantic coast were included in US interviews and all state or territory and federal institutions were included in Australia. Interviewees included 12 fisheries scientists and 10 fisheries managers in Australia, while the US Atlantic coast interviews consisted of 10 fisheries scientists and eight fisheries managers ($n = 40$). All fisheries professionals interviewed were involved in the management or scientific assessment of fish stocks in state (0–3 nautical miles) and/or federal (3–200 nautical miles) waters. Interviews were audio-recorded using the same list of questions as a guide to semi-structured

conversations (see Appendix 1 for a copy of the interview pro forma).

The term fisheries scientist refers primarily to stock assessment scientists while the term fisheries manager refers to those professionals who play a formal role in making decisions (usually in terms of developing regulations) about marine fishery resources. Fisheries professionals are generally expected to have a working knowledge of both biological science and fisheries management and policy. This can make the classification of profession unclear. Past studies have indicated that even within designated professional groups, perceptions of fisheries management may vary (see Wilson *et al*. 2002 and Delaney & Hastie 2007). However, for the purposes of this study, participants were asked to identify the risks they encountered within their current professional role, which was self-identified as either a fisheries scientist or a fisheries manager.

Survey instrument

A semi-structured interview tool (see Appendix 1) was used to assess: (1) in what capacity the participant was involved in fisheries management or science; (2) how the concept of risk was used in their assessment/management work and whether they found the concept useful; and (3) if there was any formal process for determining what risk assessment technique or techniques are used on the fisheries they are involved with. The first two questions were designed to uncover specific identifications of risk within their professional schema and the third question was designed to elicit identification of specific risks with which they were engaged. Only the answers to these three questions were used for this present study. The full interview included 24 questions and was used as part of a separate project designed to develop national risk management guidelines for data-poor fisheries (Scandol *et al*. 2009).

This analysis focussed on: (1) categorising the risks identified by fisheries professionals from the two international jurisdictions; (2) comparing risk identification between professional groups and international jurisdictions and; (3) examining where risks are identified most often after the risks were categorised. Individual participants remained anonymous but each individual was identified as either a manager or scientist from either Australia or the USA.

Analytical methods

Participant responses were categorised using post-coding (Miller 1983) to identify emergent themes that followed Strauss and Corbin's (1990) interview data interpretation techniques. Based on a review of field notes and transcribed texts, categories of risk were developed by grouping similar themes, phrases and words into categories. These categories were grounded on the participants own words collected during interviews. A sample of the transcribed interviews from both nations was then reviewed to verify the initial categories and identify additional subcategories. All transcribed interviews were then scored by two different researchers using the risk categories. Any differences between the two researcher's scoring results were discussed until agreement was reached.

Quantitative comparisons were then undertaken between countries and between professions to determine to what extent the identification of risk varied between groups. Twelve separate non-exclusive categories emerged through data analysis, so the highest possible score for any contribution to a risk category would be 40 (since $n = 40$), whereas the highest possible score for any one individual's identification of risk would be 12 (as 12 categories emerged). Fisher's exact tests were used to determine whether the scores were significantly different between groups.

Coding example

In one of the responses to the question 'How do you see the concept of 'risk' being used in your fisheries assessment/management work?' one manager answered:

> 'As a fisheries manager, we have to evaluate the resources available and the benefits that we can obtain from those resources without putting that fishery at risk. By putting at risk, I am talking about sustainability of the fisheries, the industry, and how it is going to affect the environment. To what point is human activity going to be putting a fishery at risk, including the fishers, the species, and the environment?'

This participant was coded as identifying risk in three ways; namely species-level (IIa), ecological (IIb), and social (IIc) as the answer explicitly mentions risk in his work associated with individual species, the environment and the fishers, respectively.

Results

Qualitative categories of risk in fishery management

Fisheries management in Australia and the US involves a system of scientists, managers and stakeholders

contributing in various capacities to develop a plan of how harvested marine resources are to be managed. In a complex system such as fisheries (which involves multiple dynamic components interacting at various temporal and spatial scales), the identified categories are not exclusive because many categories are linked and influence each other to varying degrees. However, for the purposes of this study, three main categories and twelve subcategories are presented to describe the way risk is identified by fishery professionals The main categories are: (I) Uncategorised Risk; (II) Managed Risk; and (III) Institutional Risk (Table 1). An explanation of each of these categories and sub-categories follows.

Category I. Uncategorised: risk is everywhere, informal or implicit Uncategorised risks were those that arose informally or were implicit in discussions of risk. This category reflects responses that emerged from interviews that stated the reason that management institutions exist is to manage potentially undesirable outcomes related to fisheries. Discussing risks in uncategorised terms is reflective of general societal uncertainty of future events combined with the notion that negative outcomes are possible when natural resources are shared collectively and individuals do not benefit from harvesting restraint (Hardin 1969). This category was divided into two subcategories: (a) unarticulated and (b) broadly defined, based on the manner in which participants discussed risk.

Ia. Unarticulated risk – the risk of loss associated with common-pool resources. The unarticulated risk subcategory includes statements that alluded to risk being discussed in informal terms (e.g. risk is implicit) and did not involve the phrases 'risk is', 'risk to', 'risk from' or 'risk in' explicitly. Additionally it was not clearly articulated that risk was found in any specific step of the fisheries management process. Unarticulated risk refers to risk being inferred in institutional process, but never explicitly handled through any definable mechanism, like risk management. Unarticulated risk was identified by 22.5% (rank 3) of interviewees. An unarticulated risk example was: 'We beat around the bush with risk, but it is not explicit in the way or sense that other areas might be. It is more implicit than explicit. I don't think we have gotten to the point where we talk about ''risk'' in terms of the outcome of the assessment.' – US Manager.

Ib. Broadly defined risk – the existence of risk is the reason for management. Broadly defined

Table 1. Summary of risk categories and rank of by frequency of response. Transcribed interviews yielded three main categories of risk in fisheries management and 12 subcategories. The risk category identified most often was the risk to the species being managed (IIa) while the category mentioned least often was that of unarticulated risk (Ia)

Risk category and subcategory	Definition	Rank by frequency of response
I. Uncategorised risk		
A. Unarticulated	The risk of loss associated with common-pool resources	9
B. Broadly defined/likelihood and consequence	The existence of perceived risk is the reason for institutional management	8
II. Managed risk		
A. Species/stock-level	The risk of a decline to a species/population	1
B. Ecosystem-level	The risk of loss to ecosystem-function	5
C. Economic or individual	The risk of loss to the economic or cultural systems (both to the individual and community)	6
III. Institutional risk		
A. Legislative	The risk of not meeting legislative objectives or requirements as outlined by law	5
B. Data collection/management	The risk associated with incorrectness of data collected for assessment (not appropriate, misguided, biased, sparse)	3
C. Data analysis	The risk associate with correctness of scientific assessment (wrong methods, high degree of uncertainty in the output).	2
D. Management objectives	The risk associated with not meeting management objectives	3
E. Stakeholder influence/political influence	The risk associated with political influences compromising management objectives (risk of politicising the process and clouding judgment)	4
F. Science/management interface	The risk associated with communication or understanding scientific assessment	8
G. Implementation uncertainty	The risk associated with management actions not having the desired effect (e.g. risk of lack of stakeholder compliance or incorrect policy enacted)	7

risk included defining 'risk' as the catalyst for fisheries management; or found everywhere throughout the system; or it was defined in terms of likelihood and consequence (or as an outcome probability). This subcategory of risk is reflected by research that proposed that society expects science-based policies to manage environmental uncertainties to improve decision-making (Funtowicz & Ravetz 1990). Broadly defined risk was identified by 35% (rank 8) of interviewees. An example of broadly defined risk was: 'There is always risk present, but whether people quantify it or not is another story' – US Scientist.

Category II. Managed risk: Risk to the biological and social systems Managed risks were those risks fisheries management is designed to mitigate. These risks encompass both the biological and social systems. Potential loss of productivity of these systems is arguably the impetus for the development of institutional fisheries management in both countries as they reflect components of the system that are considered valuable and expected to be maintained or sustained (Hatton *et al*. 2006). The identification of these risks is attributable to the nature of ecosystems, populations and social systems that fisheries encompass, and the associated losses to human and environmental systems. When interviewees mentioned this risk, many participants discussed specific stock assessments, stakeholder groups, or other case studies that pertained to a particular fishery decision as a way to articulate risks that they encountered.

IIa. Species/stock-level risk – the risk of population decline. Species/Stock-level risk was identified as the potential harm to the sustainability of a species or stock. Since fisheries in both nations are most often managed on the basis of fish stocks, study participants often discussed the risks to the specific stocks they were involved in managing and the uncertainty involved in that process. All mention of potential loss to specific stocks were coded as species-level risk. Species or stock-level risk was mentioned by most (75%) (rank 1) of the study group. An example of species/stock-level risk is: 'There is a risk of the biological impact to the fish' – US Manager.

IIb. Ecosystem-level risk – the risk of loss of ecosystem-function. Ecosystem risks included potential harm to the general ecosystem, including species not targeted by fishers (such as by-catch), and habitat impacts of fishing activities. This risk was mentioned by 42.5% (rank 5) of the interviewees. An example of ecosystem-level risk is: '[There exists] a risk of ecological damage and risks to the entire ecosystem' – Australian Scientist.

IIc. Social risk – the risk of loss to the economic or cultural systems (both individually and community). Any mention of socioeconomics, individual livelihood or individual risk was coded as social risk. Social risks included mention of socioeconomic disruption as well as potential risks that effect loss of economic viability due to either the implementation of fishing restrictions, changing economic conditions or the decline in the abundance of stocks. Social risk was identified by 40% (rank 6) of interviewees. An example of social risk is: '… the assessment of risk is the measure of benefit of the mortality control versus the potential impact in the fishing community that you are governing.' – US Manager.

Category III. Institutional: Risks that arise from the practice of fisheries management Institutional risks are those created by the formal processes of managing marine fisheries and include such issues as making incorrect decisions based on misinformation, poor management, and problems in implementation. Institutional risks are mitigated through various management techniques such as diversification, quality assurance procedures and the precautionary approach (Hilborn *et al*. 2001). The institutional risk category is divided into seven subcategories.

IIIa. Legislative risk – the risk of not meeting requirements as outlined in US Federal or Australian state or Commonwealth law. Legislative risks include the identified risk of not meeting legislated objectives as well as the ability of fisheries managers to evaluate risks against these legislated objectives. The latter risk is due to legislated objectives sometimes being ambiguous from problems with normative or unscientific language and due to society's uncertain expectations (Duarte-Davidson & Pollard 2006). Participants that identified legislative risks often referred to specific laws (most notably the 2006 Re-Authorization of the Magnuson Stevens Act) and the challenges that are inherent in translating written statutory requirements into management. Legislative risk was identified by 42.5% (rank 5) of interviewees. An example of legislative risk is: 'With the new Magnuson [Act] we have to develop recommendations to meet the letter of the law' –US Manager.

IIIb. Data Collection risk – the risk associated with the incorrectness of data collected for assessment work. Data collection risks are those associated with the uncertainties involved in the collection of quantitative and qualitative data used to assess the status of the biological or social systems.

Data collection risk is the risk of gathering incorrect, inappropriate, misguided, biased, or sparse datasets for risk/stock assessment work. It was identified by 55% (rank 3) of interviewees.

IIIc. Data Analysis risk – the risk associated with the correctness of scientific assessments. Data analysis risk relates primarily to quantitative assessment work and refers to the risks associated with the methods used to analyse data, such as stock assessments. The risks include assessments that are inaccurate, imprecise or are extrapolated beyond their utility, and thus lead to incorrect advice being given to managers. Risks associated with data analysis arise from imperfect modelling practices, ignorance of the system to be modelled or a lack of calibration tools. Data analysis risks were identified in 62.5% (rank 2) of the interviews. An example of collection and data analysis risk is: 'We need to identify the limitations of our stock assessments from the absence of data or particular types or lack of data which may not be representative. There is a risk of over-interpreting the data for our assessments.' – Australian Scientist.

IIId. Management Objective risk – the risk associated with not meeting management objectives. Management objective risks are those associated with the uncertainties inherent in the day-to-day management of fisheries. They differ from the legislative risks in that management objectives may be more specific than broader legislative requirements. In some cases, management objectives may attempt to meet legislative requirements while taking into account current institutional arrangements. Not meeting management objectives was usually discussed in terms of not simultaneously balancing biological and social interests, such as preventing overfishing whilst maintaining fishery profits. The risks associated with not meeting management objectives were identified by 55% (rank 3) of the respondents. An example of management objective risk is: 'Ultimately for fisheries the risk they should be concerned with is the risk of not meeting your management objectives.' – Australian Scientist.

IIIe. Political Influence risk – the risk associated with political influences compromising current management objectives. The fifth subcategory of institutional risk involves risks associated with political influence over the decision-making process. This risk includes the mention of factors that influence or bias management decisions in the direction of a stakeholder group(s). The risk involved here is that of disproportional influence to favour one stakeholder group over another. It arises as a result of institutional uncertainty and irreducible biological/social process uncertainty in such systems (Bammer & Smithson 2008). Political risk was identified by 47.5% (rank 4) of the participants. An example of political influence risk is: 'Risk is basically assessed by walking this line of political pressure; on one hand you have constituents and the other following scientific advice from stock assessments.' – US Scientist.

IIIf. Science/Management interface risk – the risk associated with the communication or understanding of scientific assessment. Science/management interface risk is that of inappropriate communication or understanding when information is exchanged between scientists and managers. These risks were primarily identified as those of misinterpretation or misunderstanding by managers of the information provided by scientific assessments. This type of risk has also been characterised by the 'linguistic uncertainty' outlined by Regan *et al.* (2002). These authors attributed communication between conservationists as a source of potential uncertainty due to vagueness, context specificity, under-specificity and ambiguity of ecological issue under discussion. The risks that arise from the science/management interface were mentioned by 35% (rank 8) of interviewees. An example of science/management interface risk is: 'The risk estimate is based on a single value presented to managers and there is a lack of desire for most managers to figure the uncertainty' – US Scientist.

IIIg. Implementation risk – the risk associated with the management actions not producing the desired effect. This risk category is associated with implementation and the risk that the management measure chosen will not have the planned effect on the fishery. Participants that identified this risk discussed such issues as the effectiveness of tools available to managers, as well as fisher compliance and monitoring and the lack of retrospective methods needed to evaluate whether past decisions have satisfied their original intent. The risks associated with implementation were mentioned by 37.5% (rank 7) of participants. An example of implementation risk is: 'Risk is to make sure that the actions that have been selected have the desired effect.' – US Manager.

Comparison between Australia and the US Atlantic Coast

Coded responses were also compared between Australia and the US Atlantic Coast (Fig. 1.). The following ratios are listed as percentages (AU:USA) for comparison, as participants of the two countries varied similarly by proportion (i.e. AU managers comprised 45% of AU total, US managers comprised 44% of US total).

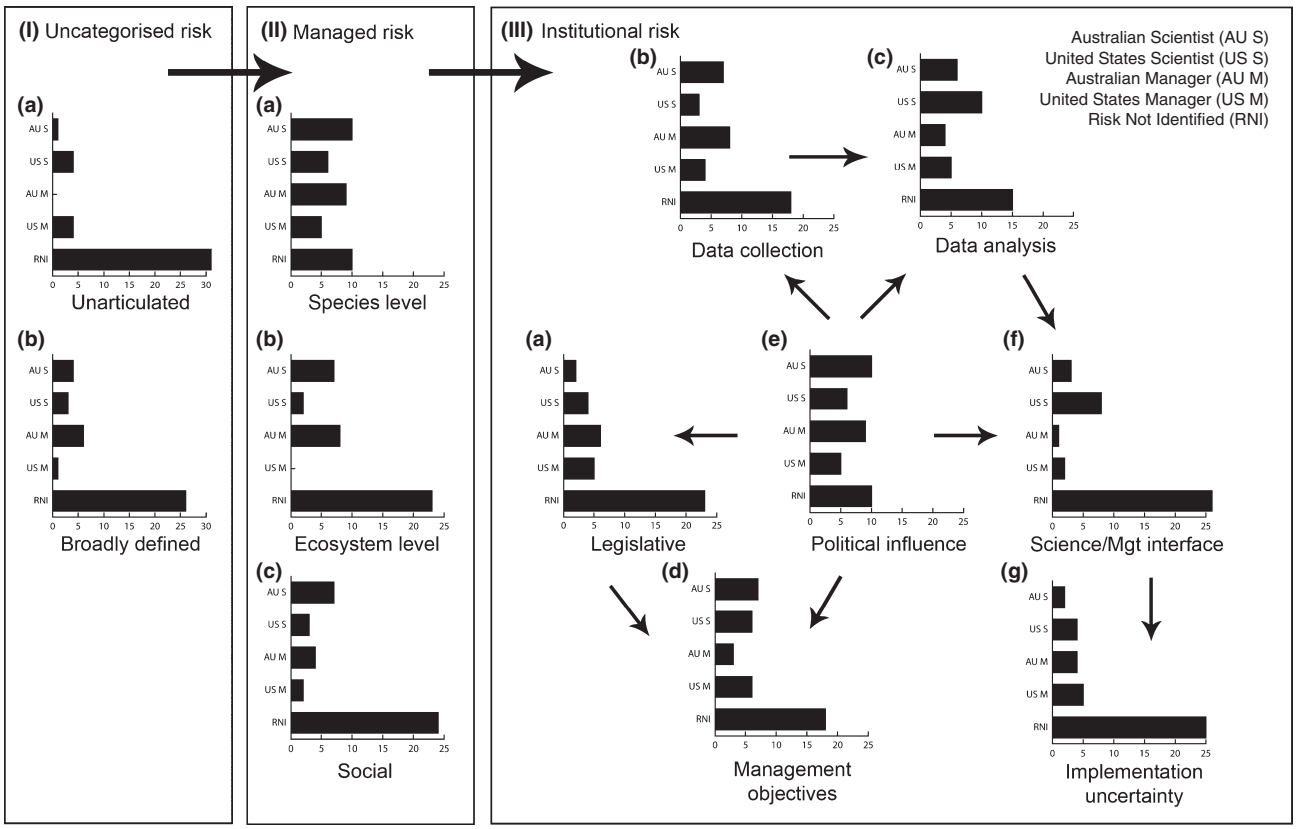

Figure 1. A schematic diagram of the risks associated with fisheries management as perceived by managers and scientists in Australia and the USA. Bar charts indicate the counts of respondents for each risk subcategory by country and professional groups including respondents that did not identify the particular risk subcategory (RNI).

In the three main categories of risk, the American interviewees reported more uncategorised risks than Australian interviewees (Australian 5%:US 44%), while broad risk was identified more frequently by Australians (45:22). The following ratios are listed as percentages by country, which varied proportionally (Australian:US). Managed risk was identified more often in all categories by Australians with regard to species (86:61), ecosystem (68:11) and social (50:28) systems. Most institutional risks, however, were identified more often by Americans including: legislative (36:50), data analysis (45:83), management objectives (45:67), political (45:50), science/management interface (18:56), and implementation uncertainty (27:50) with the exception of data collection (68:39), which was mentioned by Australians more often. Quantitative analysis indicated that Australians and Americans differ in the risk categories of managed ($P < 0.001$; Fishers Exact Test – FET) and institutional risk ($P = 0.003$, FET), but uncategorised risk was not different ($P = 0.14$, FET).

Comparison between scientists and managers

Coded responses were also analysed by professional role in the same manner for each category and subcategory of risk. The following ratios are listed as percentages by professional role in management, which varied proportionally (Scientist: Manager). Uncategorised risk scored similarly between scientists and managers with unarticulated (23:22) and broadly defined risk (32:39) comparable. Managed risk was also similar for species (73:78) and ecosystem (41:44), although social risks were recognised more often by scientists (45:33). Institutional risk diverged with fishery scientists identifying data analysis (73:50), management objectives (59:50), and science/management interface (58:17) more frequently, while managers identified data collection (45:67) and implementation uncertainty (27:50) more often. Overall, scientists and managers responses were not significantly different in their identification of unarticulated ($P = 0.081$, FET), managed ($P = 0.144$, FET) or institutional risk ($P = 0.08$, FET).

Organising the risks

The 12 subcategories that emerged from the coding can be organised within the 3 broad categories into a schematic diagram of the risks associated with fisheries management as perceived by managers and scientists (Fig. 1). The bar charts identify the count of the interviews in which a subcategory was identified by each of the country's professional groups including a count of interviews in which respondents did not identify the subcategory (RNI).

Discussion

The most important finding from this study is that almost every subcategory of risk was identified by each of the two national groups and the two professional groups (with the exception of Australian managers who did not mention 'unarticulated' risk and US managers who did not mention ecosystem risk). This indicates that although variation in risk identification was found between groups, based on the interview data, similar risk categories emerged. Further, these risk categories strongly reflect typologies of uncertainty outlined by previous studies of risk in fisheries (Francis & Shotton 1997; Charles 1998; Regan *et al.* 2002; Harwood & Stokes 2003; Peterman 2004). However, these identified categories and subcategories refine the concept of risk to incorporate the consequences for economies, ecosystems and fish stocks, as well as to reflect how fishery professionals communicate and discuss risk. Differences in risk identification are most likely attributable to subtleties that exist on finer scales of fisheries management in both countries as there was some variation by country but not by profession. For example, the US respondents identified risk more often in uncategorised terms than did Australians. This is possibly caused by Australia's recent integration of qualitative risk-based frameworks (Hobday *et al.* 2004; Fletcher 2005; Astles *et al.* 2006; Astles 2008) into assessments following the requirements of the Environment Protection and Biodiversity Conservation Act (1999). This strategic assessment process promoted risk management in fisheries and defined risks (at least to some extent) in explicit terms. By contrast, American respondents mentioned institutional risks, such as legislative risks, more often than Australians. This is possibly attributable to recent developments within the US system such as the 2006 Re-Authorization of the Magnuson Stevens Act and the increasingly large number of fishery management actions that are being challenged in US federal courts (Powers 2004).

Beyond species, ecosystem-level and stock assessment risks; risks of not meeting management objectives and the risks associated with political influence were identified with high frequency regardless of professional role or nation. The risks associated with political pressure have many points of influence within institutional risk (as presented by the arrows in Fig. 1) and are difficult to isolate within one step of the management process – given the many roles of stakeholders. While participatory management is considered to increase transparency, accountability and robustness of management decisions by incorporating stakeholder knowledge and concerns into the process (Kaplan & McCay 2004), it has also been shown to change support and direction of management decisions and contribute to unfavourable or 'risky' outcomes (Dudley 2008). Further, political influence may have the power to decrease the efficacy of other risk-based methods as the risk arising from investment in a more participatory process may marginalise risk management applied in other areas – such as presenting arguments around uncertainty as a way to influence decision-making. A common approach to dealing with uncertainty is to delay management action in the hope of reducing uncertainty through research and deliberation. Delaying fisheries management decisions, however, has not usually resulted in a reduction to the risk of species decline (Shepherd & Rodda 2001), and past research and many policy frameworks recommend that the precautionary approach should be adopted at times of high uncertainty and serious consequences (Hutchings 2000) instead of delayed action. Additionally postponing decisions to undertake more research can actually increase uncertainty by revealing more complexity than was previously understood, such as spatial variance in growth rates (e.g. McShane & Naylor 1995). This is not to say that a participatory process does not mitigate implementation risks. For example, allowing high levels of uncertainty to continue can result in a decline in social trust over time (Bammer & Smithson 2008). If conditions of low social trust prevail they can pose major challenges and additional costs to decision-makers. More in-depth analysis focused on refining the categories and subcategories identified here might give further insight into possible risk-based methods for areas of fisheries management such as political risk where few data are being collected and few or no standardised procedures exist (Underwood 1998).

The categorisation of uncertainty was an important step in the development of methods for the management of uncertainty in fisheries (Charles 1998). In a similar fashion, categorisation of the risks may help

fisheries professionals break down the risk problem into separate manageable components. For the majority of the categories identified in this study, risk management methods have already been developed. For instance, data collection risks are managed through good experimentation and project management methods, such as data validation, and through incorporation of observation error into models (Solow 1998). More complex fisheries management controls have been suggested as a means of reducing risks to species and fisheries (Peterson & Smith 1982; Butterworth & Punt 2003; Edwards *et al*. 2004; Stefansson & Rosenberg 2005), but such controls generally fall short of accounting for all sources of risk as identified in this study. Risk categorisation is therefore an important first step in the process of developing a comprehensive risk management system that covers each of the different risks present in fisheries management (e.g. Hobday *et al*. 2004; Fletcher 2005; Astles 2008). Future research is needed to refine these categories; to incorporate them into theoretically based classifications schemes; and to align them with appropriate risk management strategies.

As fisheries continue to move towards formalised methods to address issues associated with the potential impacts of harvesting, it is also important to define the risks that various stakeholders bring into this debate (Francis & Shotton 1997; Harms & Sylvia 2001). This paper provides a categorisation of risks from the perspective of fishery professionals. It does not, however, address risks identified by other groups involved in fisheries systems such as commercial or recreational fishers, members of the seafood industry, suppliers of fishing equipment and non-governmental organisations. For example, through an analysis of interview data with commercial fishermen, Smith (1988) concluded that commercial fishermen's perceptions of risk arise primarily from non-fishermen (e.g. sports fishermen, economists, politicians, biologists, environmentalists, and bureaucrats). Therefore, the risks identified from commercial fishermen would be expected to be considerably divergent from the risks discussed in this study. More research is needed to refine how other groups involved (beyond those engaged in professional management) articulate and perceive risk in fisheries. This becomes increasingly important the more that risk becomes the vernacular by which fisheries management issues are discussed.

Interview-based analyses, such as those presented here, are subject to a number of possible biases (Fowler 1984; Converse & Presser 1986; Sarantakos 2005; Fink 2006). The questions and interview format used for this study was designed to reduce biases as much as possible. All interviews were conducted on individuals to avoid social conformity bias. Biases associated with leading questions were minimised by ensuring that the questions were designed for a larger study and both interviewee and interviewer were unaware that this information would be used for a categorisation of risk. However, interviewer bias could have occurred as US interviews were conducted by different interviewers than the Australian interviews. This bias was reduced by extensive consultation between the interviewers from both countries. Possibly the most important source of bias was in the form of personal cost bias. Although each respondent was told that the interviews would be anonymous, their answers could have been biased by the respondents' awareness that they were being tape recorded and thus may have tailored their answers to reduce any possible risk to their job or professional standing.

Conclusions

The complexities found within fisheries have long been acknowledged, but have proven difficult to consider in routine fishery management decisions (Dudley 2008; Garcia & Charles 2008). It is therefore important for fisheries professionals to work towards a shared understanding of the different conceptions of risks so that divergent and convergent concepts can be articulated to the best extent possible. Refining the identification(s) of risk from the perspective of the groups involved adds clarity to such an abstract concept such as risk (Francis & Shotton 1997). The primary lessons learned from this study are:

- fisheries management risks can be broadly identified based on frequency of identification through interview data;
- risks identified by individuals are reflective of the management system in which they operate, but significant differences were not found between professional roles within that system; and
- risk categorisation can be a valuable tool from a management perspective as each type of risk may be assessed and managed using different risk management approaches.

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Appendix 1: Semi-structured interview tool. Interview Pro Forma

The interview should take less than 80 min to complete.

Survey Questions

1. Do we have your permission to take notes (or digitally record) for this meeting?

General questions about risk and stock assessment

2. What has your role in fisheries been over the last couple of years?

3. How do you see the concept of 'risk' being used in your fisheries assessment/management work?

Scope: Identification of species earmarked for assessment

4. Is there a formal process for determining what risk assessment technique or techniques are employed for each species or group of species?
5. Do you identify fisheries or species as 'data-poor' and what criteria do you use to make this determination?

Implementation: Determination of the processes, types of data used and analyses completed for the assessment of species

6. What are the main steps involved in this assessment procedure (including risk, stock or other assessment strategies) for the (data-poor) species?
7. Which of the steps involve stakeholders?
8. How would you rate your assessment process on the following criteria?
   a. Efficiency
   b. Repeatability
   c. Transparency
9. Does your organisation assessment process account for cumulative risk, e.g. where species are taken by a number of fisheries.
10. How is uncertainty incorporated in your risk level calculations?
11. How long does a standard assessment for a fishery or species generally take? What is the most time consuming task?
12. How frequently are such assessments undertaken or updated for each species?
13. If the assessments are quantitative then:
    a. What software packages are used for developing quantitative assessments?
    b. Are standard spreadsheets, calculations, algorithms or protocols used in the production of quantitative risk assessments?
    c. How are your quantitative algorithms tested (e.g. simulated data, zero catch)?
14. Are you undertaking research on new assessment methods? If so, please describe your research.
15. What are the strongest and weakest links in your assessment of (data-poor) species?

    Strengths:

    Weaknesses:
16. Do you have any ideas of how to improve the exchange of information regarding the assessment of species such as an internet based Wikipedia-style forum or Fishbase?

Interpretation: – the managerial interface to the outcome of an assessment

17. Is there a formal process for how assessments are to be interpreted by managers? Is this documented? If yes, where can I obtain a copy? If not, what is the process?
18. Do you use management thresholds or trigger points? How were these benchmarks determined?
19. Is there a pre-agreed response to when species are determined to have crossed a threshold?
20. If these pre-agreed responses exist, do you have any comments about the actual implementation of these responses?
21. What do you see as the strengths and weaknesses of your organisation's interface between the assessment and management?
22. Are their any changes to this management/assessment interface on the horizon?
23. Is there anything more you want to add regarding all that we have just spoken about?