Development of national guidelines to improve the application of risk-based methods in the scope, implementation and interpretation of stock assessments for data-poor species

James Scandol, Matthew Ives and Matthew Lockett

Industry & Investment NSW
Cronulla Fisheries Research Centre of Excellence
PO Box 21, Cronulla, NSW 2230
Australia

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Authors: Scandol, J.P., Ives, M.C. and Lockett, M.M.

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The authors would like to acknowledge the comprehensive support from the project co-investigators (see Table 1). Their contribution in helping to create, what we hope, is an improved and balanced understanding of risk management in Australian fisheries is gratefully appreciated. Many of the insights of this project were based on one-to-one discussions with tens of fishery managers and scientists in Australia. We acknowledge their time and patience in explaining to us the many dimensions that make up risk management in their jurisdiction. This acknowledgement is echoed for the managers and scientists who participated in the risk workshops in late 2008. These were highly varied events that stimulated plenty of healthy debate about risk. We especially recognise the support of co-investigators who helped organise the logistics of the interviews and the workshop.

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PROJECT CO-INVESTIGATORS

Role, Jurisdiction and Agency	Name
Co-investigator – Commonwealth Australian Fisheries Management Authority	Andy Bodsworth (initial application) Amanda Parr (from Sept 2007)
Co-investigator – Commonwealth Bureau of Rural Sciences	Kevin McLoughlin James Larcombe
Co-investigator – Commonwealth CSIRO Marine Research	Tony Smith
Co-investigator – Northern Territory Department of Regional Development, Primary Industry, Fisheries and Resources	Andria Handley (initial application) Julie Martin Rik Buckworth
Co-investigator – Queensland Department of Primary Industries and Fisheries	Rick Officer (initial application) Brad Zeller (from July 2008)
Co-investigator – South Australia South Australian Research and Development Institute	Tim Ward
Co-investigator – Tasmania Tasmanian Fisheries and Aquaculture Institute	Philippe Ziegler
Co-investigator – Victoria Department of Primary Industries	Terry Walker (initial application) Sonia Talman (initial application) Alice McDonald (from Mar 2008)
Co-investigator – Western Australia Department of Fisheries, Western Australia	Rick Fletcher

NON-TECHNICAL SUMMARY

2007/016	Development of national guidelines to improve the application of risk-based methods in the scope, implementation and interpretation of stock assessments for data-poor species

PRINCIPAL INVESTIGATOR: Dr James Scandol

ADDRESS: Cronulla Fisheries Research Centre of Excellence
PO Box 21
Cronulla, NSW, 2230
Telephone: 02 9527 8411 Fax: 02 9527 8513

OBJECTIVES:

1. Review the use of "risk" within the scope, implementation and interpretation of stock assessments of data-poor species in Australia and, with lesser detail, within the international domain.

2. Define benchmarks (which are likely to include quantitative, qualitative and procedural factors) to compare and contrast the use of "risk" within the scope, implementation and interpretation of stock assessments across all Australian jurisdictions.

3. Using the review and the benchmarks, identify the strengths and weaknesses of the various applications of risk-based methods used to scope, implement and interpret stock assessments in Australia.

4. Develop national guidelines that will assist jurisdictions to develop and apply risk-based methods to the assessment of data-poor species. These guidelines will promote the adoption of nationally consistent standards but be cognisant of diverse institutional arrangements that exist.

NON TECHNICAL SUMMARY:

The concept of risk has always played a crucial role in the management of fisheries in Australia. Historically, much of what we know of as risk management has been implicit, but with more exacting and accountable standards for fisheries management now expected, there has been an inexorable shift towards explicit models of risk management. Australia is currently at the forefront of risk-based fisheries management and has developed and tested at least three inter-related methods for assessing and managing both the real and perceived risks associated with fishing activities. The primary objective of this project was to capture the knowledge and experience of the fisheries research and management community into a set of national guidelines that will assist Australian jurisdictions in the application of risk-based methods to the assessment of data-poor species.

To meet this objective the project began with a comprehensive review of the extensive risk and stock assessment work undertaken for data-poor species in Australia. This review was completed with two distinct approaches: a conventional literature review (top-down) and an interview-based (bottom up) review process. Over four hundred papers and reports were compiled within the literature review and 33 fisheries scientists and 28 fisheries managers were interviewed from around Australia. These two approaches enabled a comparison between the policy, strategy and

assessment documents, with the day-to-day experiences of governmental officers. Using this semi-structured information, a series of national guidelines were drafted that aimed to capture the strategies that were being used for the assessment and management of data-poor species.

The guidelines were developed by the project team and the co-investigators and thus provided an opportunity for senior assessment scientists and research leaders in Australia to integrate their ideas into one complete set of guidelines. These guidelines represent the full spectrum of issues involved in improving risk management for Australian fisheries including: consistent definitions, following established standards, understanding the roles of scientists and policy makers; commitment to the ongoing development of skills; understanding the reasons, and managerial options, for data-poor species; understanding the relationship between risk management and the precautionary approach; clarifying the role of risk-based approaches in prioritisation; applying harvest strategies; implementing the weight-of-evidence approach; considering the potential role of indicator species; and the necessity of effective decision-making processes. Although the focus of this project was the so-called “data-poor species”, many of the guidelines developed have in-principle application to conventional stock management issues, as well as habitat and ecosystem issues.

In general, we found individuals to be very positive about the role of explicit risk management in fisheries, but there were a variety of perceptions about what the risks were and how they should be addressed. Four general themes were identified: (1) risk management will continue to play a key role in Australian fisheries management and a diversity of approaches will be applied; (2) as a result of this key role, there is a need for an ongoing investment in methods, documentation and skills development in risk management; (3) the agencies with the greatest public policy commitment to risk management were, in general, the most consistent and transparent in actual application; (4) data-poor species are a consequence of the highly heterogeneous nature of Australian fisheries and the high standards of environmental management expected; and risk management is an accountable strategy to deal with this phenomenon.

These national guidelines were communicated to over 47 scientists and 31 managers during a series of 9 workshops. Various approaches, including case studies, were used to illustrate how the guidelines could be used in real-world examples of data-poor fisheries management. These cases studies illustrated the importance of: policy and legislative frameworks; key information about the fishery, the species of interest and their interaction with the fishery; and, the essential role of experienced and knowledgeable staff who can synthesis information and communicate responses.

This project considered the qualitative, semi-qualitative and quantitative assessments used by all Australian jurisdictions. Each jurisdiction uses a range of strategies to undertake the assessment and management of data-poor species. The integration into the national guidelines of these various approaches enabled the project officers to develop a traffic-light benchmarking exercise against which the progress of each jurisdiction could be assessed. This exercise encouraged groups of managers and scientists to arrive at a consensus on how their agency performed with respect to the guidelines (including some benchmarks they may not have been in full agreement with). Combining these benchmarks at a national scale provided an overview of risk management strategies in Australian fisheries management. Patterns within these benchmarks, supported by the examples provided, illustrate the strengths and weakness of various strategies to assess and manage data-poor species. Importantly, there were several alternative strategies that all generated similar overall patterns of positive responses. Although, there was the potential for self-assessment bias in this exercise, the project team always observed a healthy degree of reflection in the workshops, with all participants genuinely looking for better ways to deal with the challenges presented by data-poor species.

This project stimulated important debate about the future of risk management for Australian fisheries. The very significant investment made by many agencies into risk management deserves

formal review and informal deliberation. Implementing the technical procedures for risk assessments is a fundamental part of the process, but unless policy and legislative frameworks exist to interpret the outcomes of those assessments, then the values of those assessments will be compromised. The phenomenon of data-poor species is not simply the result of insufficient data, but is the consequence of managing complex bio-physical systems under the principles of ecologically sustainable development. Risk management is an approach for prioritising what needs to be done and identifying circumstances where current responses are insufficient, appropriate or excessive. With the right management systems, which will most likely include strict harvest controls, species that are data-poor can continue to be assessed as low-risk. This option is just as much about administrative accountability as it is about prioritising research and management for high-risk species.

Risk and stock assessments can both be expensive and time-consuming procedures for agencies. A long-term broad-based strategy to improve the cost- and time-effectiveness of both risk and stock assessments is better resource sharing within and between agencies. There are, however, impediments to such resource sharing (including statutory responsibilities, intellectual property and privacy) that must be considered. The most likely long-term medium for cost-effective sharing of data, expertise and interpretations is the internet, and preliminary suggestions are provided for how this could be developed.

The next few years are likely to see economic conditions tighten and issues associated with climate change dominate the agenda for primary industries and environmental management agencies. If these developments occur, there will be increasing pressure for prioritisation of expenditure and actions from both industry and government. Risk management provides the potential for a standardised and accountable strategy for tackling these challenges.

KEYWORDS: risk; risk management; ecological risk assessment; stock assessment; likelihood; consequence; data-poor; data-deficient; data-limited; quantitative; quantitative; cumulative risk; biodiversity; aquatic resource management; ecologically sustainable development; ecosystems-based fisheries management.

1. BACKGROUND

1.1. Project background

All fisheries management agencies face the on-going challenge to develop and implement management arrangements in the environment of incomplete or imperfect information. This is particularly relevant to many small-scale fisheries which are relatively low value and often data-poor. Many of these fisheries are also shared between the jurisdictions as well as between the commercial and recreational sectors. To assist in the management of such fisheries there is a need to integrate risk-based methods into stock assessment.

In an Australian Fisheries Management Authority (AFMA) research gap analysis and priority setting workshop in March 2005 it was recognised that there was a need for a "consistent and structured approach to risk management in fisheries, for all FMA objectives" (AFMA 2005a). Concurrently the Australian Fisheries Management Forum (AFMF) 2006/08 set as its research priority #2 to "develop a rating of risk within rapid stock assessment methodologies for data-poor species that is consistent with the more formal assessments done for target species" (AFMF 2006). In December 2005, the AFMF Subcommittee for Science and Research nominated James Scandol (NSW DPI) to convene a workshop to progress this priority. On the 11th to 12th September 2006, expert representatives from almost all jurisdictions met at the Cronulla Fisheries Centre to discuss this research priority and to structure a research proposal to address it. There was consensus amongst the workshop participants that the concept of risk has a multitude of facets within stock assessment, and that to narrow the scope of a project to quantitative interpretations of risk would compromise the utility of such a project, particularly for data-poor species.

Participants at the workshop also noted that all jurisdictions are moving forward with strategies to improve stock assessments for both data-poor and data-rich fisheries. Rather than expect jurisdictions to revisit these strategies in the short-term, the focus should be to use the outcomes of this project within agency review processes and, where appropriate, the development of new assessment frameworks.

Furthermore, workshop participants agreed that the integration of "risk" within the practices and processes of stock assessment occurred at three identifiable stages: (1) scope: identification of species earmarked for stock assessment; (2) implementation: determination of the types of data used and analyses completed for a particular assessment; (3) interpretation: managerial interface to the outcome of a stock assessment. The risk methods that were, and are, being applied within these three stages of assessment differed between the assessment stage and jurisdiction. These differences reflect: the problem being addressed; the values associated with the stocks; institutional capacities; and the legislative and policy frameworks in place.

Rather than just focus on the technical interpretation of risk, the workshop participants agreed that a national process that provided a detailed review of how stock assessments of data-poor species are actually undertaken and interpreted would provide valuable insight. Such a process will enable the development of national guidelines for applying risk-based methods to the assessment of data-poor stocks. Using these guidelines, benchmarks will be developed that illustrate the strengths and weaknesses of the various approaches that are used within Australia.

Stock assessment is the fundamental link between the status of a resource and the sustainable management of that resource. This project therefore directly tackles the FRDC Research Challenge to "Maintain and improve the management and use of aquatic natural resources to ensure their sustainability". Although the focus of this project is data-poor species, the guidelines developed in this project aim to contribute to long-term improvements in the assessment and management of all harvested species in Australia.

1.2. Legislative and policy context

This project was commenced in October 2007 at a point when considerable progress had already been made in risk management for Australian fisheries. A brief history of the developments to this point will provide additional context to this project.

In the early 1980s, under the then Prime Minister Bob Hawke, Australia began developing environmental policies around the concept of Ecologically Sustainable Development (ESD). This initiative was based on the Brundtland Report from the World Commission on Environment and Development (1987) which argued that economic development and environmental protection were two reconcilable societal objectives.

In 1992 the Council of Australian Governments made the declaration that all relevant policies and programs in the future should take place in the framework of ESD. Since then all levels of government in Australia have progressed the implementation of ESD, and a complex network of policies and laws exist to support this, particularly in natural resource management. Consequently ESD is now a major component of all fisheries legislation at both Commonwealth and State levels (Gullett 2008; McPhee 2008).

ESD is a complex concept (see Dryzek 1997) and a substantial amount of work was and is required for its incorporation into government policy and management. Within the Intergovernmental Agreement on the Environment (DEWHA 1992), ESD was determined to incorporate the following four principles: intergenerational equity; conservation of biological diversity and ecological integrity; the precautionary principle; and improved valuation, pricing and incentive mechanisms. In clarifying the application of the precautionary principle, the IGAE declared that it required public and private decisions to be guided by a careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment, as well as an assessment of the risk-weighted consequences of various options (DEWHA 1992).

In 1999[1], the Australian Government took the opportunity to consolidate a number of environmental statutes into the *Environment Protection and Biodiversity Conservation (EPBC) Act* 1999. This key legal instrument had significant ramifications for Australian fisheries, as there were now additional statutory requirements for Commonwealth and State fisheries that exported product. This Act is the primary environmental legislation in Australia (at Commonwealth level) and is currently administered by Department of Environment, Water, Heritage and the Arts) (Deborah 2006; McPhee 2008). The Commonwealth also published the "Guidelines for the Ecologically Sustainable Management of Fisheries" (DEWR 2007) which provided more specific direction to fisheries about what was required for export approval under various provisions of the *EPBC Act*. The *EPBC Act* has had less influence on the management of state fisheries which do not export their product – and recreational fisheries are the most significant example.

Within the international domain, the United Nations Food and Agriculture Organization published guidelines for the ecosystem approach to fisheries (FAO 2001; FAO 2003) and the Worldwide Fund also presented operational guidelines for the ecosystem-based management of marine capture fisheries (Ward *et al.* 2002).

[1] The *Wildlife Protection (Regulation of Exports and Imports) Act* (1982) was incorporated into the *EPBC Act* in 2002.

At the time of these changes, a National ESD Reporting Framework for Australian Fisheries was being developed (Fletcher *et al.* 2002; Fletcher *et al.* 2003). The purpose of this reporting framework was to provide a consistent way to implement and assess fisheries with respect to the principles of ESD in Australia. There are a number of elements to the ESD reporting process including the initial steps of identifying the issues relevant to the fishery and then prioritising these issues (Fletcher *et al.* 2004). The primary method chosen to complete these two elements was to conduct a qualitative risk assessment for each of the main biological and socio-economic components that make up a fishery.

During this time other drivers began to affect further changes in fisheries management in Australia. In 2000, a landmark court case in NSW[2] (also see Hurrell 2000; also see Hurrell *et al.* 2000) resulted in amendments to *Fisheries Management Act* 1994 that required that scheduled fisheries (which included recreational fisheries at the time) be subject to environmental impact assessment under Part 5 of the NSW *Environmental Planning and Assessment Act* (1979). At around the same time the Commonwealth made a commitment to ecosystems-based management of Australia's fisheries resources as part of the development of Australia's Oceans Policy (Commonwealth of Australia 1998). This commitment became manifest at a number of levels of government including as a policy directive to the Australian Fisheries Management Authority (AFMA) (e.g. Anonymous 2004)

Thus the landscape had changed somewhat since the initial development of the ESD Reporting Framework. The Commonwealth and NSW had slightly different objectives to their environmental assessments than other jurisdictions. This, when combined with the intrinsic tendency of both people and institutions to diverge over time, resulted in a braiding of approaches to environmental assessment of fisheries – including the all-important risk assessments.

Regardless of the specific legislative and policy frameworks in place, all of the Australian environmental assessments required adherence to the principles of ESD and hence consideration of the impacts of the fishing activity on target species, by-product species, discarded species, TEP[3] species, habitats, communities and the ecosystems[4]. As management agencies attempted to draw together the available information on the biological and ecological impacts of fishing activities, they quickly realised that there were highly varied levels of maturity in our understanding of the potential impacts of fishing on these different components.

In the case of target stocks, some species had sophisticated population models that could be used to estimate the probability of outcomes given various policy scenarios (a requisite of quantitative risk analysis). In other cases, there was only a very preliminary understanding of the potential impacts of fishing on particular species. A range of qualitative or semi-quantitative risk-based methods were applied to understand and document these potential impacts (and these methods are reviewed in this report). The AFMF Research Priority associated with this project, is about clarifying the relationship between these approaches for assessment, to improve consistency and objectivity about what is meant by 'risk'.

Qualitative and semi-quantitative risk-assessment approaches were also developed to deal with the impacts on habitats, communities and ecosystems. These are clearly key components to consider within ecosystem-based fisheries management, but they are not within the scope of the research presented here. Where possible, any outcomes of this project which have clear relationship with the

[2] Sustainable Fishing and Tourism Inc v Minister for Fisheries and Another (2000) in LGERA, NSW Land and Environment Court 322.

[3] Threatened, endangered and protected species.

[4] The stronger obligations to addressing these issues are associated with Australia's ratification of the United Nations Convention on Biological Diversity (www.cbd.int).

risk assessment of potential fishing impacts on habitats, communities and ecosystems will be identified. Likewise, any outcomes which have an inseparable relationship with issues in fisheries governance, economics or social science will also be described.

1.3. Risk, probability, uncertainty and environmental management

Althaus (2005) provides an excellent overview of the epistemological (study of knowledge) status of risk in various disciplines. This status varies from being a calculable phenomenon in logic and mathematics, an objective reality in science and medicine, an emotional phenomenon in the arts, a societal phenomenon in the social science and as an act faith in religion. As a research project undertaken by scientists and managers, looking to provide accountable and defensible improvements to the management of publicly owned resources, this project will focus on risk as an objective and measurable concept. In particular, this report will argue that the adoption of terminology and practices consistent with the Australian and New Zealand Standard (AS/NZS 2006) will have the greatest long term benefit for the success of this approach. That said, it would be naive to assume that the disciplines of economics, anthropology, sociology, law, psychology and linguistics did not also play a significant role in the risk management of Australian fisheries. These influences will be identified at various stages in this report, and risk classification and linguistic issues were the focus of the additional study undertaken by Gray *et al.* (Appendix 7).

Perhaps the most frustrating ambiguity in the risk literature is in the different ways in which risk and uncertainty are differentiated. In an early treatise on the subject Knight (1921) made a distinction between risk and uncertainty by defining “risk” as where the odds are measurable or where probabilities are known and “uncertainty” as where the odds are not known or where probabilities cannot be assigned. This is an impractical definition for modern risk management and what Knight terms “risk” would in modern terms be more aptly called “measurable risk” (Boyne 2003), and what he has termed “uncertainty” is more aptly referred to as “pure” or “deep” uncertainty. Various other taxonomies of uncertainty have been developed (Bullock *et al.* 1988; Morgan *et al.* 1990; Wynne 1992) and section 9.7 discusses the concept of uncertainty in some more detail.

In many cases (FAO 1996) the concept of risk is simply equated with that of probability (or likelihood)[5]. However, the above definitions of risk and uncertainty are both inclusive of the “outcomes of a course of action”, or the *consequence*. In such instances the difficult issues associated with consequence are simply left as being context dependant[6]. Unless an additional explanation is given as to the outcomes involved or the consequences of actions, this equivalence is simply confusing. The consequence dimension of risk cannot be ignored[7].

This fundamental requirement to integrate the consideration of outcomes (consequences) into risk management has significant ramifications for the application of risk-based methods in contemporary environmental policy. Scientists and risk analysts can calculate as many probabilities as they like, but unless these results have a clear context within policy and legislative frameworks,

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[5] The definition of ‘risk’ used in FAO (1996). Precautionary Approach to Capture Fisheries and Species Introductions, FAO Technical Guidelines for Responsible Fisheries. Food and Agriculture Organization, Report No. 2, Rome. was “The probability of something undesirable happening (note that when a technical definition in a decision theoretic framework is needed, it would be appropriate to use the terms "expected loss" or "average forecasted loss", not risk).”

[6] Most financial literature assumes that the consequence component of risk is about making or losing money.

[7] As an historical aside, many of the fundamental (gambling!) problems that stimulated the development of probability theory were not solvable until Jacob Bernoulli introduced the concept of utility in 1738, which forms the basis of both decision and game theory (Bernstein, P., L (1996). 'Against the gods: The remarkable story of risk.' (John Wiley & Sons, Inc.: New York). Utility is a measure of the worth of an outcome to an individual and is the technical basis behind the concept of consequence.

then these probabilities are just numbers, and not risk management. Policy and legislation is often complex to interpret, is usually presented in a qualitative form, may lack consistency within and between jurisdictions, and can be frustratingly ambiguous. Such instruments are, however, the basis of executive authority, as approved by the legislature and, in the case of legislation, enforced by the judiciary. Advocates of risk management in any aspect of environmental policy must engage with the challenges presented by these issues (Fisher 2007).

2. NEED

Risk management is an effective strategy for prioritising actions when confronted by a complex range of issues, many of which are uncertain. A well implemented risk management strategy provides an accountable and transparent mechanism for environmental governance. This has long been recognised in a range of applications from biological invasions (Hayes 1998; Hayes 2002), pollution (Longhurst *et al.* 2006), occupational health and safety (Lave 1987) and natural resource management (Kangasa *et al.* 2004; Peterman 2004; Sivakumar *et al.* 2007). The UK recently outlined new directions for national environment policy and gave risk-based approaches a central role in environmental regulation in the 21st century (Environment Agency 2005).

When the challenges associated with the ESD reporting and environmental assessments of Australia fisheries were presented in the late 1990s, a significant investment was initiated into the development of risk-based methods to better understand the potential impact of fishing activities on the environment. Many of the associated permits for wildlife trade operations (which were given on the basis of initial risk assessments) are now up for renewal and some agencies are broadening the application of risk-based methods to non-export fisheries. Given the very significant resources and opportunity costs associated with these assessments, it is opportune to review the work completed, have frank discussions with the professionals involved, and compile some national guidelines for moving forward with these approaches. These issues are particularly pertinent for data-poor species, where uncertainties may initially appear to dominate assessments, but the issues are equally relevant for data-rich fisheries.

Risk-based approaches influence resource assessment in many ways. Agencies use these risk-based methods to identify which species are to be assessed; how they are assessed; and, the managerial interpretation of those assessments. Therefore, the concept of “risk” plays a very complex role in stock assessment and is used in a variety of contexts. Although these new and innovative approaches for undertaking stock assessment are to be welcomed, there are potential drawbacks to a national fragmentation of methods, particularly the divergent applications of risk-based assessment methods. There are costs associated with “re-inventing wheels” and not learning from the experiences of other jurisdictions. Furthermore, any framework for risk or resource assessment will benefit from peer review.

Benchmarks for the use of risk-based approaches within resource assessment enable an objective comparison of how such methods are applied. This will provide agencies with a valuable tool to better understand the strengths and weaknesses of the approach they adopt, including insight into: gaps and overlaps in assessment programs; managerial interpretation of assessments; staff skills and knowledge; and infrastructure issues (such as database and reporting technologies). This analysis of strengths and weaknesses will be an important resource for agencies when reviews of environmental assessments (and any associated managerial instruments) are undertaken.

The outcomes from this project will support agencies to make more informed decisions with respect to their strategies to assess data-poor species. The outputs of this project will encourage the adoption of nationally consistent approaches that integrate rapid, low-cost assessment techniques, such as risk-based methods, into stock assessment programs.

3. OBJECTIVES

The project objectives are as follows:

1. Review the use of "risk" within the scope, implementation and interpretation of stock assessments of data-poor species in Australia and, with lesser detail, within the international domain.

2. Define benchmarks (which are likely to include quantitative, qualitative and procedural factors) to compare and contrast the use of "risk" within the scope, implementation and interpretation of stock assessments across all Australian jurisdictions.

3. Using the review and the benchmarks, identify the strengths and weaknesses of the various applications of risk-based methods used to scope, implement and interpret stock assessments in Australia.

4. Develop national guidelines that will assist jurisdictions to develop and apply risk-based methods to the assessment of data-poor species. These guidelines will promote the adoption of nationally consistent standards but be cognisant of diverse institutional arrangements that exist.

4. METHODS

4.1. Project personnel

This project was managed by a NSW-based project team which consisted of the Principal Investigator (James Scandol) and a Scientific Officer (Matt Ives). Casual Fisheries Technician (Matthew Lockett) was also employed from September 2007 to June 2008 to assist in the preparation of the literature review. The project also had a single co-investigator to represent each state with three representatives (CSIRO, BRS and AFMA) from the Commonwealth.

Due to the length of time between the project initiation and finalisation, there was turn-over of several co-investigators in the project. The project team and any changes to the co-investigators is summarised in Table 1.

Table 1. List of individuals involved in the project.

Role	Person
Principal Investigator	James Scandol
Scientific Officer	Matt Ives
Technical Officer (casual)	Matthew Lockett
Co-investigator – Commonwealth (CSIRO)	Tony Smith
Co-investigator – Commonwealth (AMFA)	Andy Bodsworth (initial application) Amanda Parr (from Sep 2007)
Co-investigator – Commonwealth (BRS)	Kevin McLoughlin James Larcombe
Co-investigator – Tasmania	Phillipe Ziegler
Co-investigator – Western Australia	Rick Fletcher
Co-investigator – Northern Territory	Andria Handley (initial application) Rik Buckworth (from Oct 2007) Julie Martin (from Aug 2008)
Co-investigator – Victoria	Terry Walker (initial application) Sonia Talman (initial application) Alice McDonald (from Mar 2008)
Co-investigator – Queensland	Rick Officer (initial application) Brad Zeller (from July 2008)
Co-investigator – South Australia	Tim Ward

The co-investigators provided a contact point for their jurisdiction or institution and the majority of them attended the Sydney-based Guidelines Workshop on 24 June2008. They also helped organise the interviews and workshops and managed the development of the final draft of the guidelines and benchmarks in their jurisdiction.

4.2. Project plan

The project plan was executed in fiscal years 2007/08 and 2008/09. The plan mirrored that of the application with the exception of a planned three month delay to the start date and some slippage of the dates towards the end of the project. Table 2 provides a summary of the key events and dates of the project. Some tasks were modified to suit the project deadlines and these amendments are noted in Table 2.

Table 2. Dates and descriptions of major project tasks. The dates of the two milestone reports are also included.

Date	Task Description
Sep 2007	Appointment of Scientific Officer and development of contact list.
Sep – Mar 2007	Review of national and international literature on the application of risk-based methods in the assessment (and subsequent management) of data-poor species.
Dec 2007 – Mar 2008	Project team undertook structured face-to-face interviews with a sample of assessment scientists and management staff in all jurisdictions. The objective of the interviews will be to ascertain the scope of assessments; the procedures used to undertake/update assessments; and identify how decision-makers interpret the assessments. The focus of these interviews was data-poor species and the application of risk-based methods within these three stages of resource assessment.
May 2008	First milestone report.
23 May 2008	Project Advisory Committee Meeting – a presentation of the status of the project was given to the AFMF Subcommittee for Science and Research. James Scandol gave a short update on this project to the Subcommittee by teleconference.
24 Jun 2008	National Guidelines Workshop – available project investigators met in Sydney for a one-day workshop to develop the draft national guidelines.
Sep – Dec 2008	Workshops were held in each jurisdiction to present the guidelines and benchmarks to available assessment scientists and management staff. Details of the design and structure of the workshop are presented in section 4.8.
Oct 2008	Second milestone report.
Jan – Mar 2009	Preparation of the draft final project report. Feedback from the workshops was incorporated into the guidelines at this stage.
Apr 2009	Review of the final draft report by co-investigators.
May 2009	Submission of final draft report to FRDC.
Aug 2009	Submission of final report to FRDC.

4.3. Changes to project methods

There were two changes to the method outlined in the project proposal. Firstly, in the original application it was indicated that the benchmarks would be developed on the basis of the interviews and the literature review. This approach was altered when it became apparent that the benchmarks would be more sensibly aligned with the guidelines rather than other criteria that would not be subsequently used in the project. Even for professional fisheries managers and scientists, the guidelines have a significant "learning curve", and to have a benchmarking process that was not clearly linked to the national guidelines would obfuscate rather than clarify the outcomes of the project. The benchmarks also required the structure of the guidelines for their development.

Once the benchmarks were defined, some preliminary responses were developed by the project team and then given to the relevant co-investigator for comment. This initial justification was presented at each of the guidelines workshops, where it was extensively reviewed and augmented.

Secondly, the project application indicated that two "Project Advisory Committee Meetings" would held in conjunction with AFMF Subcommittee for Science and Research (SSR). Rather than a formal meeting, James Scandol gave a short presentation on the status of the project to the Subcommittee via teleconference on the 23 May 2008. Another SSR meeting has not been held since. Given that Rick Fletcher is a member of SSR and a co-investigator on this project it was deemed that the SSR committee had sufficient oversight of this project.

4.4. Literature review

One of the primary objectives of this project was to "review the use of 'risk' within the scope, implementation and interpretation of stock assessments of data-poor species in Australia and, with lesser detail, within the international domain". To fulfil this objective an extensive review was undertaken into the risk assessment literature both in Australia and internationally. The primary focus of the literature review was to gather sufficient background information to develop defensible guidelines for the assessment of data-poor fisheries. The search was initially focused upon the use of risk management in all fields and then narrowed down to risk and stock assessments in the field of fisheries. The final emphasis was on strategies for data-poor species or systems. The search was concentrated on Australian-based efforts but also included research from other countries with research published in English.

Examination of the fisheries assessment work that had been conducted in Australia showed that there were three major ecological risk assessment methods in use. A detailed summary of these three methods is therefore presented. This not only provided an understanding into their applicability as risk-based methods for data-poor species, but also gave context for their role within the national guidelines.

4.5. Interviews with scientists and managers

4.5.1. Background

The primary purpose of the interviews was to solicit a thorough understanding of the techniques being used to manage data poor species in Australia on a day-to-day basis. Scientific publications on risk and stock assessments tend to deal with new developments in the field. So although a considerable amount of literature has been published on the subject, it was suspected that some of the on-the-ground management processes had not been reported in any high impact scientific journals.

The large numbers of risk assessments available for Australian fisheries provided plenty of examples of how the risk-based methods are applied in practice. There will be, however, a lot of developments and issues that are not published per se, yet form an important part of what actual practices entail. What we hoped to extract from the interviews was a poll, so to speak, of which methods were actually being applied and what was proving to be successful. Furthermore, the interviews aimed to quickly identify any new ideas or approaches that had yet to be the subject of a publication or report.

One additional area that was explored in the interviews was the speed or efficiency in which stock assessments were done. This issue was initiated by the wording of the AFMF SSR research priority which referred to “rapid stock assessment methodologies”. This inspired an alternative question of – what components slowed down the usual stock assessment methods? Subsequently, interview questions were developed about rate determining steps in assessment processes.

4.5.2. *Interview design and method*

The project researchers conducted a series of interviews with fisheries professionals in each jurisdiction around the country. James Scandol and/or Matt Ives travelled to each capital, from December 2007 to April 2008, to conduct the interviews. As shown in Figure 1 a total of 61 fisheries professionals were interviewed consisting of 33 scientists and 28 managers.

Prior to the interviews in each jurisdiction a brief review was conducted of that jurisdiction’s policies and fisheries to enhance the interviewer’s ability to understand the parameters they worked within and to allow them to orientate their questions to the actual policies and data-poor fisheries in that jurisdiction.

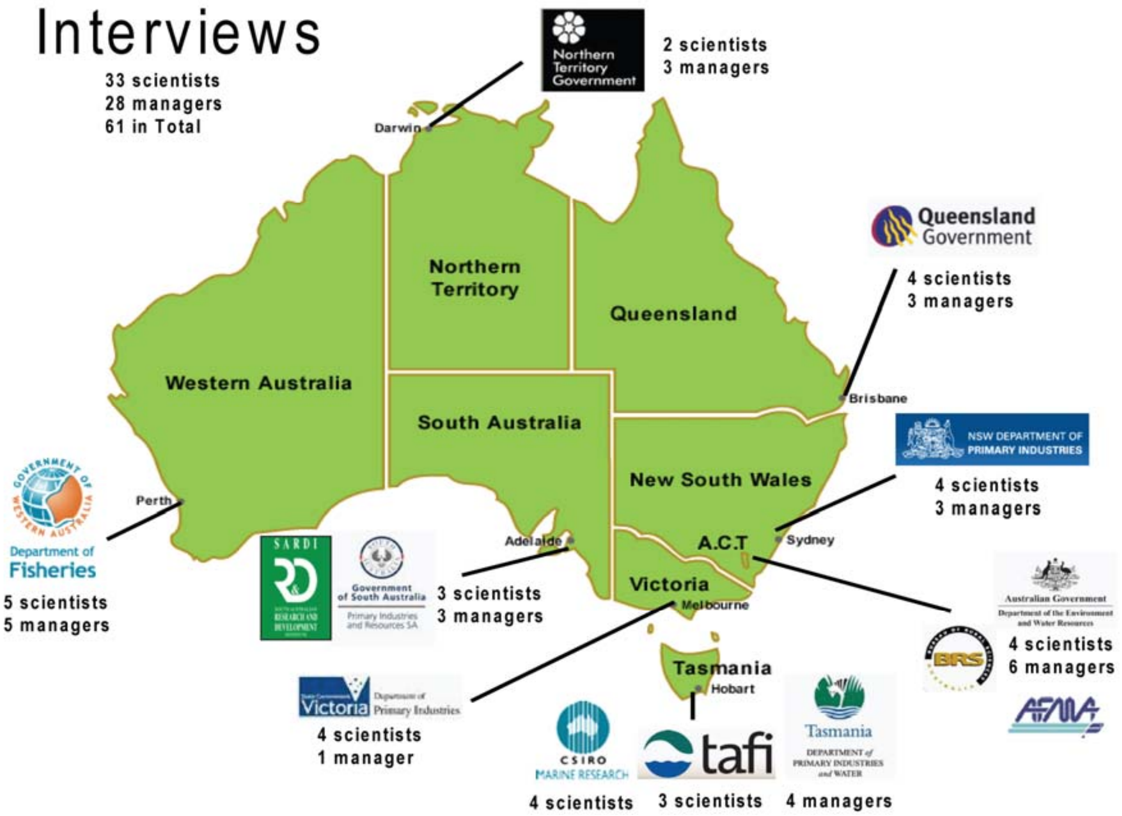

Figure 1. A schematic map showing the interviews conducted with fisheries professionals from various fisheries management organisations around Australia.

A semi-structured interview tool (see Appendix 4) was used to facilitate and standardise the interview process. The main focus of the interviews was to determine how fisheries professionals were using risk and stock assessments in their analysis and management of data-poor species. However, research prior to the interviews had shown a range of definitions regarding some concepts central to this project, including the terms “risk” and “data-poor”. Therefore each interview was opened with a number of questions aimed at uncovering such diversity and, in particular, how such terms were being used in the everyday work environment.

The remainder of the questions were broken up into the areas of:

- Scope – the identification of species earmarked for assessment.
- Implementation – the determination of the processes, types of data used and analyses completed for the assessment of (data poor) species.
- Interpretation – the managerial interface to the outcome of an assessment.

In all, the survey instrument included 24 questions with some questions more appropriate for managers (dealing with decision making) and others better suited for scientists (aimed at assessment and technical analyses). Thus, not all questions were used in each interview as the interviewers purposely focused on the questions most appropriate to the interviewee.

At the beginning of each interview, the interviewee was given an explanation on the objectives of the research, the expected length of the interview, the reporting process involved and the confidential and anonymous nature of the interviews. After asking the interviewee if they accepted being audio-recorded, the interview was recorded on an Olympus WS-100 which stored the digital recordings as a windows media audio file (wma). In some rare cases, the interviewee indicated that they did not wished to be recorded and only written notes were taken. These recording files were coded by number and stored in a secure location. Similarly, the associated transcripts were also stored with numerically coded filenames.

Research based on such survey instruments can be susceptible to a number of possible biases (Converse *et al.* 1986; Sarantakos 2005; Fink 2006). The questions and interview format used for this study was designed to reduce biases as much as possible. Virtually all the interviews were conducted on individuals to avoid social conformity bias. Although the interviewees were all told that the interviews would be anonymous, one important source of bias could have been personal cost bias resulting from respondents' awareness that they were being recorded.

4.5.3. Contrast with U.S.

As part of a U.S. National Science Foundation scholarship program a U.S. graduate student conducted an analysis with direct relevance to this project. For this analysis, the student, Mr Steven Gray, conducted interviews with managers and scientists along the U.S. Atlantic coast using the survey instrument designed for this project. Steven's interview transcripts were then used to develop a paper comparing and contrasting his U.S. interviews with those conducted in Australia. The purpose of this paper was to examine risk identification as reported by fishery scientists and managers in Australia and along the U.S. Atlantic Coast in an effort to: define the risks identified by fisheries professionals; compare the identification of risk by professional group and by country and; identify within a model of fishery management where these risks are located. A copy of the draft paper is presented in Appendix 9.

4.6. Drafting the national guidelines

Following the completion of the core of the literature review and the interviews, work commenced on the drafting of the national guidelines. The first draft of the guidelines was developed by the project team by identifying the dominant themes that had arisen from the interviews and the literature review. Three general themes emerged: definition of risk and risk management; broadening the concept of data-poor species; and practical suggestions for using risk-based methods in the scope, implementation and interpretation of assessments of data-poor species. These general themes were mapped to principles and then specific guidelines developed within these principles.

The draft guidelines were then sent to each of the project co-investigators (see Table 1 for a list of personnel) prior to the co-investigators meeting on 24 June 2008. The majority of this one day meeting was used to work through each of the guidelines with comments taken from each attendee at the meeting. These comments were then used to develop a second draft of the guidelines. Subsequent drafts were sent out to the co-investigators for further comment until the draft guidelines were finalised in August of 2008.

4.7. Benchmarks

4.7.1. Background

Benchmarking is a tool for institutional improvement that provides a frame of reference to make comparison with other leading entities to obtain information that will help organisations identify and implement improvements. Benchmarking exercises can be either quantitative or qualitative (Andersen *et al.* 1996). Recent examples of the use of qualitative benchmarks in fisheries management include Powers (1996), Grafton *et al.* (2007), Pitcher *et al.* (2008) and Pitcher *et al.* (2009). Additional ideas on the benchmarking exercise were obtained from Neville (2008) who is undertaking a benchmarking exercise on the implementation of ecosystem-based fisheries management for his PhD research.

The main purpose of this benchmarking exercise was to provide a means by which each agency could compare their strategies against the other agencies. The benchmarks also provided a convenient and anonymous mechanism for providing each agency with the feedback that was promised to each during the interview process. By including all Australian jurisdictions in the benchmarking process it is hoped that the benchmarks will also help facilitate cross-jurisdictional standardisation and knowledge-sharing and highlight areas in need of further research and development at a national level.

The benchmarks were designed as an integrated whole that comprises the key factors important to a fully functional risk management system. They focus upon the performance of the fishery management systems in each jurisdiction from the perspective of the national guidelines. The broad base of both the guidelines and the benchmarks was necessary to capture all the issues that contribute to contemporary risk-management of data-poor species.

4.7.2. Benchmark development

The benchmark statements were developed after the draft national guidelines were finalised (~Sep 2008) and are closely associated with the guidelines. Each benchmark is thus aligned to one or two guidelines. A number of additional benchmarks were also included that recognised areas of excellence that may aid in the management of data-poor fisheries but were deemed outside the scope of the guidelines (examples include ecosystem-based fisheries management processes and the incorporation of socio-economic considerations). There are also benchmarks which included efficient/low-cost approaches that have been implemented by a number of agencies, including weight-of-evidence, indicator species, data management strategies and new technologies. Finally, benchmarks were included to acknowledge the practical needs of organisations in reducing the institutional risks associated with the accuracy and efficiency of their own business processes. Some benchmarks thus touch on the jurisdictions/agencies performance in areas such as project management, documentation and information management.

Responses to the benchmarks were then drafted by the project team using information from the interviews, the literature review and agency publications. These draft benchmarks were then forwarded to the jurisdictional co-investigator(s) for comment and augmentation. The benchmarks responses were then further edited and validated by each agency team during the workshop process. The “final draft versions” was then circulated again to co-investigators in January 2009 for their agencies approval in a public document (i.e., this report).

Each benchmark response was a statement or proposition for which there was an associated level of agreement. Given the high level nature of this project, this agreement was couched in terms of a “policy” and was associated with a traffic-light approach. The benchmark scores are summarised in Table 3.

Table 3. Traffic-light scores used in the benchmarking exercise.

Code	Benchmark Score	Description
R	Red	No evidence of policy
LR	Light Red	Some evidence of policy and partial implementation
Y	Yellow	Policy in place; evidence of implementation
LG	Light Green	Policy in place; evidence of substantial implementation
G	Green	Policy in place; evidence of full implementation

The word “policy” was used in the broadest sense of the word i.e., “course or general plan of action (to be) adopted by government, party, person, etc.” (Sykes 1982). Some workshop participants interpreted this as official government policy which, for some of the benchmarks, was not likely to exist.

At the guidelines workshops, there was an exercise (see section 4.7) where each of the draft benchmarks was considered in more detail. If the agreed score for a benchmark was Green, then the next benchmark was considered. Otherwise, the following questions were asked of the group:

- What would be the *impact* of the agency raising this benchmark to green (low, moderate or high)?
- What is the *capability* of the agency to raise this benchmark to green (low, moderate or high)?

If the impact was high and the capability was moderate or high, then this benchmark was highlighted during the workshop wrap-up. These impact and capability scores are not presented in this final report as they received limited review by the agency and were mostly beneficial for internal deliberation.

4.8. National guidelines workshops

4.8.1. Objectives

The national guidelines workshops had the following objectives:
- Clarify the definition and use of risk management in fisheries.
- Stimulate discussion within an agency about the role of risk management.
- Present the national guidelines for risk management of data poor fisheries.
- Develop strategies for risk management of data-poor species in Australia to facilitate cross-jurisdictional management of species and consistent national reporting.

- Provide feedback to each jurisdiction on the nation-wide interviews and on their comparative progress in the development of a risk management system for fisheries management.

4.8.2. Workshop structure

The one-day national guidelines workshops were conducted in each jurisdiction with the following agenda (Table 4). In some cases, timings were adjusted to suit participants and in other cases the presentations at the end of the day were abbreviated because other content had run longer than expected. The day was designed to be varied and stimulating for participants. Where possible, seating was arranged so that sub-groups consisted of equal numbers of managers and scientists. A trial workshop was held at NSW DPI on the 26 September 2008 to test several exercises and identify the parts of the workshop that were likely to be difficult to manage.

Table 4. Typical agenda of the national guidelines workshops.

Time	Content
10:00am – 10:20am	Welcome, Introductions (Presenter: James Scandol)
10:20am – 10:50am	Presentation: Intro Slides (Presenter: James Scandol)
10:50am – 11:20am	Six Hats: What is the point of risk management in fisheries? (Convener: Matt Ives)
11:20am – 11:45pm	Presentation: ERA Risk Methods (Presenter: Matt Ives)
11:45am – 12:00pm	Coffee Break
12:30pm – 13:00pm	Case Studies: Applying the Risk Guidelines (Conveners: James Scandol, Matt Ives)
13:00pm – 13:30pm	Lunch
13:30pm – 15:00pm	National Risk Benchmarks (Conveners: James Scandol, Matt Ives)
15:00am – 15:20pm	Afternoon Break
15:20pm – 15:30pm	Benchmarks Discussion (Presenters: James Scandol, Matt Ives)
15:30pm – 15:50pm	Presentation: Data Poor – Problems and Solutions (Presenter: James Scandol)
15:50pm – 16:00pm	Wrap-up, Feedback, Evaluations (Conveners: James Scandol, Matt Ives)

4.8.3. Presentations

Three separate presentations were given at each of the national guidelines workshops. Copies of the Microsoft PowerPoint slides are included in Appendix 6. The first presentation summarised the purpose of the project and the national guidelines. The second presentation provided a quick overview of the three main ERA methodologies as presented in section 5.7. The final presentation provided an overview of some new quantitative methods for the evaluation of the status of data-poor species and fisheries as covered in section 5.8.

4.8.4. Six thinking hats exercise

The Six Thinking Hats was used to generate initial debate amongst the group as to the key issues associated with their organisation's implementation of a risk management system. The exercise not only allowed a sharing of expertise and ideas amongst the group, but gave insights into the main issues being encountered by each jurisdiction.

The six thinking hats exercise (De Bono 2000) is intended to allow an individual or groups to systematically structure the different types of thinking required to solve problems, resolve issues and make decisions. In facilitating this exercise, the activity leader steers the group through each of the thinking hats and takes notes on a white board to allow the group to see their thoughts and arguments as they are presented. The six hats and their main purpose are described in Table 5.

Table 5. Summary of the role of the six hats used in the initial 'brainstorming' exercise.

Hat – Type	**Description**
Blue Hat – Control	Organises the thinking and calls for the use of the other hats. i.e., Determines what the problem is to be solved e.g., what is the point of risk assessments?
White Hat – Facts	Checked and proven facts – first class facts and facts that are believed to be true but have not yet been fully checked – second class facts.
Green Hat – Creative Thinking	Search for alternatives: go beyond the known, the obvious and the satisfactory.
Yellow Hat – Positives	Probes for value and benefit and strives to provide support for positive outcomes.
Black Hat – Negatives	What is wrong, incorrect and in error. How something does not fit with experience or accepted knowledge, why something will not work and what risks exist.
Red Hat – Feelings	Legitimises emotions and feelings as an important part of thinking. Ordinary emotions of fear, dislike, suspicion and more complex judgements that go into such types of feelings as hunch, intuition, sense, taste and aesthetic feeling.

4.8.5. Case studies

The purpose of the case studies was to provide a simple means by which attendees could become familiar with the guidelines and partake in an exercise in applying the guidelines to an actual example of a data-poor fishery/species. For this purpose, a one page summary case study was provided by some of the co-investigators of a data-poor fishery managed within their jurisdiction. The one-page format was used so that participants could read the document rapidly and be briefed on the context of the problem. Examples of two of the case studies are provided in Appendix 7.

The strategy was to have participants consider a case study of which they were unfamiliar. For example, at the Commonwealth workshop used examples where recreational fisheries and freshwater flows were a significant part of the fishery management scenario. Using the "Applying the National Guidelines" sheets shown in Appendix 5, the attendees were asked to step through the risk management process based on the AS/NZS (2006) standards (and as reflected by a subset of the guidelines). When facilitating this activity, a member of the project team stepped through each of the guidelines and asked the participants to discuss each guideline in reference to the case study. One of the participants took brief notes and was asked to present a summary of the group's discussion at the end of the workshop. The summary focused on the greatest risks identified by the group, any management recommendations and any novel ideas or insights.

4.8.6. Benchmarks

As indicated in section 4.7.2, workshop participants were provided with a draft score and justification for each benchmark for their jurisdiction. This information was compiled from the interviews, publicly available policy documents, risk assessments, stock assessments, scientific reports and other papers. The project team attempted to provide neutral scores for the draft benchmarks, but in some cases they were too optimistic and in other cases too pessimistic. The workshop participants were split into two smaller groups who respectively considered the odd and even-numbered benchmarks.

4.8.7. Workshop evaluation

At the conclusion of the workshop each participant was asked to complete a one page evaluation form. A copy of the evaluation questionnaire is included in Appendix 8.

5. RESULTS – LITERATURE REVIEW

5.1. Structure of the literature review

The following literature review covers a number of non-contiguous areas that are best summarised in a diagrammatic format (Figure 2).

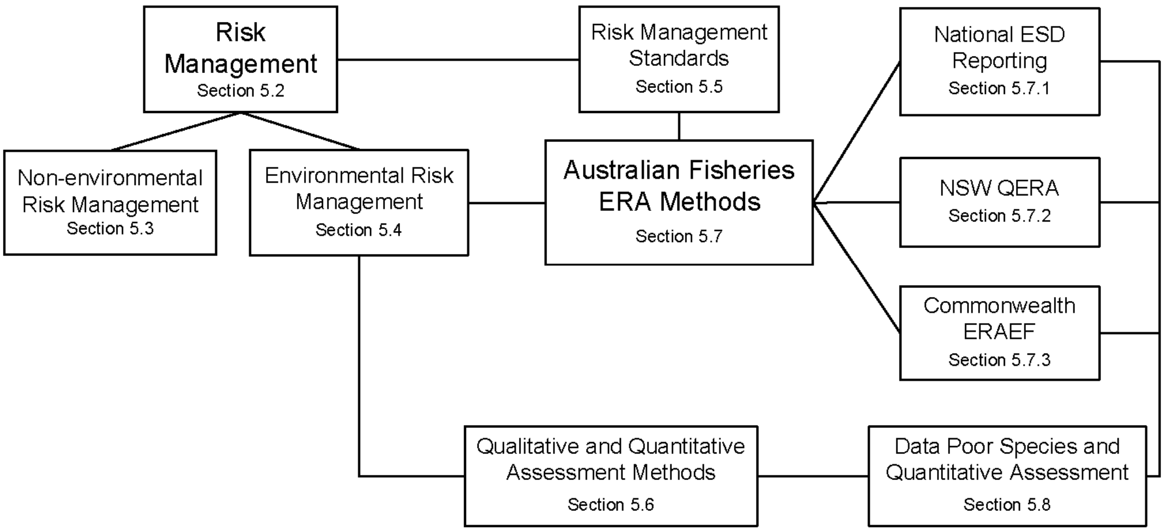

Figure 2. Concept map of the areas covered in the literature review.

5.2. Risk and risk management

The term 'risk' has been defined in many ways (Kaplan *et al.* 1981; Adams 1995; Francis *et al.* 1997; Althaus 2005) however in its simplest definition it is the chance of something happening that will have an impact on objectives (AS/NZS 2006). It is thus a combination of both a probability or likelihood and an impact or consequence. A risk arises from an event; an action or from the lack of action; from natural variability; or from uncertainty but it must by definition include some consequence or damage (Kaplan *et al.* 1981).

Risk management represents a logical and systematic method of establishing the context and identifying, analysing, evaluating, treating, monitoring and communicating risks associated with any activity, function or process in a way that will enable organisations to minimise losses and maximise opportunities (AS/NZS 2006).

In principle there are four phases to any risk management process – risk context, risk identification, risk characterisation and risk management (Hope 2006). In *risk context* the underlying legislation and policy is identified to determine the basic parameters within which risks must be managed and the scope is set for the rest of the risk management process. The risk to be minimised is defined, as is the structure of the analysis, the criteria against which risk will be evaluated, and the stakeholders are identified along with the communication and consultation policies. *Risk identification* involves identifying where, when, why and how events or hazards could prevent, degrade, delay or enhance the achievement of the objectives and also involves determining the consequences of each of these risks (RiskThinkers 2008). In risk characterisation the information regarding the likelihood and consequence of each of the identified risks (or hazards) are summarised to meet the needs of the decision makers and other stakeholders. Risk characterisation is a prelude to the decision making that occurs in risk management and depends on an iterative process (Stern *et al.* 1996). In the risk management phase the risks identified across the organisation are ranked and the appropriate management actions are applied to each. In cases where uncertainty is a significant cause of an identified level of unacceptable risk, the management action could be to fund more research to reduce this uncertainty. If, however, the level of risk has been deemed to be acceptable, a legitimate management action is to maintain the current strategy.

The advantages of following a risk management framework are summarised as follows:

- Combines various technical assessments and consultative approaches into a process that supports informed, consistent and defensible decision making (AS/NZS 2006; Hope 2006).
- Provides a structured, systematic approach to gathering data and evaluating their sufficiency for environmental decision making (AS/NZS 2006; Hope 2006).
- Recognises, considers and reports uncertainties in estimating adverse effects of stressors (uncertainty is always present due to the complexity of ecosystems) (Hope 2006).
- Combines technical assessments and consultative approaches into a process that supports informed consistent and defensible decision making (AS/NZS 2006).
- Steps in the risk management process follow in a strict sequence, thus forming the basis for rigorous decision-making (Gaidow *et al.* 2005).

Risk management is currently recognised in many fields of human endeavour as an integral part of good management practice. The following two sections provide a brief review of the application of risk management to both non-environmental and environmental fields.

5.3. Risk management: non-environmental

The following section contains a brief review of the application of risk-based methods in disciplines that are not related to environmental management.

5.3.1.1. Property/security (including fire)

Property must be managed, maintained and protected against a range of risks including construction, explosion, fire, asbestos, machinery, natural disaster, security and theft. *Risk management* has replaced *risk avoidance* in recent years as the guiding philosophy of modern security programs (Roper 1999). Risk management offers a more pragmatic and defensible approach to making decisions about the expenditure of scarce resources on counter measures for risk to property security. Contemporary risk management strategies now include methods that provide a cost-benefit payback factor on all proposed measures (Wilder 1997). Modern property/security risk management involves the standard risk identification, prioritisation, prevention and monitoring steps with many practices having being institutionalised in Australia through government standards, guidelines and regulations.

5.3.1.2. Information technology

Risk management is used in two key areas of information technology (IT). Firstly, it is used as a program management tool to reduce the risks of adverse problems caused by software failures and secondly it is used in the management of private computer networks and the protection of information held within these networks. In software development, risk management is an ideal tool as there is a relationship between risk and the amount of software testing undertaken. Because software can rarely be exhaustively tested, risk management is used to help prioritise testing so that more testing is conducted on the issues that can cause the greatest loss (McCaffrey 2009). IT security is another area that has lent itself easily to risk management. Risk assessment provides the processes and documentation for corporate management to undertake and demonstrate due diligence in their decision-making processes. It is through the use of risk management that firms have recently begun to recognise that the biggest threats to their information security are not necessarily from anonymous hackers but rather from disgruntled or dishonest employees (Peltier 2005).

5.3.1.3. National defence

Managing risk has always been inherent to any type of activity in national defence. Recent events of global and local importance have also increased the perceived need for a co-ordinated and systematic approach to managing defence risks. Since 2002, the Department of Defence has adopted an enterprise-wide risk management approach based on the AS/NZS 4360:1999 standards (Gaidow *et al.* 2005). The Enterprise Risk Management Directorate guides the development and implementation of risk management at all levels across Defence and forms part of corporate governance, business models and day to day operations of the Department. The Directorate includes as a risk management policy, an implementation plan, guidelines, and a risk management framework.

5.3.1.4. Hospitals

Risk management in health is greatly facilitated by the information that is kept on medical cases. It is a well controlled environment that allows the likelihood of various medical conditions and events to be estimated with reasonable accuracy. This is a very valuable approach but can be susceptible to changes in contexts and unexpected elements (Bammer *et al.* 2008). The greatest difficulty in medical risk management has arisen in the evaluation and ranking of various consequences, such as loss of life, which to any given person can be regarded as a completely unacceptable. This is generally dealt with through tight adherence to policies and legislation that break the impasse on such problems and through adherence to rules, documentation, continual improvement and re-evaluation of rules (Barach *et al.* 2000).

5.3.1.5. Occupational health and safety

Occupational health and safety (OH&S) is probably the area of risk management that most people are familiar with due the scope of OH&S legislation. OH&S encompasses all work related health and safety issues including medical, psychological, technical, managerial and legal (regulatory) risks (Stellman 1998). The OH&S risk management model follows the standard processes of risk context, identification, characterisation and management (Lave 1987). As with medical risk management, OH&S risks measure all consequences in terms of the loss or impairment of human life. Due to such losses being difficult to objectively evaluate, many of the processes and procedures within this field are governed by public legislation and oversight. As a consequence significant resources must be allocated within contemporary institutions to assess and manage OH&S risks.

5.3.1.6. Local government administration

Risk management in local government administration has primarily arisen to meet the rising costs of litigation against public organisations (Denhardt 1991). Cases involving civil damages, breach of conduct and worker's compensation have gradually increased the cost of local government administration in recent years. Some organisations purchase insurance, often from private firms, but this is becoming increasingly expensive forcing some to eliminate uninsured services (such as certain recreational activities). Others have chosen self-insurance in the form of an insurance pool by jurisdiction or across several municipalities.

5.3.1.7. Economics and finance

In economics and finance, risk is accepted as an endemic aspect of economic activity. The general concept of risk in economics is a mix of challenge and security, with the predominant focus on the risk-reward paradigm (Althaus 2005). The main theme of the economics literature is that risk can be conceptually manipulated in a manner similar to the problem of scarcity (i.e., given finite resources not all needs can be pursued simultaneously so *trade-offs* are required) (Doherty 2000; Althaus 2005). All economic activity has a financial return (reward) as its goal, however inherent risks have a negative impact on expected returns, with greater returns generally required for investors to assume greater risk. Thus maximising reward becomes a tradeoff between risk and reward. This concept of risk has been the dominant one throughout the 20th century (Bernstein 1996).

Provided environmental capital and services can be properly valued economically, economic risk management can also be applied to environmental risks. However some key differences exist between economic risk and environmental risk. Economic risks can be divided into two types, pure risk and speculative risk. *Pure risk* (often termed *insurable risk*) is associated with hazards such as health, safety, environment and security where success with controlling the risk can never be better than when the hazard is removed and thus no harm can result e.g., no accidents, zero exposure, zero product defects, no pollution. *Speculative risk* is associated with threats to business, finance, investment (and politics), where success is always *relative* to that of the economy as a whole, the market sector and competitors. Speculative risk is more associated with economics and finance and differs from pure risk in that both desirable and undesirable outcomes are possible. Thus, theories and systems dealing with the management of speculative risk are not necessarily applicable to environmental risks.

Portfolio theory is currently the dominant tool of financial risk management and is centred around the concept of diversification which helps avoid or minimise the probability of extreme outcomes (simply summarised as "don't put all your eggs in one basket"). Portfolio theory treats the returns from various items (e.g., securities) as random variables and utilises aspects of normal probability distributions to calculate the mean return and the standard deviation (volatility). Portfolio management has been suggested as a possible avenue for broad fisheries management (diversifying risks across species) (Hilborn *et al.* 2001; Edwards *et al.* 2004), however this idea has yet to gain any momentum possibly due to the complexities in applying such a management regime in practice. Figge (2004) also developed some of these ideas for the management of biodiversity.

5.4. Risk management: environmental

Environmental risk management deals specifically with the relationship between humans and human activity and the environment (AS/NZS 2006). The definition of "environment" can depend on the context but generally refers to the natural environment. Environmental risk management includes risks to ecosystems that arise from human activity, as well as risks relating to human health and wellbeing (pollution), the impact of natural hazards on people and the risks of not complying with environmental legislation (which can manifest as a risk of litigation). Environmental risk management evolved out of a hazard-based management of industrial pollutants and other toxins (Bashkin 2006). The gradual evolution towards risk management in environmental policy and regulation is due to its applicability to environmental problems but also due to the recognition that the environment has an assimilative capacity, so that for many environmental issues a level of zero risk is impractical and simply not necessary.

Unlike other forms of risk, environmental risks are only negative and thus the definition of environmental risk becomes the chance of something happening that will have a *negative* impact on environmental objectives. Environmental risk management also differs somewhat from the management of other types of risk because of the high levels of uncertainty involved and because impacts may have a very long time span (generations) (AS/NZS 2006).

Environmental management contains several major areas including air, water and land contamination, environment protection and conservation of biodiversity (including bio-security), natural resource management (mining, agriculture, forestry and fisheries), and the more recent multi-sector problem of climate change.

5.4.1.1. Air and water quality and land contamination

Air, water and land contamination is generally dealt with through national standards, which in Australia, are administered by Department of the Environment, Water, Heritage and the Arts. Environmental risk management is regarded by Australian governments as a fundamental approach to the management of Australia's environment (UNEP FI Australasian Advisory Committee on Insurance 2003; Natural Resource Management Ministerial Council 2004). Environmental risk management requirements are included in most such standards and are required by any industry or organisation whose activities may have an adverse impact on air, water, flora, fauna and ecosystems.

Ecological risk assessment (ERA) is the subset of environmental risk management that deals specifically with such risks. ERA is a process that evaluates the likelihood (probability) that adverse environmental effects (consequences) may occur or are occurring as a result of exposure to one or more stressors related to human activities. It is a flexible process for organising and analysing data, assumptions and uncertainties in order to help understand and predict the relationships between stressors and ecological effects in a way that is useful for environmental decision making. An assessment may involve chemical, physical, or biological stressors, and one stressor or many stressors may be considered (US Environmental Protection Agency 1998; Hope 2006).

Most of the ERA processes employed throughout the world have been adapted from the protocols developed by the US Environment Protection Authority (US Environmental Protection Agency 1998) developed to deal primarily with contaminated landfill sites (*Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) commonly referred to as Superfund). According to the US EPA approach there are three phases to risk analysis namely problem formulation, analysis of exposure and effects, and risk characterisation, linked by "an overarching consideration of uncertainty" (US Environmental Protection Agency 1998; Hope 2006).

An interesting aspect to environmental risk evaluation by industry is that even given an equivalent financial loss, an environmental risk may be less acceptable then a financial risk (Bammer *et al.* 2008). That is, a firm may be willing to accept a significant level of financial risk exposure, such as currency movements that is acknowledged as an acceptable business risk by the wider community; however the exposure to a monetarily equivalent risk from an environmental liability may not be as acceptable to the broader community. There is thus an added social dimension to the environmental risk that may be difficult to quantify but will nevertheless affect the risk management strategies of businesses. The recognition of such social risks is no doubt responsible for the increase in importance given to public relations departments within companies. This parallels the challenge of evaluating social risks found in the management of natural resources, such as fisheries, and the increasing use of the media by both government and industry.

5.4.1.2. Bio-security

Within the field of bio-security risk assessment is defined in the World Organisation for Animal Health (OIE) Code as "*an evaluation of the likelihood and the biological and economic* *consequences of entry, establishment or spread of a pathogenic agent within the territory of an importing country.*" (Biosecurity Australia 2007). A number of Australian government agencies are involved in the protection of Australian's animal and plant health status and natural environment including the Quarantine and Inspection Service (AQIS) and Biosecurity Australia.

Within its quarantine framework, Biosecurity Australia uses qualitative risk assessments to assist in determining the level of risk that may be associated with the importation or proposed importation of animals, plants or other goods (Biosecurity Australia 2007). Quarantine risk is composed of two related factors – the probability of the disease agent entering and becoming established in Australia, and the expected impact or significance of such establishment. If the assessed level of quarantine risk exceeds Australia's 'appropriate level of protection' (ALOP) and no management measures can be found to reduce the quarantine risk to achieve the ALOP, Biosecurity Australia is authorised to not allow trade.

In conducting a risk analysis, Biosecurity Australia performs the following tasks:

- Identifies the pests and diseases of quarantine concern that may be carried by the good.
- Assesses the likelihood that an identified pest or disease would enter, establish or spread.
- Assesses the probable extent of the harm that would result.

5.4.1.3. Natural resource management

Natural resource management includes the management of all land and water resources such as agriculture, forestry, and fisheries. Risk management as a formal approach is relatively new in the realm of natural resource management, although it can be argued that this is the primary task of all natural resource managers. Risks arise from a variety of factors ranging from natural variability, industrial pollutants, natural disasters, uncertainties in yields and prices, weak infrastructure, imperfect markets and changing societal preferences. The fact that these problems span natural and human systems – which are both highly complex systems in their own right – means that natural resource management can involve extremely high levels of uncertainty. As mentioned earlier such uncertainty has meant that formal risk management processes have not been so easily applied in this field (as opposed to other less complicated situations such as traffic accidents or financial markets). Ironically it is increased awareness of the full extent of our uncertainty that has forced natural resource managers to look to more qualitative assessment methods, such as qualitative risk assessments, for more cost effective management of natural resources.

The majority of research in natural resource risk management has been on exploited natural resources such as agriculture (Sivakumar *et al.* 2007), forestry (Kangasa *et al.* 2004) and fisheries. The use of risk assessment as a management tool in fisheries is on the increase both in Australia and internationally (McPhee 2008). Applications include stock assessment, management strategy evaluation, research prioritisation, and compliance and monitoring.

One key issue that has intensified interest in natural resource risk management is that of anthropogenic climate change. An interesting aside to this phenomenon is that it has led to a growth in 'risk transfer' whereby the risk that one organisation is unable or unwilling to bear is able to be transferred to another – e.g., insurance. In exchange for the payment of an agreed amount (the premium), one party (the insurer) agrees to indemnify the client for losses that result from specified risks (UNEP FI Australasian Advisory Committee on Insurance 2003). Along with the concept of 'risk transfer' is the complementary concept of 'risk retention' which is the amount of risk that an organisation chooses to retain or is unable to transfer to another organisation. Sophisticated markets have developed, primarily in the U.S., that allow organisations whose output is dependent on environmental conditions to insure against such risks (Sivakumar *et al.* 2007). Of possible interest for fisheries management is the fact that such markets have developed to allow for not only insurance on the value at risk (VaR) or exposure from an extreme event but also on the effects of changes in variability (Banks *et al.* 2002).

5.5. AS/NZS risk management standards

It should be noted that, regardless of any differences in the nature and scope of the risks in each discipline, all risk management methods should be able to be interpreted within the Joint Standards Australia/Standards New Zealand model (AS/NZS 4360:2004). This underlying similarity translates into the overall structure of risk management being generally the same across all disciplines (Walker 2001).

According to the AS/NZS risk management standards there are seven main elements to the risk analysis process as set out in Figure 3. As illustrated, the risk analysis process is iterative and may be repeated many times. Within each cycle any additional or modified risk evaluation criteria are added to achieve progressively better levels of risk management and leading to a process of continual improvement.

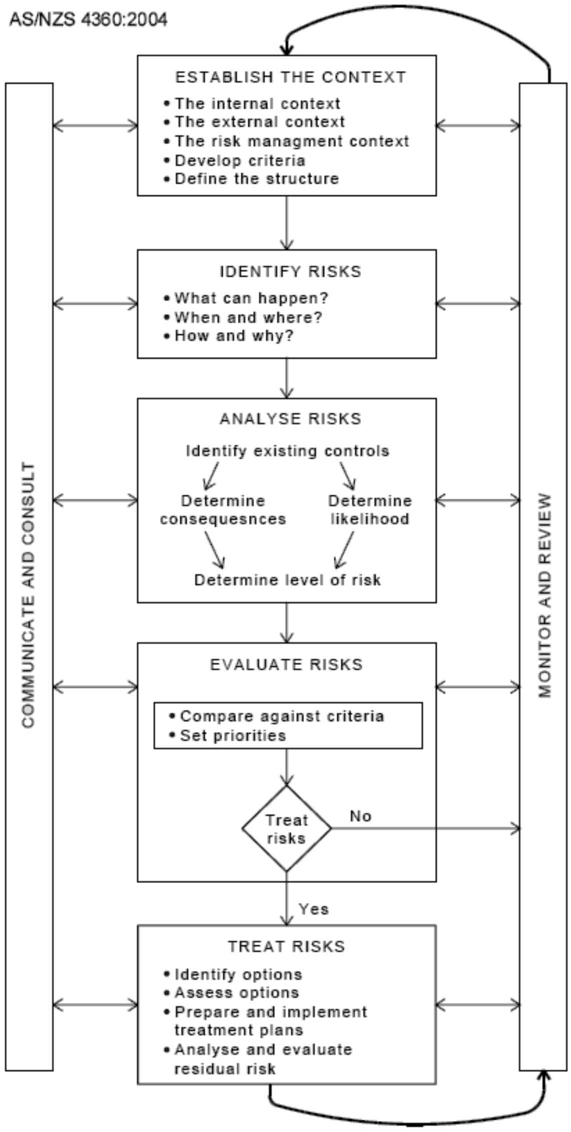

Figure 3. The seven main elements of the risk management process as outlined in AS/NZS 4360:2004.

The steps of the generic risk analysis model are as follows:

1. *Establish the context* (Risk context): Defines the basic parameters within which risks must be managed and sets the scope for the rest of the risk management process. Provides point of reference for assessment and defines risk that is to be minimised (Scoping). Establishes the structure of the analysis and the criteria against which risk will be evaluated. Identify stakeholders and define communication and consultation policies. Also known as *Problem formulation*, (Hope 2006), or *Problem formulation/Hazard identification* (Chapman *et al.* 2000) (based on US EPA ERA).

2. *Identify risks* (Risk identification): Determine the source of risks and identify the risks to be managed: what can happen, why and how (including hazards, aspects and impacts). All potential risks need to be identified using a well-structured systematic process. Also known as *Hazard identification*, *Exposure* and/or *Effects assessment* (Chapman *et al.* 2000; Hope 2006).

3. *Analyse risks* (Risk characterisation): Develop an understanding of risk and identify which risks need to be treated. Determine existing controls and analyse risks in terms of consequence and likelihood in the context of those controls. Consequence and likelihood are combined, often using a risk matrix, to produce an estimated level of risk. A preliminary analysis can be carried out so that similar risks are combined or low-impact risks are excluded from detailed study. This stage and the next are often referred to collectively as risk characterisation.

4. *Evaluate risks* (also Risk characterisation): Make decisions based on risk analysis about which risks need to be treated and to prioritise these risks. This is achieved by comparing estimated levels of risk against the criteria established when the context was considered. Risk evaluation may lead to a decision to undertake further, possibly more detailed, analysis.

5. *Treat risks* (Risk Management): Risk treatment involves identifying and assessing the range of options for treating risks. Low priority risks are monitored while specific management plans are developed and implemented for those risks requiring treatment.

6. *Communicate and consult* (Risk communication): Communication is important at each stage of the risk management process and should involve a dialogue with stakeholders with efforts focused on consultation rather than a one-way flow of information from the decision maker to other stakeholders. It is important to develop a communication plan at the earliest stage of the process which addresses issues relating to both the risk itself and the process to manage it. Effective communication is important to ensure that those responsible for implementing risk management, and those with a vested interest, understand the basis on which decisions are made and why particular actions are required. Stakeholders are likely to make judgements about risk based on their perceptions. These can vary due to differences in values, needs, assumptions, concepts and concerns as they relate to the risks or the issues under discussion. Since the views of stakeholders can have a significant impact on the decisions made, it is important that their perceptions of risk be identified and recorded and integrated into the decision making process (Chapman *et al.* 2000; AS/NZS 2006; Hope 2006).

7. *Monitor and review* (Risk Management): Ongoing review is essential to ensure that the management plan remains relevant. It is necessary to repeat the risk management cycle regularly since factors that may affect the likelihood and consequences of an outcome may change, as may the factors that affect the suitability of the treatment options. Reviewing

events, treatment plans and outcomes facilitates learning lessons that can be applied in future iterations of the process.

5.6. Qualitative and quantitative risk assessment

Risk assessments may be undertaken to various degrees of refinement depending on the information and data available. Analysis may be (in order of complexity and cost) qualitative, semi-quantitative or quantitative, with the depth of analysis depending, in part, on the magnitude of the risk (AS/NZS 1999; AS/NZS 2006). Descriptions of the likelihood of adverse effects and their consequences may thus range from qualitative judgements to quantitative measures of probabilities or model-based estimates with separate issues of concern within a single risk assessment dealt with using very different levels of precision or detail (ICES 2007). An excellent, but now somewhat outdated, review of risk in fisheries management was completed by Francis and Shotton (1997).

5.6.1. Qualitative assessments

A qualitative assessment is one in which word form or descriptive scales are used to describe the magnitude of potential consequences and the likelihood that they will occur. They frequently involve the use of descriptive scales for consequence and likelihood in a table form which are then combined into a risk matrix where risks are assigned to priority classes based on their consequence and likelihood. In practice, a qualitative risk assessment is often used first to obtain a general indication of the level of risk and to screen out low risk activities. A more specific quantitative analysis is then conducted on the more high risk activities that warrant a greater expenditure of time and effort (highlights the iterative nature of risk assessment). Qualitative risk assessments can often be the only option available in situations where numerical data are inadequate. Environmental risk assessments are usually qualitative in nature due to the complexity and number of inputs where environmental risk studies have to deal with multiple receptors (specific component under study: species, ecosystem etc.) and multiple impacts (AS/NZS 1999; AS/NZS 2006). Due to the number of data poor fisheries a significant number of risk assessments conducted in Australia have been qualitative (McPhee 2008).

Example methods:

- National ESD Reporting Framework (NESDRF) incorporating only qualitative assessment information (Fletcher *et al.* 2002; Fletcher *et al.* 2005).
- Ecological Risk Assessment for the Effects of Fishing (ERAEF) Level 1 (Hobday *et al.* 2007).

Examples risk assessments:

- NESDRF incorporating only qualitative assessment information (Department of Fisheries 2003; Department of Fisheries 2004b).
- ERAEF Level 1 (Milton *et al.* 2004).

5.6.2. Semi-quantitative assessments

The semi-quantitative approach can be defined as a risk assessment in which values are applied to quantitative scales but where these values do not have to bear an accurate relationship to the actual magnitude of consequence or likelihood. Numbers for consequence and likelihood can be combined by a range of formulae, providing the system used for prioritising is consistent with the system chosen for assigning numbers and combining them. The objective is to produce a more detailed prioritisation than is usually achieved in purely qualitative assessments but without assigning *actual* values for risk, as is attempted in a purely quantitative assessment. Care must be taken when interpreting semi-quantitative analyses since choosing numbers that do not fully reflect relativities can lead to inconsistent outcomes. It is for this reason that the NSW QERA method does not use numbers for its risk ranking system (Astles *et al.* 2006). Also semi-quantitative assessment does not properly differentiate between risks when either consequence or likelihood is extreme.

Example methods:

- NSW Qualitative Ecological Risk Assessment (QERA) (Astles *et al.* 2006; Astles 2008).
- NESDRF incorporating quantitative assessment information (Fletcher *et al.* 2002; Fletcher *et al.* 2005).
- ERAEF Level 1 and 2 (Hobday *et al.* 2007).

Examples of semi-quantitative risk assessments:

- NSW QERA (NSW Department of Primary Industries 2001; NSW Department of Primary Industries 2004a).
- NESDRF incorporating quantitative assessment information (Department of Fisheries 2004a).
- ERAEF Level 1 and 2 (Ling *et al.* 2004).

5.6.3. Quantitative assessments

Quantitative assessments use numerical values (rather than descriptive scales) for the evaluation of risk, using data from a variety of sources. Quantitative approaches are often associated with good scientific understanding and numerical information. The validity of the risk assessment is dependent on the availability of data, and on the accuracy and completeness of the numerical values and the methods/models used. Certain types of consequence may be estimated by modelling outcomes of an event or set of events or by extrapolation from experimental studies or past data. Likelihood is usually expressed as a probability, a frequency, or a combination of exposure and probability. Examples of quantitative risk assessment include physiological models of impact (dose-response models), stock assessment (immediate), management (or harvest) strategy evaluation (long term) (Francis *et al.* 1997; Smith *et al.* 2007a), fishing mortality assessment techniques (Forrest *et al.* 2008; Zhou *et al.* 2008) and ecotrophic/ecosystem modelling (Fulton *et al.* 2005b; Smith *et al.* 2007a).

In general, the steps involved in a quantitative stock assessment include (Lane *et al.* 1998):

- Problem definition – quantification of objectives and constraints, includes biological, economic, social and operational considerations.
- Deterministic modelling – scenario development, projection of controllable and uncontrollable variables and preliminary deterministic modelling.
- Simulation modelling – Monte Carlo simulation of aspects of fishery system.
- Risk assessment – compile distribution of performance measures from a simulation model and assign probabilities to the outcomes for each decision alternative. If possible this would include the use of management strategy evaluation which allows management recommendations to be linked to probabilities that the stock abundance will meet some agreed level of performance.
- Decision analysis – evaluate and rank alternative decisions for presentation to decision makers.

It is important to emphasise that the estimates and data used in quantitative assessment are often subject to variation and uncertainty so a sensitivity analysis or Bayesian approach is encouraged in order to test the effect of changes in values, parameters and assumptions on the results. All risk assessments depend to some degree on assumptions, extrapolations, estimates and approximations, and even the most sophisticated quantitative methods can have weaknesses that should be clearly documented and kept under review. Furthermore, even when quantitative assessments are highly robust they require a significant level of information and can only be applied to a small number of situations, usually in the assessment of a small number of data-rich target species. In fact, given the somewhat patchy success of the use of quantitative assessments in the past (e.g. collapse of data-rich northern cod (*Gadus morhua*) fishery in Canada – Astles *et al.* 2006), it could be argued that a qualitative risk assessment should also be applied in data-rich situations as an additional precautionary measure. Note that anthropogenic climate change is likely to make some of the assumptions that are regularly used in quantitative assessment models even more of an over-simplification than they currently are. The possible non-stationary nature of parameters like natural mortality (M) will make any dependent reference points (like F_{MSY}) also non-stationary (i.e., will change though time).

Examples methods and assessments include:

- Sustainability assessment for fishing effects (Zhou *et al.* 2007; Zhou *et al.* 2008; Zhou *et al.* in review).
- Stock assessments (Punt *et al.* 1998; Hobday *et al.* 2001; Ault *et al.* 2003; Alvarez-Flores *et al.* 2004).
- Management strategy evaluation on a stock with uncertainty incorporated into the results (Smith *et al.* 1999; Gardner *et al.* 2007; Ives *et al.* 2007; Smith *et al.* 2007a; Deroba *et al.* 2008).
- Ecotrophic modelling (Fulton *et al.* 2005b; Smith *et al.* 2007a).

5.6.4. Subjectivity in qualitative and quantitative assessments

The primary difference between qualitative and quantitative methods is that the goal of qualitative modelling is to *understand* rather than to numerically predict (Puccia *et al.* 1985). Qualitative information is often perceived as the vague, messy and the highly uncertain underdog to quantitative data. It is usually associated with incomplete understandings and verbal representations of information based on the subjective judgments of individuals (Redmill 2002). Such judgements can be affected by the generally poor ability of people to judge probabilistic events (Fischhoff 1995), by personal experience and beliefs (Pidgeon 1992), by cultural differences in the perception of risk (Rohrmann 1994) and by cognitive biases such as framing effects. The Australian risk standards recognise the potential for group assessments to accommodate the effects of individual subjectivity, however in many applications the assessment of likelihood and consequence are heavily influenced by individuals (Burgman 2001).

What is perhaps not as well recognised is that quantitative assessments generally involve a considerable amount of subjectivity in the choice of model structure, in parameter values chosen and in the extent to which all such areas of uncertainty are explored and expressed in the results (Henrion *et al.* 1992; Hilborn *et al.* 1992; Jiao *et al.* 2005). Generally, many of these modelling decisions are made by only a small group of individuals experienced with population modelling and not by a group of varied stakeholders. This situation is compounded by the fact that any changes to such quantitative models can be both time and resource expensive to alter so that once any decisions regarding the model structure have been made they generally become fixed. Finally, even the most advanced methods of evaluating robustness of predictions to uncertainty, such as Bayesian analysis and management strategy evaluation, could merely be masking the true uncertainty in a mathematical disguise that can give an unwarranted appearance of rigour to the analysis (Rochet *et al.* 2009).

It has therefore been argued that in the absence of data, or in the face of incomplete or ambiguous knowledge, striving for precision can actually be counterproductive and produce meaningless risk metrics (Dambacher *et al.* 2007). A false sense of security can be achieved by the use of computer-based modelling. The qualitative approach may sacrifice precision but may produce greater realism and generality and can focus on the most important relationships rather than the relationships that have the most data. This is a particularly pertinent point given our current limited understanding of ecosystems and socio-economic systems.

5.6.5. The tiered approach

One possible solution to the choice between using a qualitative or quantitative assessment method is the use of an iterative, tiered approach (Hope 2006) (Figure 4). Tiers typically progress from more informal qualitative surveys, through semi-quantitative levels to fully quantitative approaches. As the number of situations to which risk assessments can be applied can vary greatly in scope and complexity, starting an analysis with the more flexible qualitative approach ensures that the more intractable problems are not so readily avoided due to lack of information. If a component is found to be of higher risk due to known hazards or uncertainty, it can then be progressed to the next, more quantitative, tier. Such an approach provides flexibility and coverage while helping to ensure more efficient use of resources by focusing effort on an ever narrowing number of increasingly significant risks.

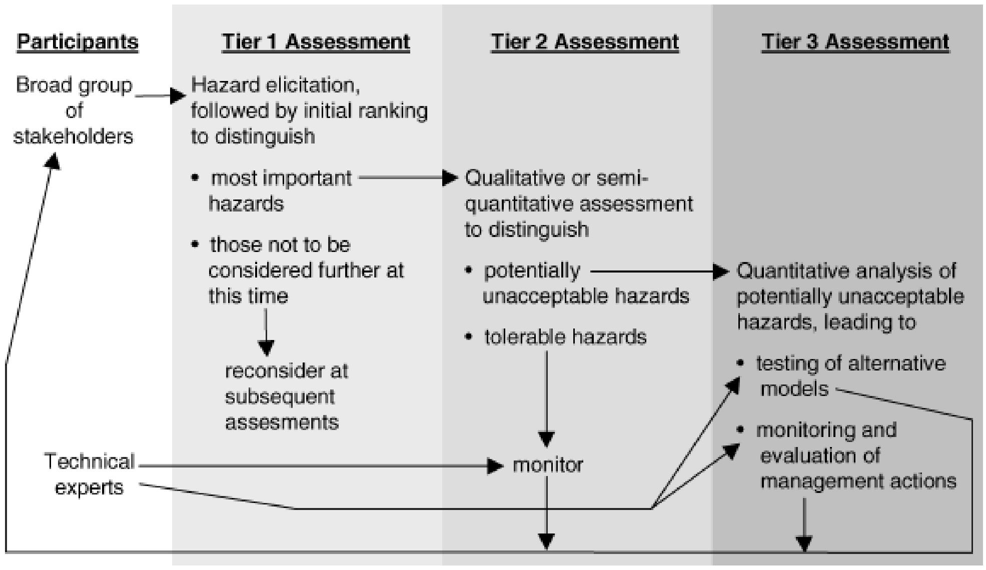

Figure 4. A tiered approach to ecological risk assessment. Source (Carey *et al.* 2007).

Examples of tiered approaches include:
- NESDRF (Fletcher *et al.* 2002).
- ERAEF (Hobday *et al.* 2007).

5.7. Ecological risk assessment methods used in Australia

The following sections includes a brief overview of each of the three ERA methods used in Australia, followed by a number of observations of the strengths and weaknesses of each method as identified in the literature and by fisheries scientists and managers around Australia. Most of the information that follows comes from the source documents cited for each method as well as from the review of these methods provided in Astles (2008).

5.7.1. *The National ESD Reporting Framework*

Strong support to develop a national ESD reporting system was obtained from all stakeholder groups at the Fisheries Research and Development Corporation (FRDC) funded workshop on ESD and fisheries held in Geelong during March 2000. The FRDC-funded ESD projects have had strong stakeholder involvement from their inception including Marine and Coastal Committee of the NRMSC, representatives from the commercial seafood industry (Australian Seafood Industry Council, ASIC), Indigenous interests, recreational fishing (RecFish), aquaculture (Aquaculture Council of Western Australia, ACWA), the then Department of Environment and Heritage (DEH), the FRDC and environmental groups (Traffic, World Wildlife Fund), and experts in economic and social research.

This group developed a conceptual framework for ESD that included: gaining agreement on terminology; identification of eight key components of ESD; and a draft reporting framework. This reporting framework was subsequently ‘road tested’ during a series of eight case studies and modified, following a workshop review of the outcomes. The revised guidelines for the National ESD Reporting Framework was then tested through a further set of case studies. The initial and subsequent versions of these guidelines are located in the Implementing ESD section of the fisheries ESD website (www.fisheries-esd.com).

Overall the National ESD Reporting Framework provides a flexible means for identifying issues, developing operational objectives and determining indicators that can be measured to monitor performance. Effective fishery performance evaluations require an objective, an indicator, and a statement/definition of what is acceptable (performance measure). Each are required before any one of them is useful and a flexible process is required to systematically identify any issues, develop operational objectives and determine what indicators need to be measured (Fletcher *et al.* 2002). Fletcher *et al.* (2005) state that previous attempts to assess ESD for fisheries had failed because they used frameworks that were too restrictive, often attempting to develop a single set of indicators that could be used across all fisheries (Staples 1997). Issues and information levels vary too widely across fisheries for such an approach to be successful.

ESD Reports are completed for each “fishery” (as defined by the management agency). The National ESD Reporting Framework contains four distinct steps for evaluation of a fishery (Fletcher *et al.* 2002) (Figure 5). Firstly, a set of ESD component trees are used to identify issues that need to be addressed within a workshop setting. Secondly, a risk assessment/prioritising process is then undertaken that determines which of the identified issues require managerial attention. Thirdly, a standard set of reports are completed for all issues. Where risk ratings are negligible or low (0 to 6) the reports only need to justify this conclusion. For issues with a risk rating of moderate or above a full performance report must be completed which details all elements of the management system. Included is a report on the current status, the development of objectives, indicators and performance limits and what management actions will be undertaken to maintain or return to an acceptable level. Finally, any background information is added to the above reporting to complete an ESD Report for the fishery. The information in this report can then be used to generate applications or submit to other institutions.

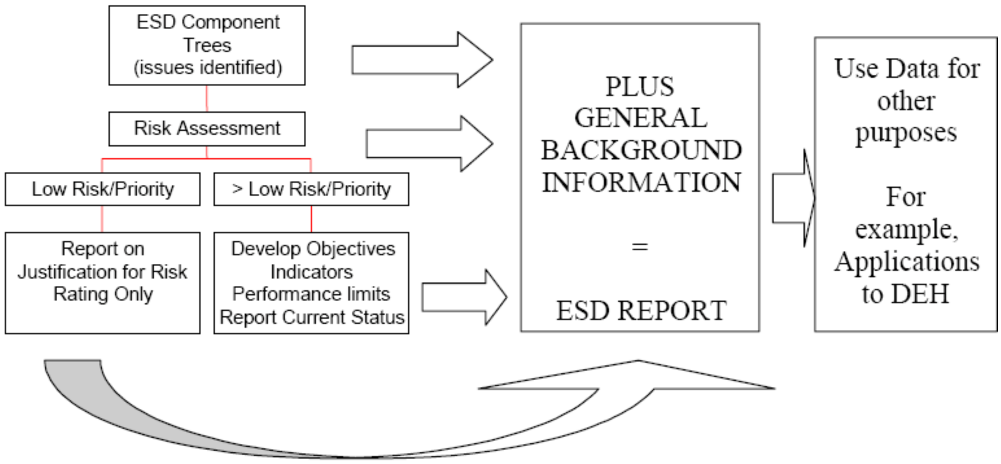

Figure 5. Summary of the ESD reporting framework processes. Source (Fletcher *et al.* 2002).

The risk assessment process of the ESD reporting framework was adapted from several Australian Standard documents on risk analysis (AS/NZS 1999; AS/NZS 2004), with the entire ESD Reporting Framework representing an application of a complete risk analysis system (Fletcher *et al.* 2002). The framework processes have been updated and revised over the past 7 years based on experience from applying the method.

The first step is to clearly determine the scope of the fishery by developing a clear description of what is being managed or assessed and identifying the relevant societal values (e.g., species sustainability, food security etc) to be addressed (see Fig. 6). The next two steps in the ESD process (Figure 6) can be considered the risk assessment steps i.e., risk context and identification (Identifying issues relevant to the fishery) and the third is risk characterisation (prioritising these issues).

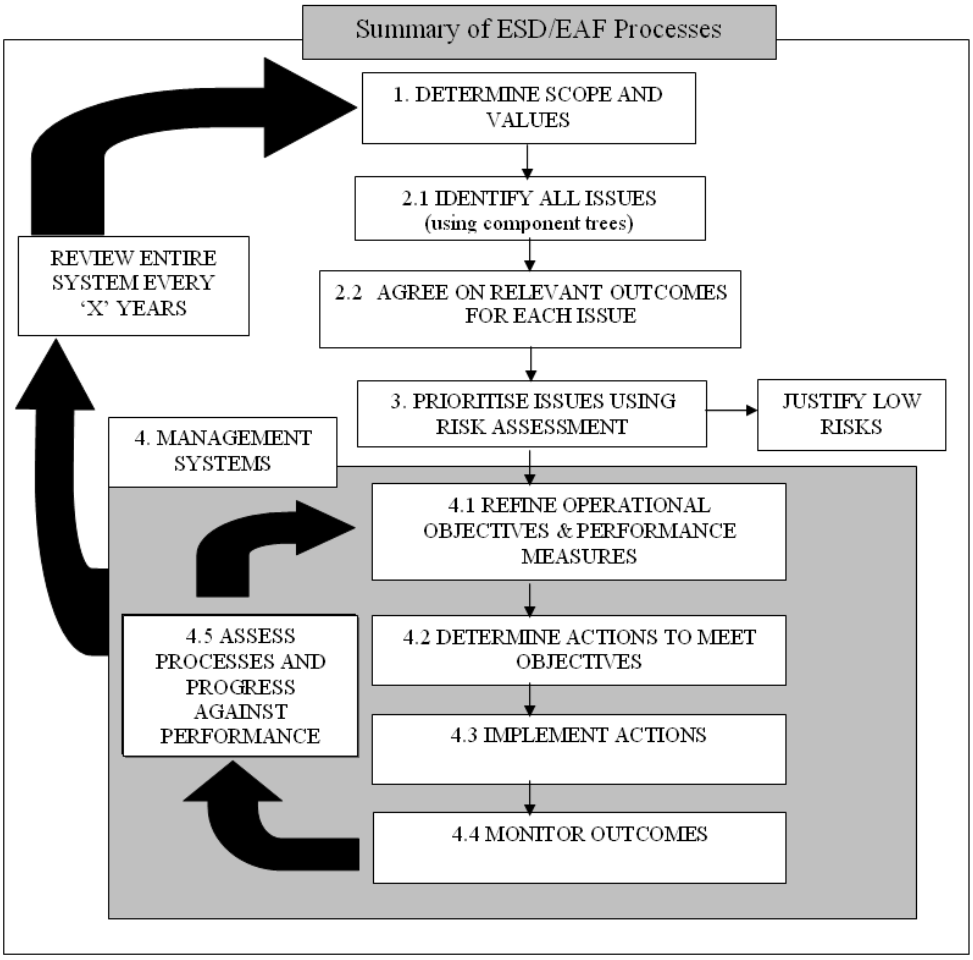

Figure 6. Outline of the updated National ESD/EBFM process (Fletcher 2008a).

The first major step in the ESD reporting framework is to identify the relevant issues for the fishery under consideration. Fisheries are extremely complex systems of biological, social and economic components. To simplify the task of evaluating their sustainability, the National ESD Reporting Framework divides a fishery into 8 main components (which are in turn members of one of 3 categories). These components are listed in Table 6.

Table 6. Summary of the main NESDRF components.

Category	Component
Contributions of the fishery to ecological well-being	1. Retained species 2. Non-retained species 3. General ecosystem
Contribution of the fishery to human well-being	4. Indigenous well-being 5. Community and regional well-being 6. National social and economic well-being
Factors affecting the ability of the fishery to contribute to ESD	7. Impact of the environment on the fishery 8. Governance arrangements

Each component is assessed through the use and modification of generic component trees (Figure 7). There is one component tree for each of the eight components of ESD. Generic component trees are provided as a starting point which can then be tailored to suit the individual circumstances of a fishery – expanding sub-components and removing or collapsing others. This expansion of the component trees is achieved through an open consultative forum (workshops) with input from relevant stakeholders and experts. An "issue" to be assessed is equivalent to a sub-component, or a smaller sub-division within it, of a specific component tree.

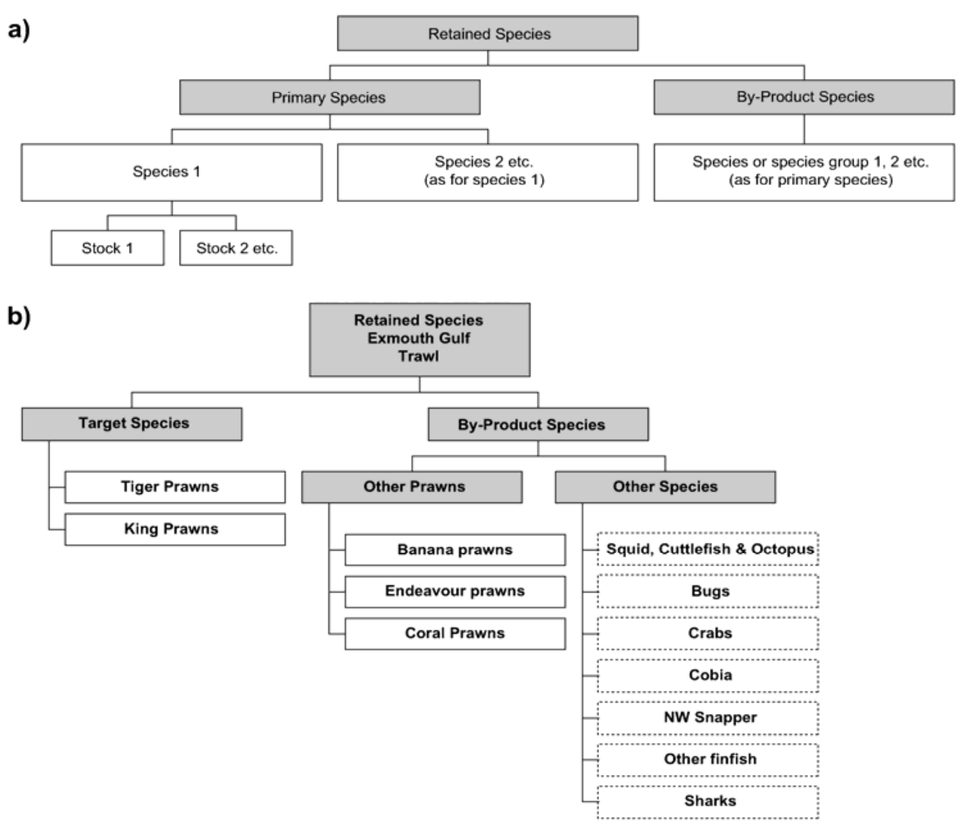

Figure 7. An example of (a) a generic component tree for retained species and (b) a completed component tree for the retained species of the Exmouth Gulf Prawn trawl fishery. The solid boxes indicate those issues that the risk assessment determined required direct management and/or monitoring. The dashed boxes indicate issues that were assessed as being of negligible risk from this fishery and therefore not requiring direct management by this fishery. Source: Fletcher (2005).

Using the component trees may identify a large number of issues which all need to be prioritised so that the level of reporting and subsequent management action matches the importance of the issue. This prioritisation is the second element of the ESD report and is achieved through a risk characterisation process that uses a qualitative consequence/likelihood method based on the AS/NZS standard. The method works by assigning a level of consequence and likelihood for each issue, and multiplying these to obtain an overall qualitative risk rating. The consequence score of an issue is derived from one of 7 consequence tables that address different aspects of fishing (i.e., a general consequences table; target species/major non-retained species; by-product/minor non-retained species; protected species; habitat issues; ecosystem/trophic level effects; political/social effects). Consequence is ranked from 0 (negligible) to 5 (catastrophic) (Table 7). A single likelihood table is used and ranks the likelihood of the consequence occurring from 6 (likely) to 1 (remote) (Table 8).

Table 7. Suggested consequence levels for major retained/non-retained species.

Level	Ecological consequence
Negligible (0)	Very insignificant impacts. Unlikely to be even measurable at the scale of the stock/ecosystem/community against natural background variability.
Minor (1)	Possibly detectable but minimal impact on structure/function or dynamics.
Moderate (2)	Maximum acceptable level of impact (e.g., full exploitation rate for a target species).
Severe (3)	This level will result in wider and longer term impacts now occurring (e.g., recruitment overfishing).
Major (4)	Very serious impacts now occurring with relatively long time frame likely to be needed to restore to an acceptable level.
Catastrophic (5)	Widespread and permanent/irreversible damage or loss will occur – unlikely to ever be fixed (e.g., extinctions).

Table 8. Likelihood definitions.

Level	Descriptor
Likely (6)	It is expected to occur
Occasional (5)	May occur
Possible (4)	Some evidence to suggest this is possible here
Unlikely (3)	Uncommon, but has occurred elsewhere
Rare (2)	May occur in exceptional circumstances
Remote (1)	Never heard of, but not impossible.

The risk scoring for each issue is determined through debate within the workshop group and an overall risk value calculated by multiplying the likelihood score by the consequence score. These scores are then translated into a risk rating using a risk matrix (Figure 8) which translates the scores as follows: Negligible (0), Low (1 – 6), Moderate (7 – 12), High (13 – 18) and Extreme (> 19). This risk rating is used in the risk prioritising phase to determine whether an issue requires specific management or not. In addition to reporting the consequence and likelihood scores and subsequent risk rating, the ESD reporting documentation must include an appropriately detailed justifications for all decisions made. Through this process the National ESD Reporting Framework provides a tiered approach that allows assessment effort to be concentrated on areas of highest risk.

Likelihood		Consequence					
		Negligible	Minor	Moderate	Severe	Major	Catastrophic
		0	1	2	3	4	5
Remote	1	0	1	2	3	4	5
Rare	2	0	2	4	6	8	10
Unlikely	3	0	3	6	9	12	15
Possible	4	0	4	8	12	16	20
Occasional	5	0	5	10	15	20	25
Likely	6	0	6	12	18	24	30

Risk ratings Negligible Low Moderate High

Figure 8. Risk Matrix – numbers in cells indicate risk value, the colours/shades indicate risk ratings.

If an irreconcilable difference is found within the workshop group regarding the likelihood and consequence scorings, then both points of view are documented and the risk rating is set based on the point of view that resulted in the highest score. Similarly, if there are concerns regarding the possibility of a number of alternate consequences then the alternative resulting in the highest risk rating is chosen (Fletcher *et al.* 2005). For instance, in the case of risk to the sustainability of a stock subject to commercial fishing where the occurrence of a stock collapse which is rated as a severe (3) consequence may only have a rare (2) likelihood, generating a risk ranking of 6 (low). Alternatively, the more likely scenario of the impacts of this fishing may be a moderate (2) consequence with an occasional (5) likelihood rating for a risk score of 10 (moderate). In this scenario the risk score for the stock from commercial fishing would be the highest plausible risk score i.e., 10 (moderate) implying that a full management system was required.

The more recent versions of this framework have recognised that different situations can require different levels of precision in the tables that are used. Thus, the version that has been adopted for use in assessing the risks associated with the tuna fisheries of the Pacific only has four consequence and likelihood categories with risk values of between 1and 16 and three risk levels Low, Moderate and High (Figure 9) (Fletcher 2008a). It has also been recognised that for situations where there is very limited data or where the stakeholders have limited formal education, the risk analysis can still be done by directly rating issues into risk levels (Fletcher 2008a).

		Consequence			
Likelihood		Minor	Moderate	Severe	Extreme
		1	2	3	4
Remote	1	1	2	3	4
Unlikely	2	2	4	6	8
Possible	3	3	6	9	12
Likely	4	4	8	12	16

Risk ratings Low Moderate High

Figure 9. The more compact version of the risk matrix developed based on application of the ESD method to fisheries in low-income countries

If good quantitative data is unavailable risk assessments can still be undertaken using the National ESD Reporting Framework utilising expert opinion, scientific inference from the literature, and previous management experience (Fletcher 2005). The more that the risk assessment relies on such inputs, the greater should be the level of uncertainty that is reflected in the risk scores generated.

5.7.2. NSW Qualitative ERA

The NSW QERA, described in Astles *et al.* (2006), is a qualitative method for ecological risk assessment which is suitable for all fisheries including those that are deficient in information about target species and/or its interaction with the ecosystem, or have few or loosely established management rules. The method was developed to satisfy legislative requirements that all NSW fisheries require environmental impact statements to determine if they consistent with the objects of the NSW *Fisheries Management Act* 1994, which included the principles of ESD. The assessments were conducted under NSW Planning Department guidelines specifying the ecological, social and economic components to be assessed and required the development of Fisheries Management Strategies. The goals of these plans were used in the QERA to define the risk being assessed for each ecological component.

The risk analysis method is adapted from the AS/NZS 4360 (Standards Australia/Standards New Zealand, 2000) risk management framework and in this application divided the process into three sections: risk assessment, risk management and risk communication. The method used by Astles *et al.* provides a broad ecosystem basis for assessing a fishery. Within the risk assessment process there were three steps: risk context, risk identification and risk characterisation (see Figure 10).

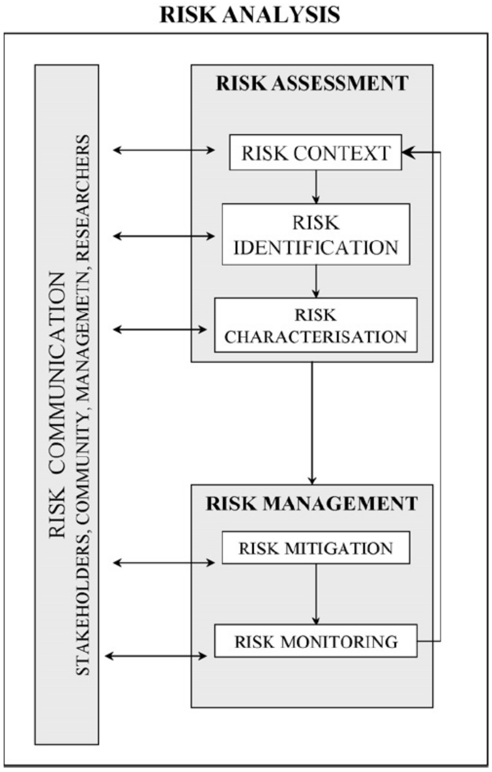

Figure 10. Framework of the qualitative risk analysis method based on AS/NZS 4360 used by Astles *et al.*(2006).

The goals of the NSW QERA risk assessment are to: rank the species within each ecosystem component according to their level of risk relative to a particular undesirable event; and to identify the issues that require management action to reduce the risk.

Risk context: This step defines the undesirable event and the minimum likely spatial and temporal extent of the event. The risk assessment process used the Fishery Management Strategies to specify these events and thus define the risk being assessed for ecological components. An example of a risk context would be the likelihood of a target species being overfished (undesirable event) within the next 20 years (temporal scale based on turnover of population) along the NSW coast out to 3 nm (spatial extent of fishing activity) (Astles *et al.* 2006).

Risk identification: This stage categorises which components of the system are at risk and why. This is achieved by generating a list of the sources of risk and then identifying which components of the ecosystem they potentially affect. Sources of risk were obtained by dividing the fishing operation into its individual activities (for example in a trawl fishery these include: deployment, towing and retrieval of nets; capture and retaining fish; discarding unwanted species; loss of fishing gear; travel to and from grounds etc.). The ecosystem was divided into component parts that included populations of target, by-product and by-catch species; habitats; ecological process and threatened and protected species. Lists of components of the ecosystem and sources of risk can be determined in several ways, including: prescribed by government guidelines, determined by expert opinion, literature reviews, historical records, consultation with stakeholders.

Risk characterisation: This step estimates the likelihood (low, intermediate-low, intermediate, intermediate-high or high) that the various sources of risk (identified in the previous step) will cause the undesirable event that has been defined in the risk context. Risk characterisation is a multi-stage process that assesses the risk for progressively smaller components of the ecosystem. It begins with broad components of the ecosystem and identifies which components are at negligible risk and those above this threshold. Risk levels are assigned based on general knowledge about the effects. Components with negligible risk are eliminated from subsequent assessments with documented justification. In a second stage each of the broad components are assessed in detail. The factors needed to maintain the ecological sustainability of each component are determined based on available ecological knowledge.

In the third stage the factor that directly contributes to maintaining a components ecological sustainability is chosen (e.g., for target species this would be the exploitable spawning biomass). The level of risk for this factor is determined using a qualitative risk matrix (Figure 11). The risk matrix is composed of two axes which describe the overriding factors that would determine the likelihood of each species experiencing a pre-defined undesirable event. Astles *et al.* (2006) used factors to reflect both the biological characteristics of ecological components, and the fishing activities that may influence the ability of a component to resist an undesirable event. The two factors chosen were resilience (the capacity of a species to recover from a disturbance; horizontal axis) and the fishery impact profile (the pressure exerted on a component by a fishing activity; vertical axis).

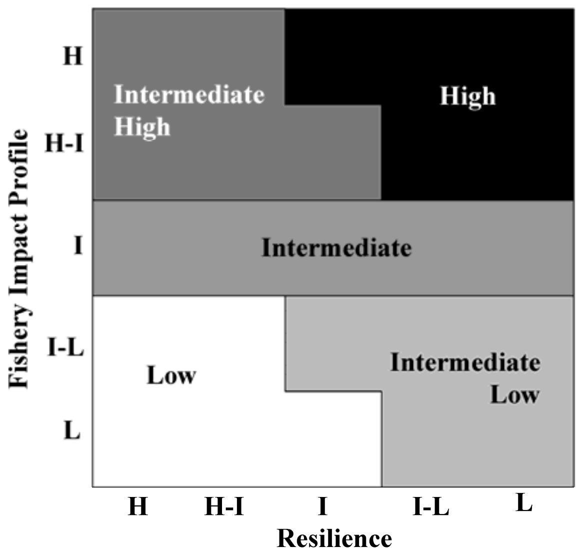

Figure 11. Risk matrix used to determine levels of risk for components of the ecosystem (e.g., target species, habitats) by combining resilience and fishery impact profile for each entity. H: high, H–I: high to intermediate, I: intermediate, I–L: intermediate to low, L: low.

Calculating the qualitative level of risk was done by determining whether the resilience of a species and the fishery impact profile of a fishery are ‘risk prone’ or ‘risk averse’. Pre-defined decision rules for each factor in the fishery impact profile and resilience were used to determine whether they were risk prone or risk averse. For example, a high level of fecundity may mean a species has a “risk averse” biological resilience, while a fishery that targets aggregations of a species may be considered to have a “risk prone” fishery impact. For each species the number of risk prone factors for both resilience and fishery impact profile are summed and both factors categorised based on this score (see the example given in Table 9). A risk rating is thus derived for each component being assessed (last column in Table 9). This last stage is repeated for all factors contributing to maintaining a component’s ecological sustainability.

Table 9. Example of the risk assessment for a number of bycatch finfish species (NSW Department of Primary Industries 2004b). Note that column "Obs" records whether that species has been recorded in observer surveys. "U" indicates unknown.

FIP - fishery impact profile, P - prone, PP - double prone, Y - yes, TT - trawl trauma, B - baratrauma, I-H - intermediate to high, I-L - intermediate to low .

Non-commercial Bycatch Finfish Species												
Family	Species	Obs	Survival	Survival Risk potential	Depth overlap Risk potential	FIP	Life history Risk potential	Mode of life Risk potential	Habitat Assoc. risk potential	Depth range Risk potential	Resilience	Risk
HETERODONTIDAE	*Heterodontus portusjacksoni*	✓	*Y*	A	P	**Low**	P	P	P	A	**Low-Mod**	**I-L**
HETERODONTIDAE	*Heterodontus galeatus*	✓	*Y*	A	P	**Low**	PP	P	P	P	**Low**	**I-L**
HEXANCHIDAE	*Heptranchias perlo*	✓	*TT*	PP	PP	**High**	PP	P	P	A	**Low-Mod**	**H**
PARASCYLLIIDAE	*Parascyllium collare*	✓	*Y*	A	P	**Low**	P	P	A	A	**Mod**	**L**
SCYLIORHINIDAE	*Asymbolus rubiginosus*	×	*Y*	A	PP	**Low**	P	P	U	A	**Mod**	**L**
SCYLIORHINIDAE	*Asymbolus analis*	✓	*Y*	A	PP	**Low**	P	P	U	A	**Mod**	**L**
SCYLIORHINIDAE	*Cephaloscyllium laticeps*	✓	*Y*	A	P	**Low**	P	P	U	A	**Mod**	**L**
SCYLIORHINIDAE	*Cephaloscyllium sp.A*	✓	*Y*	A	PP	**Low**	P	P	U	A	**Mod**	**L**
SCYLIORINIDAE	*Galeus boardmani*	✓	*TT*	PP	PP	**High**	P	P	U	A	**Mod**	**H**
NARCINIDAE	*Narcine tasmaniensis*	✓	*TT*	PP	P	**High**	P	P	P	A	**Low-Mod**	**H**
SQUALIDAE	*Etmopterus lucifer*	✓	*TT*	PP	PP	**High**	P	A	U	A	**Mod-High**	**I-H**

Identification of issues arising from the risk assessment: The outcome of risk characterisation is the identification of specific issues arising from the risk assessment. These issues point to the reasons why species are at risk and are derived from the collated and categorised information of the biological and fishery factors used to determine the levels of risk. For example, species may be fished at a size below their age at maturity. For species at high risk the required management action is to somehow decrease the level of interaction between this species and the operation of the fishery. For example, changing the gear selectivity of nets to catch fish at a mature size. The risk matrix (Figure 11) separates what management has control over (the fishery impact profile) from what management has little control over (resilience). The arrangement of the risk matrix therefore provides more scope for managers to reduce risk by reducing the fishery impact profile.

Uncertainty: A lack of understanding of the nature of a fishery, and the ecosystem in which it operates, a common situation in data deficient fisheries, may lead to error in assigning risk levels (Peterman 1990; Astles *et al.* 2006). Generally, assigning a higher level of risk than is actually the case is seen as preferable to assigning too low a level of risk which may lead to irreversible damage to that component of the fishery and more costly consequences. In the Astles *et al.* (2006) model, the decision rules used to determine the resilience and fishery impact profile for each species was made more sensitive to risk-prone characteristics than risk-averse ones to reduce the likelihood of assigning lower levels of risk than is actually the case. This was consistent with the precautionary approach.

5.7.3. ERAEF for Commonwealth Fisheries

The Ecological Risk Assessment for Effects of Fishing (ERAEF) project was set up in 2001 by the Australian Fisheries Management Authority (AFMA) (Hobday *et al.* 2007). This project was established to assist AFMA to achieve its ESD objectives under the *EPBC Act*, in addition to being an important element in the Commonwealth's ecosystem approach to fisheries management (Hobday *et al.* 2004). In the ERAEF framework 'risk' is defined as the probability of not achieving a management objective and is determined from the consequences of current fishing activity. Thus, the technical focus is on calculating the consequence rather than likelihood with the later set equal to one given that the current level of fishing activity is inevitable due to current management.

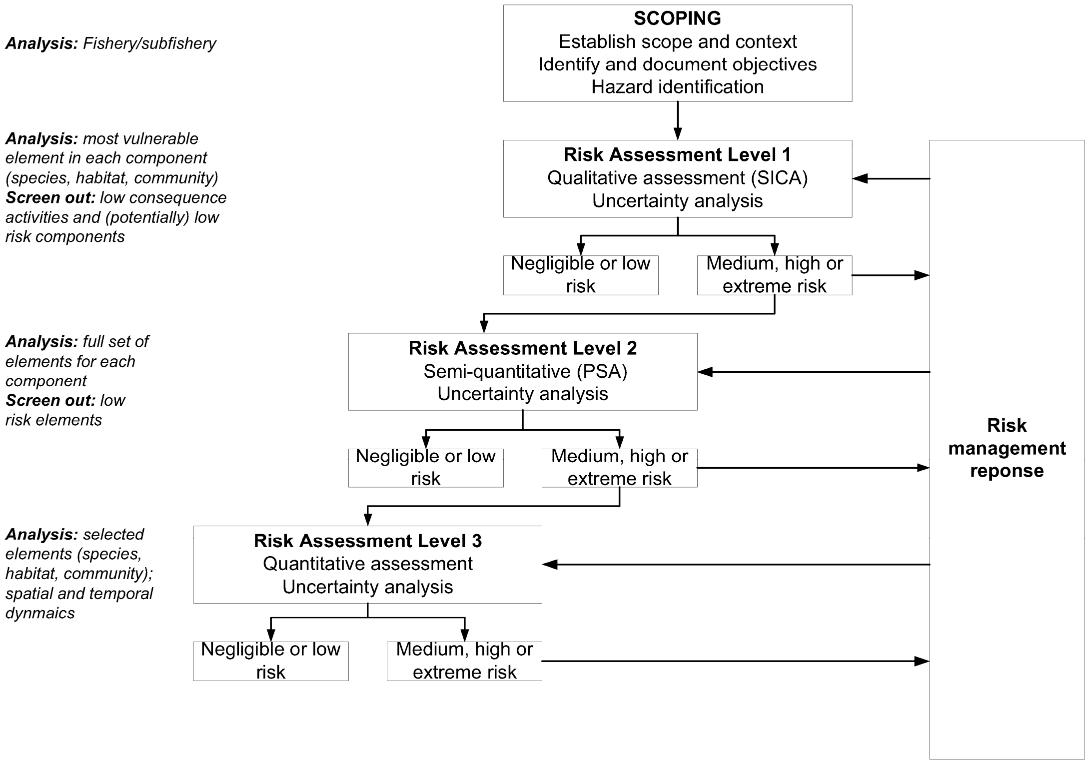

Figure 12. Overview of the Commonwealth ERAEF showing focus of analysis for each level at the left in italics. Source: (Hobday *et al.* 2007).

ERAEF uses a hierarchical approach, consistent with other approaches to ERA, that has four stages: an initial scoping phase (risk identification) followed by 3 stages of risk assessment (risk characterisation) moving from a comprehensive but largely qualitative analysis of risk (Level 1), through a more focused and semi-quantitative stage (Level 2) to a fully quantitative “model-based” approach (Level 3). Each level (1 to 3) in the analysis results in some form of risk ranking and only those components whose risks were ranked medium or above are analysed at the higher level. Thus, many low risk processes can be screened out at Level 1, allowing the more intensive and quantitative analyses at Level 2 (and ultimately at Level 3) to be limited to a subset of the higher risk activities. Such a hierarchical approach promotes efficiency but also allows a more rapid identification of high-risk activities which, if required, can lead to immediate remedial action (risk management response).

For the ERAEF approach, five general ecological components are evaluated, corresponding to five areas of focus in evaluating impacts of fishing for assessment under the *EPBC Act* 1999. The five components are: target species; byproduct and bycatch species; threatened, endangered and protected species (TEPS); habitats and ecological communities.

Each of these components is further divided into sub-components (e.g., for target species these are: population size; geographic range; genetic structure; age/sex/size structure; reproductive capacity; and behaviour). The method uses a conceptual model (flow diagram) of how fishing impacts on ecological systems. This is used as the basis for the risk assessment evaluations at each level of analysis (Figure 13). The model links a fishery to the ecological components in a logical sequence starting from the individual activities of the fishery, moving to the impacts of these activities, through to the natural processes they act on and the ecological sub-components these natural processes affect. Objectives are defined for each component and the impacts from a defined list of fishing activities are considered and assessed. A separate conceptual model is completed for each of the five ecological components and these are constructed during the scoping phase.

A crucial process in the ERAEF framework is documenting the rationale behind assessments and decisions at each step in the analysis. The decision to proceed to subsequent levels depends on: estimated risk at the previous level; availability of the data to proceed to the next level; and the management response (e.g., if risk is high but immediate changes to management or fishing practices will reduce risk, further analysis may be unnecessary).

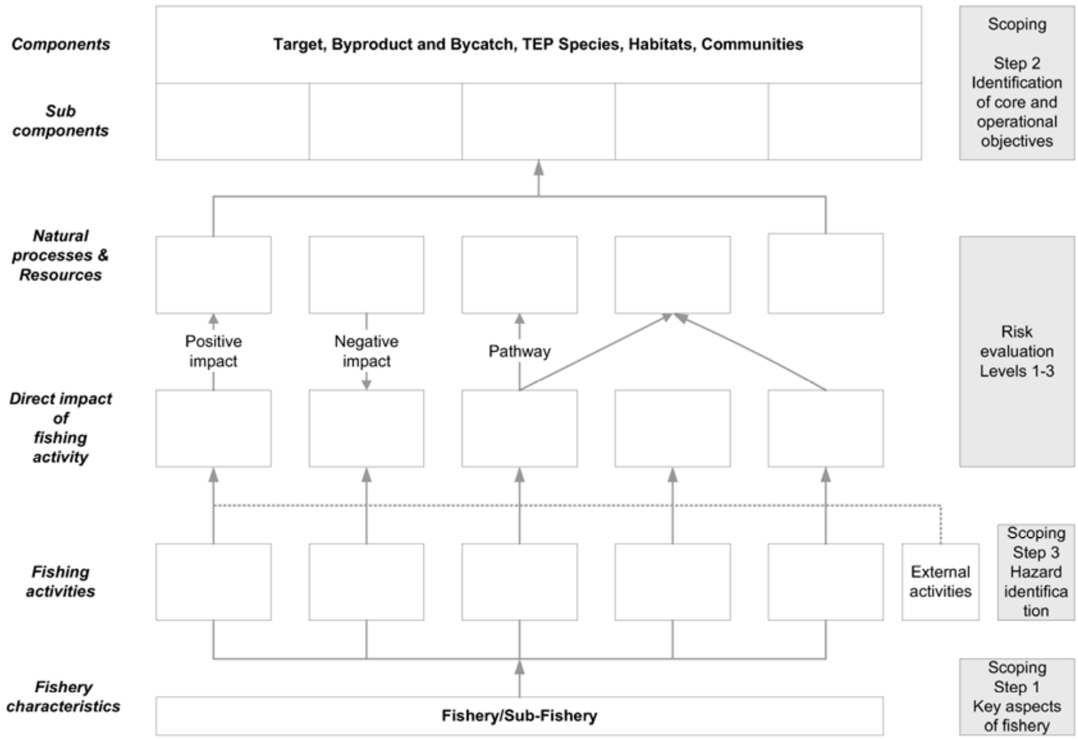

Figure 13. Generic conceptual model used in ERAEF.

Scoping

The scoping phase of the assessment provides the information for the remaining levels of analysis and is the point at which the conceptual models are generated. It involves collating existing information on the fishery and is comprised of three steps: identifying general fishery characteristics and units of analysis, identification and selection of objectives, and hazard identification. The focus of analysis is the fishery which may be divided into sub fisheries based on fishing method and/or spatial extent. Stakeholder consultation occurs at various stages of the process. The scoping process is undertaken using a combination of documents prepared by experts and reviewed by stakeholders and workshop forums with industry reps and other experts and stakeholders.

1. General fishery characteristics and identification of "units of analysis"

Completed for each sub fishery and provides a summary of the key aspects of the fishery (e.g., identifying sub-fisheries, geographic extent of fishery, fishing season, methods employed etc.). Information may come from a range of documents, expert advice and anecdotal evidence. Level and range of information will vary with some fisheries having extensive, reliable info whereas others may have limited information.

Generic outline is:

- Detailed description of general fishery/sub-fishery characteristics and general management. (Scoping document S1.1).
- Identification of the "units of analysis" that make up each of the five ecological components. Summary tables produced for each unit (Scoping document S1.2):
  - Species: grouped by target, by-catch, by-product and TEPS. All specified to species and have separate tables for each group.
  - Habitats: summary of habitat types that occur within the fishery area (e.g., inshore, shelf, slope or oceanic, and benthic or pelagic) in each biogeographic region (tropical, temperate).
  - Communities: summary of communities that occur within the fishery area by biogeographic region (same set up as habitats).
- A bibliography of relevant literature. (Scoping document S1.3).

2. Selection of objectives

Objectives are identified for each sub-fishery in each of the 5 ecological components (broken down to sub-components). Management objectives need to be identified for each component (*core objectives* or endpoints: "what we are trying to achieve") and sub-component (*operational objectives* or measurement endpoints; "what can be measured"). Operational objectives are usually already agreed on for a fishery and are based on policy and legislation.

For example, a list of objectives for a target species could be as follows:

Component: Target species
  Core objective: Avoid recruitment failure
    Sub component 1: Population size.
      Operational objective 1: maintain biomass above a specified level.
      Operational objective 2: maintain catch at specified level.
    Sub component 2: Geographic range.
      Operational objective 1: range does not change outside acceptable bounds.
      etc.

3. Hazard identification

Hazards are the activities specific to each sub-fishery that are undertaken in the process of fishing, or any external activities, that have the potential to lead to harm. Hazards are placed into one of six categories, which are further subdivided into fishing and external activities. These hazards are then scored on a presence/absence basis with a scoring of 1 if it does occur and 0 if it does not.

Table 10. Hazard categories for the impact of fishing.

Result of fishing activity	**Fishing activity**
Capture	e.g., fishing, bait collection
Direct impact without capture	e.g., fishing, gear loss, anchoring/mooring
Addition/movement of biological material	e.g., discarding catch, stock enhancement
Addition of non-biological material	e.g., debris, gear loss, chemical pollution
Disturbance of physical processes	e.g., fishing, bait collection, anchoring/mooring
External hazards	e.g., other fisheries, coastal development

Level 1 – SICA: Scale, Intensity and Consequence Analysis

Level 1 is a qualitative risk assessment based on scale, intensity and consequence analysis (SICA) and aims to identify which hazards (fishing activities or external activities) lead to a significant impact on any species, habitat or community (component).

Analysis at this level is for whole components and is accomplished by considering the most vulnerable sub-component (e.g., population size of target species) and the most vulnerable unit of analysis. The analysis links the effects of fishing and external activities (hazards, e.g., capture) to natural processes that are affected by fishing (growth, recruitment, mortality) which in turn affect the sub-components (operational objectives; e.g., population size) and components (core objectives). A "worst case" approach is used to ensure that the elements screened out are genuinely at low risk. Where judgements about risk are uncertain, the highest plausible level of risk is chosen. SICA involves 10 steps but these can be summarised as:

1. Evaluation of the temporal and spatial scale of the activity, these are scored (1 – 6) based on tables provided.
2. Evaluation of the intensity of the activity.
3. Scoring the consequence of the activity for each component based on information from the scoping document, and using the "worst case" scenario. This involves selecting the unit of analysis for that component thought to be most vulnerable to the activity. Justification must be provided for an assigned level of consequence.
4. Record the degree of confidence associated with the consequence score.

The risk level for each activity/component combination is scored on a scale of 1 (negligible) to 6 (intolerable). Consequence scores greater than 2 require either an immediate risk management response or further assessment of the hazard at level 2. Activities that do not result in a risk score above 2 for any of the five ecological components can be eliminated from further consideration. As with all of the methods the critical aspect to level 1 is clear documentation for the rationale of all scores and rankings. Completing level 1 should thus provide a table that summarises all the information used in the 10 steps as well as tables describing the consequences for each subcomponent.

Level 2 – PSA: Productivity, Susceptibility Analysis

The level 2 step is more formally known as a productivity, susceptibility analysis (PSA) and is based on the methodology devised by Stobutzki *et al.* (2001a) for the Australian Northern Prawn Trawl (ANPT) by-catch sustainability assessment. The risk to a unit of analysis (e.g., species, habitats or communities) is estimated based on the unit's productivity, which is the time taken to recover from the effects of fishing, and the unit's susceptibility, which is the degree to which it is exposed to the fishing activity. The method is based on the assumption that units will be at higher risk if they have low productivity (long recovery times) and/or if they are more susceptible to the activities of the fishery (higher exposure). A separate PSA is undertaken for each component that is not screened out at Level 1 (Hobday *et al.* 2007).

A list of attributes that describe the productivity and susceptibility of each unit for each ecological component are provided with the ERAEF framework and these standard lists are modified for the particular fishery or ecological component being assessed (Astles 2008). For each attribute a score is determined for productivity and susceptibility (from 1 – high productivity/susceptibility; to 3 – low productivity/susceptibility) based on categorical or data divisions. The average productivity and susceptibility scores for each unit of analysis (e.g., for each species) are then plotted on a PSA plot with productivity on the *x*-axis and susceptibility on the *y*-axis (Figure 14). Overall risk levels of high, medium or low are determined by dividing the plot into three parts using Euclidean distances from the origin, i.e., one third of the total distribution of all possible values for a component. Units that fall in the upper third of the PSA plot are considered to be at high risk while those in the middle are at moderate risk and those units in the lower third are at low risk (Hobday *et al.* 2007).

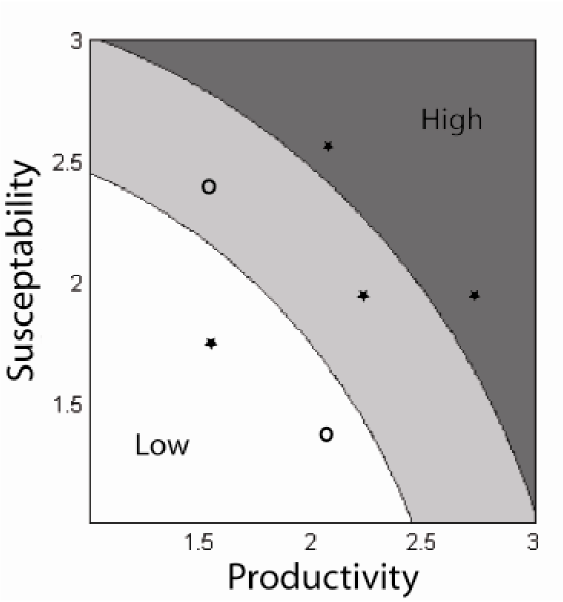

Figure 14. The PSA plot on which the risk to the ecological units is plotted. The x-axis includes attributes that influence the productivity of a unit and the y-axis includes attributes that influence the susceptibility of the unit to impacts from fishing. The contour lines divide regions of equal overall risk levels. Risk scores for different units are shown as points (asterisks) on the same plot. Units with missing attributes are shown as open circles for quick identification.

The PSA output allows identification and prioritisation of the units at greatest risk to fishing activities. Following calculation of productivity and susceptibility scores, a PSA plot is produced along with tables that collate the scores for productivity, susceptibility, number of attributes for each characteristic, overall risk value, risk category and risk ranking for each unit assessed. This allows identification of which attributes are contributing most to the overall risk value and provides insights into appropriate management action or research required to address the issues (Hobday *et al.* 2007).

Uncertainty in the PSA results can arise when there is limited data for a unit. Units with missing scores for attributes will have a more conservative overall risk value since the highest score for the attribute is used in the absence of data. During the Level 2 assessment the number of missing attributes (and hence conservative scores) is tallied for each unit and a confidence score given to the unit. Those units with missing attributes are displayed on the PSA plot (Figure 14) as open circles so that they can be easily differentiated. Identification of high risk units with missing attributes could lead to prioritisation of additional research since simply gathering the data to allow the attribute to be scored may lower the overall risk. Uncertainty may also arise due to the selection of attributes. The influence of particular attributes is examined by using a Monte Carlo re-sampling technique in which productivity and susceptibility scores are calculated for each unit by removing the unit's attributes one at a time. The variability in the productivity and susceptibility scores is a measure of the uncertainty in the overall PSA score and those units with high levels of uncertainty are flagged for possible further research (Hobday *et al.* 2007).

Level 3 – Quantitative Assessment and Uncertainty Analysis

This stage of the risk assessment is fully-quantitative and involving in-depth scientific studies that are time, expertise and data-intensive. Individual stakeholders are engaged as required in a more intensive fashion. Results are presented to the stakeholder group and feedback incorporated if possible. Some examples of such assessments are traditional quantitative stock assessments, management strategy evaluation, quantitative risk assessments (e.g., SAFE (Zhou *et al.* 2008)) and ecosystem-based modelling (e.g., Ecosim, Atlantis, InVitro).

5.7.4. Comparison of the methods used in Australia

Each of the three major risk assessment methodologies presented above have been successfully applied to a number of fisheries in Australia. A number of agencies have experimented with more than one method. The feedback gathered during the interviews and from the literature regarding the strengths and weaknesses of each of these methods is summarised below along with a number of clarifications on some differences.

5.7.4.1. Meeting the AS/NZS risk management standards

Each of the three methods was based on the AS/NZS 4360 Risk Management Standards and have each been validated against these standards. Thus, each method goes through the same stages of *risk context* and *risk identification* (using different techniques), and these steps provide the information with which to conduct the actual "analysis" or *risk characterisation* (again done differently in each method) in order to assign a risk rating or category to be assessed by management (risk mitigation).

5.7.4.2. Fitting each method into the likelihood and consequence model

A possible source of confusion in evaluating the three alternative methods is in how each method determines its risk ratings. Despite their differences it will be demonstrated that each method fits within the likelihood and consequence model.

In the NSW QERA method the decision was made to base the consequences on the goals of the existing management plan. This method recognises that impacts do not occur with known probability and cannot be evaluated independently of each other (Astles *et al.* 2006). Thus, in the NSW QERA method the consequence is included in the definition of the component for which the risk is being assessed (e.g., target species), meaning that the consequence is set by the management plan (e.g., collapse of a target species stock as a result of recruitment overfishing) and the calculation of the risk becomes a calculation of the likelihood of this consequence occurring. In short, the consequence is set by legislation so the risk becomes the likelihood.

In contrast, the ERAEF Level 1 or SICA method (Scale, Intensity and Consequence Analysis) uses the reasoning that the likelihood of an activity such as fishing occurring is set by the current management arrangement. That is, if it is sanctioned within the current management plan then a certain amount of fishing will definitely occur. Thus, the likelihood of fishing is equal to 1 and the risk then becomes the consequences from the permitted fishing activity possibly not meeting management objectives (e.g., stock sustainability) (Hobday *et al.* 2007). In short, the likelihood is set by the management arrangements so the risk becomes the consequences of these arrangements.

A third approach to risk scoring was taken for the National ESD approach. Of the three methods this approach is the most direct application of the AS/NZ4360 guidelines (AS/NZS 2006) and hence fits most easily into the consequence and likelihood model. In this method the likelihood ratings are based on the conditional probability of the activities of the fishery generating a particular level of consequence. Thus the risk is the likelihood that, given a particular fishing management strategy (*e.g.,* the current allowable catch levels for a tuna fishery), a particular level of impact (*e.g.*, a reduction in spawning biomass to x% of unfished levels) may ultimately be the result (either from an accumulation of small events over time, or from a single large event). The consequence levels are based on the severity of impact and what are considered acceptable and unacceptable levels of impact in meeting the fisheries objectives. The highest credible likelihood and consequence product combination becomes the risk score. While there was some confusion due to the choice of words used in the initial consequence tables (e.g., possible, likely, unlikely), these problems have been subsequently revised and made more explicit in more recent versions (Fletcher 2008a).

5.7.4.3. The strengths and weaknesses of each method

What follows is a summary of the strengths and weaknesses of each of the three alternative risk assessment systems as provided in the literature and by fisheries scientists and managers in the interviews and workshops conducted for this project.

5.7.4.4. NESDRF

Strengths:

- This rapid assessment approach was considered very suitable for an interactive workgroup environment which is particularly important when workgroup time is limited. The hierarchical tree structure is considered very logical and easy to follow for all participants.
- Many found this approach quite intuitive and easy to implement given the information made available on the ESD website.
- The amount of reporting documentation required was considered very manageable.
- This method has high coverage in that it can consider as many species are required e.g., bycatch can include all bycatch or just key bycatch species.
- The approach contains a tiered system whereby low risk components require minimum reporting. This allows more effort to be directed to higher risk components.
- This method is capable of being adapted to other types of risk assessment e.g., compliance risk assessments.
- This is the only method that can be used to also assess social, economic and political risks.
- This is the only method that does not need quantitative data to generate risk scores
- Being a direct application of the risk assessment guidelines the likelihood and consequence scoring mirrors that used in other disciplines, such as OH&S, making this approach familiar to many workshop participants.
- This method has been successfully applied to fisheries around Australia and the world (Fletcher 2006).
- “The process provided a framework for discussion among stakeholders, succeeded in exposing stakeholders to the perspectives of other stakeholders, serves as a supporting basis from which ecosystem concerns can be addressed in the respective fisheries, and it provides a reference for newly appointed fisheries managers” (ICES 2007).
- The National ESD Reporting Framework will enable the identification and assessment of all relevant issues and the establishment of processes to enable management to be undertaken effectively and efficiently. This process helps stakeholders recognise their role and potential impacts and identifies overlaps between fisheries, jurisdictions and other activities (Fletcher 2006).

Weaknesses:

- Some have thought this approach may not be as comprehensive as other methods. Although the guidelines state that all issues should be examined it does not force consideration of all aspects that may impact on a fishery, so that those components that ‘generally don’t seem an issue’ may not necessarily considered.

- Concerns were raised regarding lack of an explicit construct to build context around issues at relevant spatial and temporal scales. Such issues made the rationale for a risk ranking more difficult for someone to understand after the fact.
- Some concerns were raised regarding missing components in the "how-to" documentation particularly in regard to uncertainty.
- For some situations, such as those where very limited data is available (which includes many socio-economic issues) or where the stakeholders have limited formal education, the use of this consequence-likelihood system has been found to be complicated (Fletcher 2006). This could easily be considered a strength of this system as it is the only method that requires consideration of such intractable issues such as socio-economics.
- There is a concern with the numeric scales used to evaluate the likelihoods and consequences and whether these were being interpreted identically by all participants in the risk assessment workshops (ICES 2007).
- The outcome of workshops may be dependent on the participants (i.e., the final results obtained from one group of participants may differ from those of a different set of participants) (ICES 2007).

5.7.4.5. NSW QERA

Strengths:

- Although the system was designed to be applicable to data-poor species it is equally applicable to data-rich.
- The system has very thorough coverage in that all species caught using a fishing method are assessed.
- It is the system that is most in line with the national guidelines recommended approach for determining consequence based on policy and legislation and calculating likelihood based on scientific analysis.
- The semi-quantitative nature of evaluating risks is based on a combination of biological resilience and fishing impact evaluated using scientific evidence that can be peer-reviewed for objectivity and accuracy.
- This method purposely avoids the use of numbers in the scoring of risk, as workgroup trials showed a tendency for users to incorrectly employ the numbers in their own unique non-standard calculations (e.g., summations, multiplications).
- The use of pre-defined decision rules ensures consistency when an ecological component is reassessed after management action has been implemented because the same rules are re-applied (Astles 2008).

Weaknesses:

- To date this method has only being applied to NSW fisheries and thus there are few studies comparing the practical strengths and weaknesses of using this method over the alternatives (but see Astles 2008).
- This approach contains only a limited tiered hierarchy. This can result in considerable effort being expended on components that are obviously not at risk.
- The use of the terms "risk adverse" and "risk prone" used to describe different biological characteristics has been described as confusing as such terms are normally associated with human attitudes to risk.
- The NSW QERA method can be more complicated because of its detailed decision rules. As with all such rules and ranking criteria they will contain biases which may either under- or overestimate the level of risk (Astles 2008).
- The outcome of workshops may be dependent on the participants (i.e., the final results obtained from one group of participants may differ from those of a different set of participants).
- This method does not allow the assessment of socio-economic or political risks.

5.7.4.6. *ERAEF*

Strengths:

- The hierarchical approach used in ERAEF helps ensure more efficient use of resources, and that resources are focused on an ever narrowing number of increasingly significant stressor-receptor interactions or risks (Hope 2006).
- As this method contains qualitative, semi-quantitative and quantitative approaches and thus encompasses the advantages of each approach.
- The model is flexible in that it can be used to assess both data-rich and data-deficient fisheries, with assessment being completed to the level for which data is available.
- The scoping documents provide a very useful overview of a fishery.
- Requires rigorous documentation at all steps creating high traceability and transparency for risk ratings.
- This is a very thorough system that requires analysis of aspects that are usually not covered in much detail such as geographic range, movement, behaviour and genetic structure.
- Some found the time taken to undertake the entire risk assessment for a fishery could actually be less using ERAEF than other methods because ERAEF demanded a much more systematic analysis prior to conducting workshops. Thus, the majority of the work was conducted prior to involving stakeholders resulting in more decisions being made when the group was together and far fewer loose-ends to be followed up after the workshop was over.
- The SICA (level 1) and PSA (level 2) analyses both include defined procedures for explicitly identifying the level of confidence in the risk valuation so that areas can be easily identified where uncertainty is causing higher levels of risk to be indicated (Astles 2008).

Weaknesses:

- This system was regarded as the most intensive and difficult to implement. Although a counter-argument given was that this approach could actually result in much fewer components requiring assessment than the ESD component tree approach. It depends on the fishery.
- Requires significant training to be familiar with the method and the terminology.
- The hierarchical nature helps in reducing the work needed on low risk components however the effort required to conduct a Level 1 analysis on all components can still result in considerable effort being expended on low risk components.
- The Level 1 SICA method still requires a fairly extensive amount of time, effort and expertise e.g., the range of fishing activities is very exhaustive and includes many activities that are probably not applicable to a particular fishery but it still requires that they be considered (and attach a rationale be attached).
- Some respondents felt the Level 1 SICA method was difficult to explain to workshop participants.
- Risk rankings are highly dependent on the ‘unit of analysis’ chosen i.e., choice of species chosen for a particular activity. Only one species is assessed per activity. It is meant to be the species most at risk but this choice can be quite arbitrary and can affect results.
- The risk regions of the PSA plots (high, medium, low) are somewhat arbitrarily chosen. Without experience implementing the PSA technique to actual fisheries, it may not be possible to defensibly partition the PSA plot into these risk categories.
- This method required significantly more time in preparation for a workshop and in generating the post-workshop documentation.
- This method does not allow the assessment of socio-economic or political risks.
- The reduction of risk to the reporting of consequence is in contrast to the colloquial interpretations of risk, which inevitably include uncertainty as a primary consideration. Uncertainty is being captured in SICA analyses (fisheries systems are not fully determined) but in a somewhat unfamiliar manner.

- Some concerns were raised regarding the adequacy and confusing nature of the documentation.

5.8. Data-poor species and quantitative assessment

5.8.1. Background

The terms 'data-poor', 'data-limited' and 'data-deficient'[8] are used in a variety of contexts in fisheries. The terms are commonly applied to smaller fisheries (low catch weight) and those that have a low gross value of production. In western countries, such fisheries are usually exploratory, developmental, only fished opportunistically and often involve only a small number of operating fishers (although there can be substantial latent effort) (Dowling *et al.* 2008). The term "data-poor" is also applied to the by-product and discard species that may be impacted when unselective fishing gears are used. In such cases, detailed scientific knowledge of the many species impacted is often restricted to the larger and more charismatic species (Carey *et al.* 2007). Finally, any species for which a large portion of the catch is taken by recreational fishers (or other sources of unreported fishing) can also be referred to as 'data-poor'.

Recently, there have been workshops in North America (Kruse *et al.* 2005), California Sea Grant, 2008[9]) and Australia (Newman *et al.* 2001) exploring strategies to assess and manage data-poor fisheries. The terminology data-poor and data-limited is also used by ICES.

Only a single author appears to have identified fisheries that are "data-less" (Johannes 1998). In this landmark paper, the author acknowledges that for many fisheries in low-income countries there will never be the quality or quantity of information with which western fisheries agencies manage fish stocks. Alternative paradigms of fisheries management are required in such situations (usually based upon spatial management). A similar attitude was taken by Orensanz *et al.* (2005) who outlined the difficulties associated with conventional assessment approaches and developed ideas for "S" fisheries (small-scale, spatially-structured and targeting sedentary stocks). Castilla *et al.* (1998) described similar management systems for abalone-like stocks in Chile.

Vasconcellos and Cochrane (2005) is one of the few papers to attempt to quantify the degree of data-limitation in fisheries. These authors suggest that 20 – 30% of global landings are from stocks where there was insufficient reliable biological information to infer exploitation status. This is a similar definition for the term "data-poor fishery" that was used by Ziegler *et al.* (2006). These authors noted that 'a fishery can be considered data poor if insufficient information is available to produce a defensible stock assessment'.

The expression 'insufficient information' has subtle differences to 'insufficient data'. For example, the reasons why a defensible stock may not be producible will include cases where the data lack informative contrast, the original records were imprecise and/or biased, or the data available simply do not represent characteristics of a population useful for fisheries management. Compounding the transformation from data into information includes infrastructure issues associated with immature data management systems and limited statistical or analytical resources to interpret the data available.

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[8] These three expressions will be considered to be synonymous in this report, but the term 'data-poor' will be preferentially used.

[9] The Managing Data-Poor Fisheries Workshop, hosted by the California Department of Fish and Game and the University of California Sea Grant Extension Program. http://mdpf.mlml.calstate.edu/ (accessed 23 March 2009).

However, data poverty can occur in cases that some would regard as data-rich. Even if a considerable amount of data has been collected, the uncertainty may still be sufficiently high to be able to argue that the fishery is data-poor. It could be just a case of 'the more you know, the more you realise how little you know' and one could argue that most fisheries are data poor to some extent. For example, the abalone fishery in Tasmania has many years of data on catch rates and life-history information, but detailed studies have shown that growth rates can vary a great deal between two nearby locations, vastly increasing the amount of information necessary to produce a credible stock assessment.

Many species in Australia are considered "data poor" for the sorts of reasons outlined above. Much of this is due to huge size of, and biodiversity within, the Australian Fishing Zone, compounded with the exacting requirements of the *EPBC Act*. The situation is also amplified by the relatively small size of Australia's fisheries and a policy trend towards some measure of cost recovery (or probably more correctly, potential cost recovery). Such policies have restricted the expansion of the expensive (and ongoing) independent survey and observer programs that operate in Europe and North America.

5.8.2. Stock assessment and sustainable fishing

The following section deliberately narrows the definition of "assessment" to what is commonly understood to be the primary goal of stock assessment – the determination of exploitation status. Two questions are generally asked of stock assessments: is a fish stock subject to overfishing and is it overfished? These two concepts are described in more detail below from a theoretical perspective, whilst section 5.8.6 identifies practical constraints associated with such approaches and some survey-based alternatives that are used in Australia.

Overfishing is usually determined by estimating the current fishing mortality rate F relative to the fishing mortality rate at maximum sustainable yield (F_{MSY}). Fishing at rates above F_{MSY} would see a long term decline in the biomass and would result in a stock being overfished. When a stock is overfished, the current exploitable biomass is less than an agreed limit reference point (a threshold fraction of the unfished biomass, B_0, where the threshold is dependent on the life history of the species). With appropriate data, time series of both fishing mortality and biomass can be estimated by population models.

The importance of attempting to understand the ratio between F and F_{MSY} cannot be under-estimated. Given that the objectives of most policies and management plans in Australian is for sustainable fisheries, then strong evidence indicating that $F << F_{MSY}$ should provide an assurance that fisheries are being managed consistently with this objective. In contrast, if $F >> F_{MSY}$, then this would be a call for immediate managerial action. Although the demands for stock assessments in an ecosystem context[10] are more demanding, the principles are similar. There is some rate of mortality on populations that will not result in a long term decline of harvested species (see Forrest *et al.* 2008 for a description of these issues and the trade-offs involved in EBFM). In general terms, if an estimate of F is available along with credible catch statistics, then the exploitable biomass can also be estimated.

There are extensive reasons why these models are, in practice, much more difficult to apply and interpret than indicated above. These reasons include issues such as ill-defined stock structure and migration patterns, illegal, unreported and unregulated catches, poorly understood growth, maturity and vulnerability schedules and inappropriate assumptions about catchability and recruitment dynamics. All of these issues are likely to be present in data-poor fisheries or species and they will be compounded with resource constraints for analysis and reporting.

[10] For example, where trophic dependencies need to be taken into account.

That said, the ratios between the current F and F_{MSY} and B and B_0 (unfished biomass), still lie at the heart of the assessment challenge for data poor species. Any strategies that successfully estimate these ratios, either directly or via proxies, have a valid role in determining the sustainability of fisheries. The following strategies documented below are examples from Australia or overseas that attempt to achieve this goal. Only strategies that would be appropriate for data-poor situations are described – it is beyond the scope of this report to review all approaches and recent developments in stock assessment.

5.8.3. Catch and effort approaches

Consideration of catch and effort statistics is usually the first step in considering the state of any commercial fishery. The importance of plotting trends in landings and catch rates cannot be over-stated. Some apparent issues in fisheries will be resolved by querying catch and effort databases, identifying the operators involved in recent changes and simply talking to them. Often changes in reporting, prices or marketing can impact catch and effort statistics.

Many Australian jurisdictions routinely use either standardised or un-standardised catch rates to infer changes to a fishery or species. The difficulties with this approach are well understood by practitioners and include hyper-stability and changes to catchability and reporting through time. Many such time series for data-poor stocks are either unrepresentative (particularly for effort), too short or lack adequate contrast to make inferences about productivity.

The fundamental difficulty with using un-modelled[11] catch or catch rates as indicators is that they have no easily defined limit or target reference points (particularly if the initial stages of the fishery were not observed). Some Australian agencies have reference points based on a historical state (e.g., sharks in NT) and Commonwealth Tier 4 harvest control rules include a defined target reference point (Department of Agriculture Fisheries and Forestry 2007). NSW, in particular, considered the use of landings-based trigger points (Scandol 2003a) and discovered the issues of false-positive signals and trigger point fatigue made the approach ineffective. An alternative to fixed reference points for landings and catch rates are trigger points associated with the direction and rate of change of an indicator (with very clearly defined rules) (e.g. Fowler *et al.* 2007).

There have been several analysis that have attempted to extract more information from commercial landings including (Caddy *et al.* 1983; Caddy *et al.* 1998; Campbell 1998; Scandol 2003b; Vasconcellos *et al.* 2005). However, none of these approaches seem to have had much impact on Australian fisheries management agencies.

5.8.4. Age and length approaches

The alternative approach to understanding fishing mortality rates is to use conventional age-composition analysis (such as catch curves) to estimate total mortality Z. An estimate of F is obtained by subtracting an estimate of M. The exploitation rate (F/Z) is then calculated. This approach has been used in WA (Wise *et al.* 2007), NSW (Stewart *et al.* 2008) and Tasmania (Ziegler *et al.* 2006). This approach has a successful track record in Australia and control rules based upon such catch-curve analysis have been developed and implemented as Commonwealth Tier 3 harvest control rules (Department of Agriculture Fisheries and Forestry 2007). Challenges with this approach include issues associated with age validation, recruitment variability, sample representativeness and the cost of obtaining and interpreting sufficient age samples. There is significant infrastructure and expertise required to maintain consistent and reliable ring counts of

[11] That is, not interpreted using a biomass dynamic or delay-difference model to estimate harvest rates. Interestingly, such biomass dynamic models seem to be somewhat out of vogue in Australia at present.

bony fish. Tagging methods can generate similar information for crustaceans, but adequate programs will be expensive and may not be appropriate for data-poor species. The likely errors arising from recruitment variability can seriously compromise the outcomes from catch curve analysis. In many cases, monitoring of age compositions and implementation of trigger points that signal excessive age-class truncation could be more effective than highly variable estimates of exploitation rate used in conjunction with conventional reference points.

Catch curves analyses can also be done with length composition data and software such as ELEFAN and MULTIFAN which attempt to estimate growth and mortality parameters from length composition data (Pauly 1987; Fournier *et al.* 1990; Fournier *et al.* 1998). Various attempts have been made to develop empirical approaches to assessment based upon either age or length statistics (Punt *et al.* 2001; Scandol 2005). In all cases the main problem lies in defining and defending target and limit reference points.

Various other metrics derived from growth and mortality studies are used in Australia. These include yield-per-recruit estimates to indicate growth overfishing and the spawning potential ratio (Walters *et al.* 2004). Metrics based upon the fraction of mature and large fish in catches are also used, particularly when developing minimum and maximum legal lengths (Froese 2004).

5.8.5. Life history approaches

There have been recent promising developments in life history-based approaches for data-poor stocks. Zhou *et al.* (2007) and Zhou and Griffiths (2008) used the differences in surveyed abundance of species between fished and lightly-fished areas to infer a fishing mortality rate. The resulting rate is compared to a proxy for F_{MSY} (usually M) and species where $F > F_{MSY}$ are identified. The method also includes a quantitative estimate of the uncertainty associated with F. This approach has been used to create a level 2.5 ERA within the Commonwealth ERAEF (see section 5.7.3) and will probably be a key method used in the recent DAFF/BRS project for Reducing Uncertainty in Stock Status (RUSS). The difficulty with this approach is that it requires spatial information on relative abundance in areas with contrasting levels of fishing pressure. Such data are available for many Commonwealth fisheries, but are not routinely collected for state fisheries. Furthermore, the analyses themselves are quite complex and require an extensive database of life history parameters.

An alternative approach developed by Forrest *et al.* (2008), building on the work of Pope *et al.* (2000) and Goodwin *et al.* (2006), is to use meta-analyses, life history parameters and vulnerability and maturity schedules to estimate F_{MSY} (or the discrete time equivalent U_{MSY}). The breakthrough in this approach is the integration of stock-recruitment relationships into such calculations. This is important for two reasons. Firstly, it removes the need to differentiate between growth overfishing and recruitment overfishing. These concepts have arisen from different branches of fisheries science and can confuse reporting processes. The Forrest *et al.* (2008) method also provides a relationship between the vulnerability schedule and F_{MSY}. In some cases F_{MSY} (as applied to the vulnerable biomass) can be increased by increasing gear selectivity or increasing minimum legal lengths (assuming small rates of discard mortality, see Coggins *et al.* 2007).

Other applications of life history based approaches (many based upon the earlier ideas of Charnov (1993) and Caswell (1982; 1989)) that are being developed as a synergy between fisheries and conservation biology include McClure *et al.* (2003), Dulvy *et al.* (2004) Senina *et al.* (1999), Alvarez-Flores and Heide-Jorgensen (2004) and Kaplan (2005).

5.8.6. Practical considerations

Realistically, many of the classical approaches outlined above will be seriously constrained in data-poor situations. For example, the practical difficulty associated with using fishing mortality as an indicator is that, unless consistently sampled and lengthy time series of age-structured information are available, then simplifying assumptions (such as constant recruitment and natural mortality) will be required to extract an estimate of *F*. Estimates of F_{MSY} will always be subject to the reliability of any assumptions required about stock-recruitment dynamics. In many cases sophisticated equations and computer programs will not convince sceptical or probing minds from either government or industry, and this will compromise the utility of outputs from either conventional or novel analytical approaches.

In such circumstances, the practical scientific response might be the implementation of independent surveys that either result in an abundance estimate (e.g. McGarvey *et al.* 2008) or a credible index of abundance. If such surveys can measure the abundance of pre-recruit individuals, they are particularly valuable when implementing output controls that are updated annually. Numerous examples of such surveys can be found in use around Australia (Harris *et al.* 1999; Steer *et al.* 2007; Brown *et al.* 2008; Dixon *et al.* 2008). The usual impediment to such approaches is the ongoing cost. In some cases, the value of the catch harvested during the surveys can be used to offset the cost of the surveys. The extent to which such solutions are viable in many data (and usually value poor) situations will depend enormously on the particular situation at hand.

5.8.7. Final comments

One of the core themes of these guidelines developed in this project is that, in a data-poor situation, it may be far more rational to change the management arrangements rather than attempt to elucidate the state and productivity of a particular fish stock. Many of the methods described above still require significant amounts of expertise to undertake and interpret, and most are single species methods which do not do justice to complexity of ecological interactions that are likely to be present. Furthermore, with climate change, reference points like B_{thresh} and F_{MSY} may become non-stationary. Application of qualitative risk methods and a precautionary management approach will likely be the most cost effective strategy in data-poor situations.

5.9. Quantitative assessment and the likelihood-consequence model

This final section provides an explanation of how the conventional "risk analyses" that are usually completed in association with stock assessment can be interpreted within the likelihood-consequence risk model. To augment this explanation, the same reasoning will be applied to the new quantitative assessment method developed by Zhou and Griffiths (2008). Within this interpretation four questions need to be resolved:

- What objective could be adversely affected by potential outcomes?
- What is the likelihood that these outcomes will occur?
- What are the consequences of these outcomes?
- How could management reduce the likelihood (or consequence) that outcomes will occur that will adversely affect these objectives?

Single species assessment models are usually applied in two distinct stages. A dynamic population model is calibrated to observations using some type of statistical logic. This results in probability distributions of key parameters which can then be used to project the population into the future given assumptions about future management. This second stage is often referred to as the "risk analysis". Various indicators can be calculated from these models which can be compared with target or limit reference points. As the models are stochastic, values of the indicators are themselves probability distributions at each point in time. This enables a probability statement about the current or future state of a stock with respect to a reference point. For example, there is a 75% chance that the biomass will be less than 20% of the unfished biomass (the limit reference point, $B_{20\%}$) in 5 years if the total allowable catch is 100 tonnes.

In this example, the objective can be interpreted from a strategic or tactical perspective. From a strategic perspective, the management agency will likely have a general legislative objective that fishing must be sustainable. From a tactical perspective, a regulatory management plan will state that, for the general legislative objective to be meet there needs to be a tactical (or operational) objective that the biomass must be greater than $B_{20\%}$. Risk analysis enables calculation of the likelihood (probability) that the biomass is (or will be) less than $B_{20\%}$ and therefore the likelihood that the objective has been (or will be) adversely affected.

What are the consequences in this example? This is a more difficult issue and requires a frame of reference to answer clearly. From the political perspective of a government, if a management agency is in breach of its own regulations or legislation, then at best the consequences will be politically embarrassing and, at worst, result in expensive legal remedies. An alternative perspective of government may focus on the socio-economic consequences of the subsequent loss in production and profits from an overfished stock. This will be balanced from the consequences of harvesting at too conservative rates and thus compromising current socio-economic opportunities[12]. Consequences from an ecological frame of reference could also be articulated but these would be just as difficult to quantify.

This example illustrates why the consequence side of the risk equation is often over-simplified by scientists. In natural resource management, it is a highly unstructured problem that is not particularly amenable to quantitative analysis. Rather, it is a complex policy debate that needs to be informed by the biological, social and economic sciences.

The usual response taken by quantitative fishery analysts is to assume that the consequences of an indicator breaching a limit reference are unacceptable for a management agency (based upon international standards). The actual consequences of such an outcome are usually left to other components of the management process. Given the highly specialised nature of all these areas of expertise, this is a very reasonable response.

The final question raised above, is how management could reduce the likelihood of outcomes which could affect objectives. Within the quantitative risk analyses undertaken within stock assessments this is particularly straightforward. Forward projections of population dynamics incorporate management parameters such as total allowable catch, projected effort, changes to gears or temporal and spatial closures. In each case, the relationship between possible management strategies and changes to the likelihood of particular outcomes is quantified by the model. This is exactly why quantitative stock assessment models fit within Level 3 ERAEF.

Zhou and Griffiths (2008) developed an important model that develops a bridge between quantitative stock assessment and ecological risk assessment. This example is used to illustrate how quantitative ecological risk assessment can also be interpreted within the likelihood-consequence model, though the authors have not explicitly done so. In an approach similar to quantitative stock assessment, the authors used statistical logic to calibrate a model to observations. In this case, presence-absence data from trawl surveys was combined with information on effort and

[12] From a very technical perspective, if the financial consequences over over-fishing and under-fishing can be mapped to a common scale (such as dollars), then a loss function can be applied to actually quantify the risk (expected loss). However, as the costs and benefits of such scenarios are usually distributed to different stakeholders or over different time-scales, such calculations generally require political solutions.

escapement to estimate a fishing-induced mortality rate. Limit reference points were defined based upon estimates of natural mortality, and the two estimates compared. When the estimated fishing mortality rate was estimated to be greater than the minimum unsustainable fishing mortality rate (a limit reference point), then the species was considered to be at risk of overfishing. As with risk analyses completed within quantitative stock assessments, this model is solely concerned with estimating the likelihood of an outcome. As with the first example, the strategic objective is a sustainable fishery, but the tactical or operational objective must be more specifically defined in terms of indicators and reference points.

As with most quantitative stock assessments, the authors make little reference to the consequences of the potential outcome (extinction of species subject to overfishing), but the consequences are identical to the previous example, and dependent upon the legislative and policy frameworks in place. The Zhou and Griffiths (2008) SAFE model could be extended to determine what changes to effort or escapement (selectivity) were required by the fishery to increase the likelihood of achieving both tactical and strategic objectives. This would be the required component of a risk management model.

6. RESULTS – INTERVIEWS AND WORKSHOPS

6.1. Interviews

As the interviews were anonymous and confidential we will not be providing any specific information about the difficulties and challenges individuals were facing in managing their data-poor species. However, to give a flavour of the interviews some key comments and observations are paraphrased below.

What is risk?

- Risk is everything we do (our day-to-day business).
- It is evaluating how bad any negative impacts are going to be and their likelihood.
- It is forward projections accounting for process and observation error, parameter uncertainty and management options.
- It's what helps us move away from the fire-fighting mentality.

Definition of data-poor:

- All fisheries are data-poor to some extent.
- A data rich fishery can still catch data-poor species – bycatch.
- A data poor fishery is one in which you can't do a quantitative stock assessment.
- We have "assessment poor" fisheries in which we have the data but not the resources to do the assessment.

Managing risks in data-poor fisheries:

- Fisheries should be managed mostly according to their value.
- The fact that you don't have data doesn't mean you shouldn't be making decisions.
- For most of our data poor fisheries the best we can do is 'expert opinion' based on the facts available.
- We manage based on the most susceptible species.
- Industry consultation helps keep us on top of unknowns – we take their concerns seriously.

Investments in risk frameworks:

- Each jurisdiction has experience with risk management in fisheries thanks to DEWHA export requirements and National ESD Reporting Framework.
- Some risk assessments are getting out of date and there are no updates on the horizon.
- Commonwealth and WA have "locked in" risk frameworks with regular update schedules
- We use "FishBase" as a primary online resource.
- National ESD, QERA and CSIRO SICA methods are all in use and planned for future use.
- Data and meta-data management is improving but still needs work.
- There exists no inter-jurisdictional databases of life-history, fisheries or habitat.
- There is almost no formalised sharing of data or modelling tools between states and Commonwealth.
- No objective comparisons of risk, likelihood and consequence exist between jurisdictions.

Although each of the interviews was transcribed we will not be providing any extensive summary of the results. However the information contained in the transcripts was utilised for the development of both the guidelines as well as the first draft of the benchmarks. Also, a paper was produced contrasting the Australian interviews with similar interviews conducted in the US as part of a study abroad project conducted by a U.S. masters student. The paper has been submitted for publication with *Fisheries Research* and a copy of the draft paper is included as Appendix 9.

6.2. National guidelines workshops

The list of workshop participates is listed below in Table 11. At least one workshop was held in each jurisdiction including a workshop in Canberra for the Commonwealth fisheries. In total we had 78 attendees consisting of 46 scientists and 32 managers.

Table 11. List of workshop participants by jurisdiction. Staff who identified themselves primarily as scientists are indicated by S, managers by M.

State	Name	Scientist/ Manager	State	Name	Scientist/ Manager
QLD	Michael Kinney	S	WA	Jenny Shaw	S
QLD	Aaron Ballagh	S	VIC	Anthony Forster	M
QLD	Clive Turnbull	M	VIC	Patrick Coutin	S
QLD	Ashley Frisch	M	VIC	Alice McDonald	M
QLD	Colin Simpfendorfer	S	VIC	Dave Molloy	M
QLD	Ann Penny	S	VIC	Murray MacDonald	M
QLD	Alastair Harry	S	SA	Tony Fowler	S
QLD	Andrew Chin	S	SA	Stephen Mayfield	S
QLD	Geoffrey Muldoon	M	SA	Tim Ward	S
QLD	David Welch	S	SA	Lianos Triantafillos	M
QLD	Jason Magilbrae	S	TAS	Jeremy Lyle	S
QLD	Ross Quinn	S	TAS	Phillipe Ziegler	S
QLD	Julia Davis	S	TAS	Caleb Gardner	S
QLD	Michelle Williams	S	TAS	Sean Tracey	S
QLD	Mai Tanimoto	S	TAS	Jayson Semmens	S
QLD	Ian Tibbits	S	TAS	Greg Ryan	M
QLD	Sujie Zhou	S	TAS	Matt Bradshaw	M
QLD	Alex Campbell	S	TAS	Francis Seaborn	M
QLD	Ian Brown	S	CTH	Natalie Dowling	S
QLD	Eddie Gebreen	M	CTH	Trent Timmiss	M
QLD	Shane Favor	M	CTH	Mariana Nahas	M
QLD	Brad Zeller	S	CTH	Natalie Couchman	M
NT	Thor Saunders	S	CTH	Amanda Parr	M
NT	Trish Beatty	M	CTH	James Woodhams	S
NT	Murray Barton	M	CTH	Alex Harrington	M
NT	Mark Gwbert	S	CTH	Fiona Giannini	S
NT	Ian Curnow	M	CTH	Robert Cutotti	S
NT	Julie Martin	S	CTH	Emma Lawrence	S
NT	Blair Grace	S	CTH	Kevin McLoughlin	S
NT	Steven Matthews	M	CTH	Gavin Begg	S
NT	Patti Kuhl	M	CTH	Sandy Morrison	S
WA	Shane O'Donoghue	M	NSW	Karen Astles	S
WA	Brett Molony	S	NSW	Phillip Gibbs	S
WA	Shirree Blazeski	M	NSW	Marcel Green	M
WA	Nick Caputi	S	NSW	Doug Ferrell	M
WA	Dan Pupazzoni	M	NSW	Darryl Sullings	M
WA	Neil Sumner	S	NSW	Nick James	M
WA	Brent Wise	S	NSW	Fiona McKinnon	M
WA	Kevin Donahue	M	NSW	Kevin Rowling	S

6.2.1. *Six thinking hats exercise*

This "brainstorming" exercise was designed to solicit the main roadblocks for jurisdictions in their attempts to implement a complete fisheries risk management system including recreational fisheries and socio-economic factors. Some of the key issues raised are paraphrased below. Note that these are informal comments by workshop participants and are not official agency positions.

General:

- Our risk based system has ministerial level support.
- We have limited support at top-level for a risk management system.
- Risk management provides a means to prioritise research and formalises future management.
- A full risk management system is the end product, with all fisheries under the one risk regime.
- Risk management formalises the tradeoffs between multiple objectives and provides a means for justifying management actions in situations with limited information.
- Risk management is proactive rather than reactive.
- It is just the new way of thinking (concept/religion/cult) that will come and go.
- Risk management is the modern way of 'passing the buck'.
- We have not moved to a risk-based system because the current structure seems to work – there are less rules which provides greater flexibility.
- We don't have the resources and expertise available.
- There is no 'champion' of risk management in the organisation.
- Risk assessments are already done intuitively by managers.
- Models have had their 30 years, it is time for an alternative.
- The presentation of science is crucial and quantitative stock assessment graphs and arguments are more persuasive with stakeholders than risk assessments.
- Risk management allows for the internalisation of the risk of decisions.
- ERAs provide good evidence and backing for management reports which can help when encountering problems.
- ERA workshops get people sitting down and talking through issues as a group.
- ERAs can provide advice in a more timely manner.
- The initial ERA documents were very resource intensive but the subsequent updates will not be as difficult.
- Many decisions are fundamentally political in nature and are not based on risk.
- Four general principles for managing data poor fisheries:
    - A system of triggers to detect changes in the fishery (multiple triggers with increasing level of rigor – catch, CPUE).
    - Spatial management – used in combination with above.
    - Develop a data bank and commit to efficient data collection (e.g., otoliths).
    - Conscious commitment to move towards a higher levels of data collection and analysis.

Recreational Fishing:

- Recreational fishing is a huge risk in some fisheries.
- There is no risk assessment for recreational fishing.
- Qualitative risk assessments rely on a group of experts but who are experts in recreational fisheries?
- Risk management and the weight-of-evidence approach are needed because of the problem of recreational fishing. We will never have enough information about recreational catch.
- Scale is the issue – hundreds of thousands of anglers are hard to deal with.
- Need to stay in contact with stakeholders to get information on key drivers of the populations.

- Stakeholders are sometimes a good source of new ideas.
- We probably have enough information to get a ball-park figure on the economic benefits of recreational fishing.

Socio-economics:

- We don't have clearly defined socio-economics requirements.
- Ecological risks don't need ecological input but socio-economic and governance risks need stakeholder input.
- Economic indicators need only be fairly rudimentary – e.g., CPUE can be an economic indicator.
- We should use socio-economic reference *directions* rather than reference points. We may not be able to agree on the best point but we might be able to agree on which direction to go.
- The economics are picking up the social aspects however there is a big problem with getting even economics in data poor fisheries.
- A lot of work needs to be done before we can implement social indicators and performance measures.
- We are starting to grapple with social data collection but the question is: what do you measure?
- We are moving towards bio-economic models but must first build the biological model before the economics can be added on.
- It can be very expensive to implement a cost-benefit analysis or a bio-economic model.
- There are problems connecting biological social and economic risks – they are very divergent inputs.
- Managing fisheries for social considerations can result to poor biological outcomes (e.g., Atlantic cod).
- There is a lack research into social and economic indicators that can be used.
- Risk management is a great tool for social and political communication.

There was a general consensus that risk management was an important tool and indeed is what most managers and scientists have always been involved in. There was recognition that a lot of risk management occurs implicitly.

6.2.2. Case studies

As discussed in the methods section 4.8.5, the case studies were designed to provide an example of using the national guidelines and to stimulate deliberation around actual examples of data-poor species in Australia. Five case studies were used for the workshops and the attendee's evaluations for these case studies are shown in Figure 15. The Whaler Shark and Black Bream studies received the lowest evaluation scores. Some of the comments associated with the low scores involved the lack of information given and the fact that the Black Bream study was on a recreational fishery. These are interesting comments given that the Whaler Shark study contained virtually all the information that the fisheries managers had to make a decision. In the case of the Black Bream, it was an environmentally-driven recreational fishery with which some participants were unfamiliar.

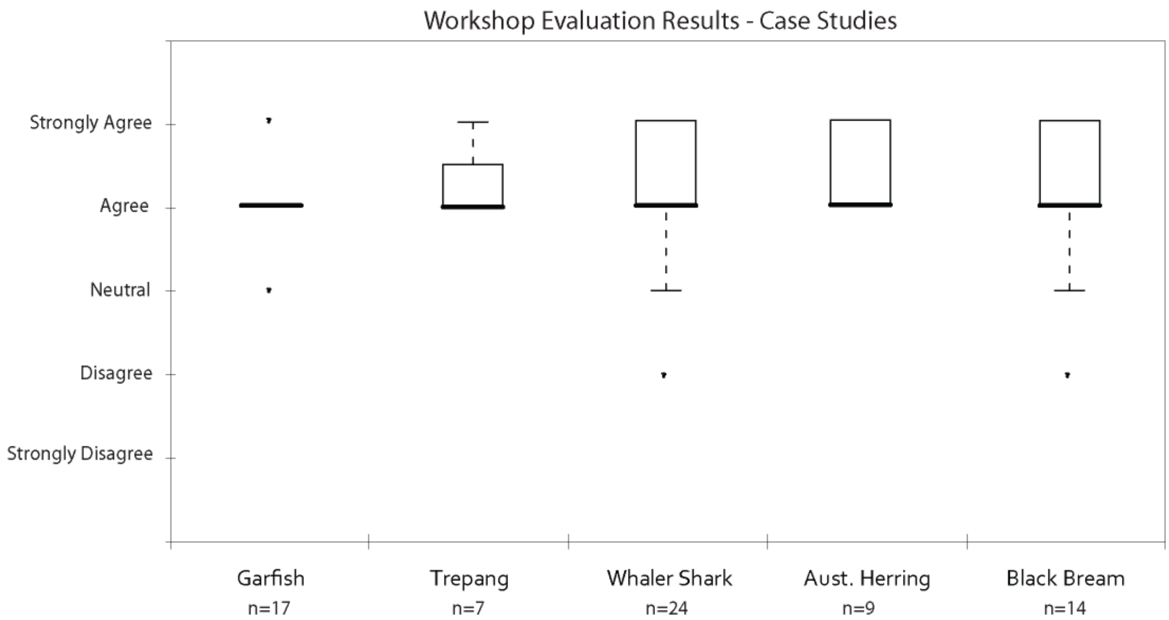

Figure 15. Evaluation ratings from all workshop attendees for the question 'the case studies were helpful for illustrating the use of the guidelines'.

6.2.3. Benchmarks

The workshop participants were asked to examine the risk benchmarks for their jurisdiction that had been prepared earlier by the project team based on the review and the interviews. The benchmarks were each examined and debated by the group and each was given a rating of how much of an impact improving their performance on this benchmark would have on their management of data poor fisheries and their capability to improve their performance given current political will and any time, money and expertise constraints. The final benchmarks for each jurisdiction are provided in Chapter 8.

6.2.4. Workshop evaluations

The results of the workshop evaluations are summarised in Figure 16. Most respondents agreed that the guidelines help clarify their understanding of risk management for fisheries. A fairly good spread of responses were obtained from asking whether respondents believed that consistent and comparable risk ratings could be achieved across fisheries and jurisdictions. This is not a surprising result and is one of the key issues examined in the discussion section of this report. Most managers and scientists appear satisfied with the guidelines interpretation of "data-poor species". Some respondents however noted that the discussions tended to gravitate towards more data rich species, which was a definite problem we encountered in both the workshops and the interviews.

All scientists and managers agreed or strongly agreed with the need for a minimum level of information for stock assessments. Some managers appeared to be less agreeable to the statement that they have a better understanding of the role of risk in the prioritisation of research. However, based on the comments on the evaluation forms it appears that there was actually some confusion with the wording of this question. Respondents do not appear to have been saying that they do not see the importance of risk prioritisation but rather that they were already well aware of the role of risk prioritisation and the workshops did not improve their understanding. Managers also appeared less agreeable to the "weight of evidence" approach. This might reflect their difficulty in gaining managerial traction with this approach, as mentioned in several interviews.

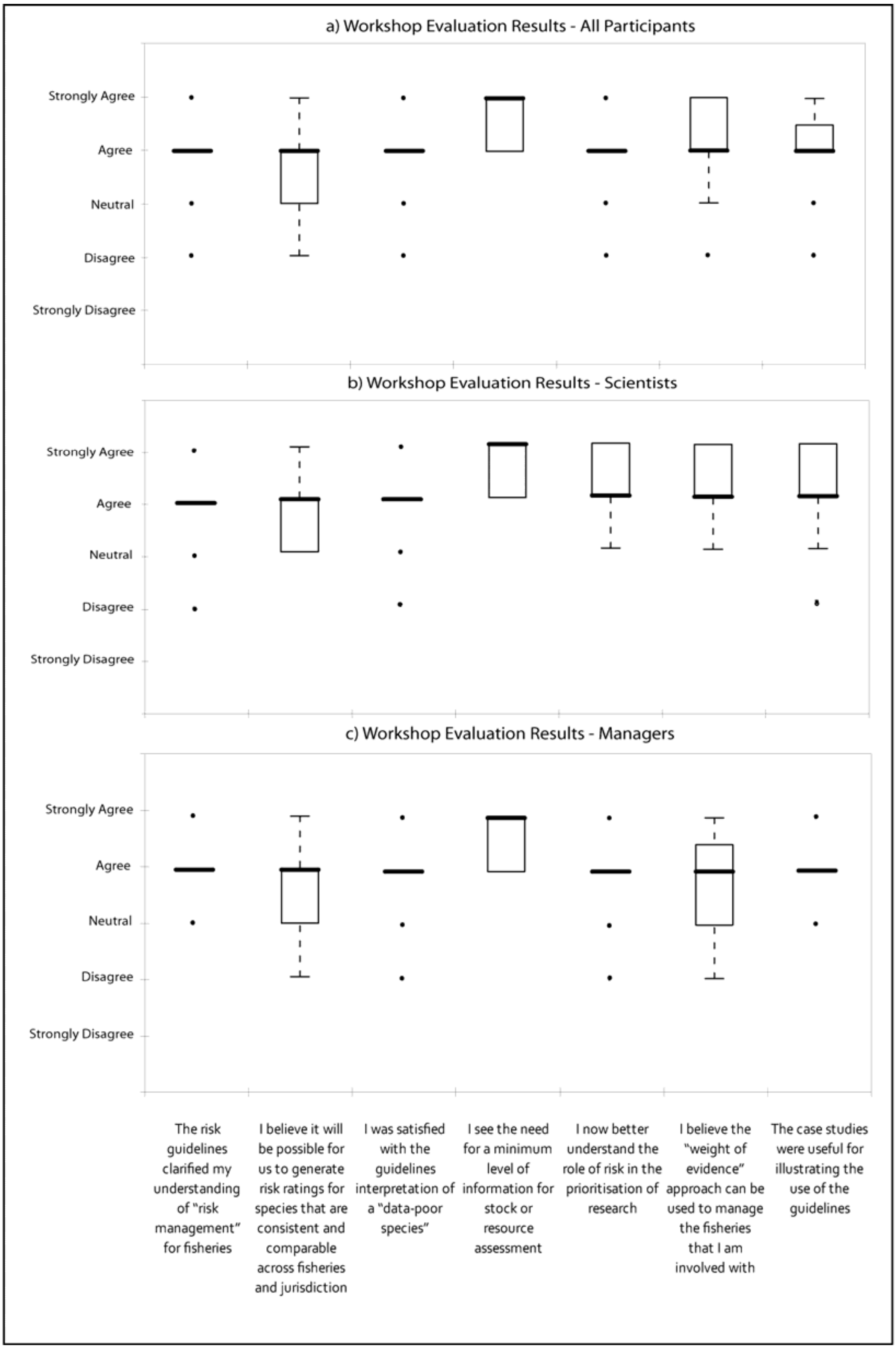

Figure 16. Box plots of responses from the national workshops evaluation questionnaire for a) all respondents (n = 71), b) Scientists (n = 39), and c) managers (n = 32).

7. THE NATIONAL GUIDELINES

7.1. Background

This section is presented in the same form that it was distributed at the workshops. Minor amendments have been made to the text to clarify issues that were identified by either the workshop participants or the co-investigators.

7.2. Context

Implementation of policies towards Ecosystem Based Fisheries Management (EBFM) will continue to require development and extension of new methods for the assessment of living marine resources. One of the most important developments in Australia in recent years is the implementation of risk assessment methods, an approach that is also gaining momentum overseas. Management agencies do, however, have ongoing responsibilities for the management of single species fisheries and all agencies still maintain stock assessment programs, particularly for species subject to quota management. The guidelines presented here have a broad scope including technical suggestions regarding assessments as well as procedural factors such as implementation and interpretation. These guidelines are focused upon "data-poor" species (a concept developed in more detail below) as such species can be evaluated with both qualitative and quantitative assessment methods.

Despite the breadth of scope for these guidelines there was a deliberate decision to exclude the consideration of the assessment of the impacts of fishing on habitats, communities or ecosystems from this project. The investigators of this project appreciate that the guidelines presented here are a subset of the issues required for EBFM. However, single species issues continue to dominate many management agencies because of legacy arrangements and the relative transparency of decisions based upon species, rather than more abstract concepts such as biodiversity. Continued development of single species assessment methods is thus a very important goal – particularly if those methods can be efficiently applied to large numbers of species.

7.3. Background

This document outlines principles and guidelines to improve the application of risk-based methods for data-poor species in Australia. By data-poor we mean species where the data are either unavailable or uninformative. Uninformative data can result from the lack of contrast, records which are imprecise and/or biased, or simply do not represent characteristics of a population useful for fisheries management. These issues are sometimes associated with immature data management systems and limited statistical or analytical resources to interpret the information available.

These guidelines are based upon international and national approaches in stock assessment, risk analysis and fisheries management. Some guidelines are based upon documented standards and strategies (e.g. AS/NZS 2006), others on the experiences of practitioners in research and management.

On the 24 June 08, the project co-investigators and project staff met in Sydney to discuss the initial version of the principles and guidelines. At this meeting, a range of opinions about the appropriate scope and detail of such a document were voiced. Some co-investigators suggested that the broader requirements of ecosystem-based fisheries management needed to be captured within the guidelines including the social and economic dimensions of risk. Other co-investigators requested more specific guidelines be developed about which particular assessment techniques could or should be applied in various data-poor circumstances.

The principles and guidelines below have attempted to capture this broad scope of requirements from this project. In some cases, specific details have yet to be determined and guidelines associated with these are marked as incomplete. In general, principles are a broad tenet, whilst the guidelines are a statement of procedure which would determine a course of action. Within this document, guidelines are nested within the principles.

The AFMF-SRR research priority upon which this project is based ("Develop a rating of risk within rapid stock assessment methodologies for data-poor species that is consistent with the more formal assessments done for target species") suggests that improved standardisation of risk-based approaches, both within and between jurisdictions, would be a valuable step towards this goal. Adoption of these principles and guidelines is a strategy to achieve this.

7.4. Principles and guidelines

Principle one and guidelines G1–G5 attempt to clarify the terminology and context of risk-based methods. These guidelines are not just relevant to fisheries (they apply to any field where risk-based methods are used) but provide the necessary context for the remainder of this document. This section also captures the linkages with the broader social and economic dimensions of risk that are prevalent in contemporary marine policy (such as ecosystem-based fisheries management).

Principle two and guidelines G6–G9 are associated with concepts such as "data-poor", the tradeoffs between risk, catch and management costs, and the precautionary approach. These guidelines are quite general and abstract, but are required to clarify some of the more specific guidelines provided within principle three.

Principle three includes more specific guidelines that provide advice on how risk-based methods should be applied in the scope, implementation and interpretation of the assessments of data-poor species. Partition of these guidelines into these categories within principle three is done for organisational purposes and to provide consistent linkages to the objectives of this project. There will always be some semantic debate about the categorisation of these guidelines. Some of these guidelines are tactical in nature, whilst others are more strategic.

These guidelines are directly associated with benchmarks (see Chapter 8) which have been used to compare and contrast the various risk-based approaches that jurisdictions have applied.

7.5. Linkages to other policies

At the outset, it must be appreciated that risk-based approaches are not undertaken in isolation from other policies that are used in the management of living aquatic resources. In particular, development and implementation of performance-based fisheries management plans is the correct framework for accountable and transparent resource management. Such plans inevitably include some form of adaptive management which is inter-related with risk management. The expansive scope of environmental management, which includes policies such as regional marine planning and ecosystem-based management, will continue to require the consideration and implementation of risk-based approaches and methods.

These guidelines also acknowledge the fundamental importance of social processes in policy formulation and resource management. For example, Indigenous fisheries strategies, community and stakeholder consultation, allocation policies and reforms to fisheries governance all play a crucial role in contemporary fisheries management.

It is beyond the scope of this project to identify the role of risk within all of these broader aspects of fisheries management (and there are many). Where necessary for the interpretation of these guidelines, the interaction of risk-based approaches with other policies will be highlighted.

Similarly, other fields of organisational management (such as project management) give significant and justifiable emphasis to risk-based approaches. Where relevant, these guidelines will identify key areas of overlap between these disciplines and risk-based methods in the assessment of data-poor fisheries.

A glossary has been provided which includes the definitions of the key words used (Appendix 3).

7.6. The principles and guidelines

P1	Risk is the combination of the likelihood and consequence of an uncertain outcome.

G1 Risk should be determined by combining the likelihood and the consequence of an uncertain outcome that will adversely affect objectives.

All technical fields (including engineering, occupational health and safety, ecology, mathematics, medicine, security) use the likelihood-consequence model of risk. There is no need for alternative definitions of risk to be adopted in fisheries management or science.

Within such a framework, risk can be either quantitative or qualitative, but all risks within an assessment framework should be measured against the same or comparative scales. Objectives which can be adversely affected can be biological, ecological, economic or social.

The social sciences recognise cultural aspects of risk which may deviate from the likelihood-consequence model, but these approaches are not within the scope of these guidelines.

Most of the risk assessment undertaken in Australian fisheries has been directed towards estimating *potential* risk rather than *actual* risk. In other words, these assessments have mostly been oriented towards the identification of hazards. This is an approach common to many risk assessments and stems from the fact that there are generally insufficient observations of outcomes to quantify actual risk (Adams 1995; Hokstad *et al.* 2006).

In determining the risk, it is imperative that there is a clearly stated justification for selecting the particular levels of likelihood and consequence over the other potential combinations and thus other estimates of risk.

G2 All risk-based approaches in Australian fisheries should fit within the likelihood-consequence model.

The risk-assessment guidelines within the National ESD Framework[13] (Fletcher *et al.* 2002; Fletcher 2005), the Scale-Intensity-Consequence Analysis (Hobday *et al.* 2007) and the NSW QERA Method (Astles *et al.* 2006) are all founded upon the likelihood-consequence risk model and all approaches clearly identify how likelihood and consequence should be interpreted.

Many other analyses used in Australian fisheries research and management are sometimes described as “risk assessments” or “risk analyses” even though it is not articulated what the likelihood and consequence components are. In most instances, such analyses or assessments are predominantly about the estimation of likelihood and simply require clarity about the consequence. This is illustrated with two examples in section 5.9. These examples also illustrate that there is no fundamental distinction between quantitative ecological risk assessment and quantitative risk analysis undertaken within stock assessment.

The ease with which such approaches can be re-interpreted into the likelihood-consequence model is important as it illustrates the generality of the model. Additional clarifications that should be associated with the identification of risk-based approaches is a clear explanation of what objectives may be affected and how management could reduce the likelihood (or consequence) of outcomes that could affect the achievement of those objectives.

Other models have been developed in Australia that provide key insights into sustainable harvesting practices for fisheries. For example, Commonwealth ERA Level 2 (Stobutzki *et al.* 2001a) or Productivity Susceptibility Analysis is a model that identifies the inherent vulnerability of species to fishing practices (such as trawling). Guideline G14 discusses the important role of such methods in the assessment and management of data-poor fisheries.

G3 Understand that consequences must have a frame of reference that, for a government agency, is determined by legislative and policy objectives.

The consequence component of risk must be examined or viewed from a particular frame of reference (such as would exist for an agency, industry or individual). For an agency this frame of reference would be their legislative and policy objectives. Within institutions committed to evidence-based policy, consequences will be informed by research, observations or data; all of which can be provided by the biophysical, economic and social sciences. Understanding the consequences of outcomes will be an ongoing iterative process involving research, stakeholders and management.

Sometimes all stakeholders can easily agree when ranking consequences or outcomes (*e.g.*, we all agree that deaths are worse than injuries), but in a diverse society, especially for natural resource management, there may not be universal agreement between stakeholders, sectors or cultures about what consequence level a specific outcome should generate. For example, for some individuals the death of one seal is of catastrophic consequence whereas others would view this as a minor consequence. A range of policies and legal instruments are available to progress issues given divergent stakeholder interpretations of these consequences.

[13] Based on the AS/NZ 4360 Risk Assessment Standard.

Within fisheries management, there are a number of outcomes which have been identified as having unacceptable consequences for a fish stock, for example, the biomass of a stock reaching a limit reference point (such as 20% of the unfished biomass $B_{20\%}$). An example of how the likelihood-consequence model can be applied to risk analyses associated with single species assessment models is expanded upon in section 5.9. Such universally accepted thresholds of consequence enable standardisation of risk assessments and will therefore be identified in this project.

The consequence component of an agency's risk assessment is often represented by the scope and interpretation of the assessment which has been, in turn, derived from the relevant legislative and policy frameworks. For example, agency risk assessments based upon statutory requirements may have the consequences actually defined by legislation (*e.g.* harvesting must be biologically sustainable, or in more specific cases, an indicator must be greater than a limit reference point).

If there is not a policy or legislative framework that enables (at the very least) the ranking of the consequence of alternative outcomes, then the estimation of risk will be fraught with difficulties. If there has been an explicit or implicit assumption that the consequences of various outcomes are all equal, the risk will be equivalent to the likelihood.

G4 Recognise that the estimation of the likelihood of an uncertain outcome is an objective task and the influence of human-values in such estimates should be minimised.

Estimating the likelihood of a particular outcome should aim to be a value-free analysis based upon objective data or non-biased expert input. Qualitative expert input is inevitable and acceptable, but the potential issues with such input (such as anchoring) should be understood. Estimating the likelihood of an outcome can be tackled using either Frequentist logic (probability of data given a model) or Bayesian logic (probability of a model given the data). All efforts should be made to standardise the estimation of the likelihood of comparable outcomes across Australian fisheries and jurisdictions.

This objective approach to the estimation of likelihood applies to the social and economic sciences just as it does to the biological sciences. For instance, the management objective of a sustainable fishery will require consideration of the biological sustainability of the harvested resource, the economic viability of the industry and the social acceptance of the fishing activity. The fields of economics and sociology have developed a number of recognised data collection methods that can be employed to estimate the likelihood of outcomes which have adverse consequences on economic and social objectives. This will require consequences to be separated into biological, social and economic components so that the associated likelihoods can be estimated using appropriate strategies.

G5 Appreciate that agency officers need to have the requisite skills in risk management to apply these approaches in research and management.

Application of risk-based methods in fisheries agencies requires staff that have a commitment to the approach and have a good grasp of the technical, scientific, policy and procedural dimensions of the field.

Given that risk-based methods will likely be the most cost-effective strategy to meet national standards for environmental performance monitoring and reporting (*e.g.* ISO 14001:2004), capacity in risk management will inevitably be considered core-business in fisheries management agencies. AS/NZS (AS/NZS 1999; AS/NZS 2006) provides instructions on the development and implementation of a risk management program.

P2	Data-poor situations in fisheries are an inevitable result of the physical, biological, social, and economic dimensions of fisheries. There are a range of policy options to address such situations and the precautionary approach continues to plays an important role in the management of such fisheries.

G6 Recognise data poverty is a broader concept than simply not having enough data.

When few resources are allocated for research, monitoring and management systems, this situation may be referred to as "data-poor". In most cases, however, the issues associated with "data poverty" are broader than simply not enough data, but also include: a lack of observations from which to infer abundance; data with insufficient contrast to be informative; time series which are too short to be informative; data which are imprecise or biased (particularly if the biases change through time); immature data management systems and limited statistical or analytical resources to interpret the data.

G7 Acknowledge that the best response to data-poor fisheries is not always to collect more data, but in some situations it is better to implement management strategies that are robust to uncertainty and are able to achieve acceptable levels of risk.

Sainsbury (2004) describes the "catch-management cost-risk" spectrum where the trade-off between fisheries catch and the costs of management is identified. In essence, fisheries could be managed at similar levels of risk by either harvesting the stock heavily and having expensive research, monitoring and management systems, or harvesting lightly and having lower-cost research, monitoring and management systems.

Although the collection of more data may resolve some issues associated with the risks resulting from data poverty or deficiency (see G11), another approach is to alter the management framework to reduce risks to an acceptable level (Whitworth *et al.* 2003; Fletcher 2008b). This is most commonly done by increasing protection on the spawning biomass through reducing or controlling catch and/or effort, increasing minimum legal lengths, creating spatial refuges and implementing spawning closures.

In some cases, assessments for which there are relatively few data will still indicate that a fishery has a low risk of causing unacceptable consequences outcomes which will affect agency objectives (based upon information about life history, ecology and fishing intensity). For such fisheries it is appropriate that they may be safely managed in a "data poor" state provided that minimum data requirements are met (G8).

G8 Recognise that there are minimum standards of data for species that are subject to some type of risk or stock assessment.

These standards will clearly depend upon the nature of the species and the fishery, but are likely to include:

- accurate identification of the species being harvested;
- a threshold understanding of life-history of those species, such as individual growth patterns, maximum age, age and size at maturity and fecundity (these are surrogates of productivity, or the ability of a stock to withstand fishing pressure), and;
- an understanding of the method, selectivity, scale and distribution of the fishing activity relative to species distributions.

G9 Acknowledge that when interpreting risk assessments, adoption of the precautionary approach implies that when the likelihood of an outcome is uncertain and the environmental consequence of this outcome is serious or irreversible, then the interpretation of this likelihood should be the higher but still plausible estimate.

This guideline is simply the formalised rule for interpreting an uncertain likelihood in a precautionary policy context.

"Precaution" has technical ramifications to the interpretation of probability distributions and statistical errors. In essence, precaution implies a preference away from false-negative inferences (or indicators with low sensitivity).

The relationship between risk and the precautionary principle is fundamental because the principle is about the interpretation of scientific uncertainty (an unknown likelihood) combined with serious or irreversible environmental consequences.

P3	Risk-based methods should be applied in scope, implementation and interpretation of assessments of data-poor species.

Scope

G10 Appreciate that risk-like approaches can be used for prioritising and scheduling research, monitoring and management tasks. Such approaches are often closely associated with multi-criteria decision analysis (MCDA).

Various agencies in Australia use models to prioritise and schedule research, monitoring and management tasks. In most cases these methods have more in common with multi-criteria decision analysis rather than risk assessment *per se*. The outcome of a particular risk assessment is usually just one component of such methods. The flexibility and efficiency with which these methods can be applied makes them very suitable for such roles.

G11 Recognise how risk assessments can be used to prioritise research. In particular, where potential outcomes are high risk because of an uncertain likelihood, research can be used to clarify the risk.

Assuming a precautionary interpretation of uncertainty, some outcomes will be high risk because of an uncertain likelihood. Directed research can often reduce this uncertainty and clarify the estimated likelihood and risk.

Note that research could actually increase the calculated level of risk in cases where the original estimate of the likelihood of a consequence was too small.

Implementation

G12 Continue to apply fishery assessment methods that have a successful track-record in data-poor environments.

All agencies already undertake stock assessments of varying degrees of complexity on “data-poor” species. Such methods, including catch-curve analysis, yield-per-recruit calculations and estimation of spawning potential ratio, provide insight into fishing mortality rates that can be compared with reference points (*e.g.* *F* versus *M*). These methods should be routinely applied to contribute to a “weight-of-evidence” approach (G15) or can be integrated into decision rules (G13 Department of Agriculture Fisheries and Forestry 2007). The biological parameters required for such analyses will be readily applicable to future analysis and are part of the minimum data requirements described in G8.

Although time-series methods (such as biomass or age/length structured models) can be difficult or impossible to calibrate without contrasting data or highly constrained model structures (such as informative priors), there is significant value in presenting raw or standardised catch rates where available. A range of these simple assessment approaches that are routinely used in Australia is presented in this report.

G13 Harvest strategy frameworks with explicit decision rules provide an effective risk management framework for fisheries.

The Commonwealth Harvest Strategy Policy (Department of Agriculture Fisheries and Forestry 2007) provides an important template for how various tiers of data and knowledge can be integrated into an assessment and management framework with a consistent interpretation of risk. This Policy makes explicit acknowledgement of the trade-off between fisheries catch and the cost of management as described in G7. Similar policies have been developed and implemented in the United States. Interpretations of the policy suitable for data-poor fisheries have also been developed by the CSIRO and AFMA.

Although the efficacy of such policies for fisheries where the catch cannot be readily estimated nor controlled (such as fisheries where there are significant recreational catches) remains to be understood, the value of a strategy that explicitly links an indicator to harvest control rules is undeniable and should be promoted.

The best approach for developing and testing these harvest strategy frameworks is management strategy evaluation (MSE). Use of computer simulations provides a relatively low cost method to determine the efficacy of such frameworks. In some cases, our understanding of data-rich fisheries can be used to test the effectiveness of the simpler rules and assessment methods for data-poor fisheries (Punt *et al.* 2002).

G14 Develop and promote analyses that estimate the vulnerability of stocks, the productivity of stocks or the likelihood that stocks are being harvested at unsustainable rates.

A number of methods have been developed which assess either: the vulnerability of stocks (Stobutzki *et al.* 2001a); the productivity of stocks (Forrest *et al.* 2008); or the likelihood that stocks are being harvested at unsustainable rates (Zhou *et al.* 2008). All approaches have a similar foundation in that the biological characteristics (and usually the fishery characteristics) are combined to identify the species and harvesting practices which require managerial attention.

Section 5.9 describes how the risk analyses within quantitative stock assessment and Zhou and Griffiths (2008) can be interpreted within the likelihood-consequence risk model. Such reasoning could also be applied to other analyses, but this is not usually done. As described in G2, authors that describe their analysis as a "risk assessment" have a responsibility to articulate how their approach relates to the fundamental components of risk and risk management.

G15 When direct support for a model is unavailable, then scientific arguments should be constructed using a "weight-of-evidence" approach.

Interviews with scientists involved in research and assessment indicated that, for many situations, there is often inadequate data or information to support (or alternatively falsify) models using common statistical criteria. In such cases, scientists should build arguments based upon layers of partial evidence. Ideally there would be independence between these layers. In some situations, an assessment model is a valuable "top layer" of evidence but should not be relied upon as the sole basis of decision-making.

This guideline is an interesting contrast to G13 which recommended harvest strategy frameworks. If there is no explicit (and pre-agreed) rules for modifying harvesting based upon indicators, then there must be some other process for coming to an agreed position from which managers can act. The "weight-of-evidence" approach (Lowell *et al.* 2000) is one such process and is gaining increasing use within Australia (particularly by the states).

The "weight-of-evidence" approach is also commonly used in other reasoned arguments within law, medicine and public administration. Some agencies refer to a 'multiple lines of evidence' approach. This is synonymous with 'weight-of-evidence'.

G16 Individual scientists should apply risk management strategies to their own research and workflows.

Risk management strategies from project management are also directly applicable to the execution of risk or stock assessments.

Formal applications of project management include risk-based approaches to ensure that planned outcomes are delivered on time and within budget. When individual research projects are converted to ongoing programs (*e.g.* monitoring and assessment programs) then the need for risk management continues. Examples of such approaches include: quality assurance procedures; documentation and data management policies; and testing/audit strategies. Such steps are required to maintain the efficiency, transparency and repeatability of research programs and to reduce the likelihood that inaccurate or untimely information is provided to management.

G17 Continue to improve the efficiency of the workflows associated with stock assessment by adopting appropriate technologies.

There are significant efficiencies in stock assessment that have been (and could be) gained through better data management, improved data and algorithm-sharing and application of new technologies (such as electronic data-logging).

Most agencies have invested significantly in new information technologies to improve the efficiency of their assessments. These reforms should continue because many scientists still consider the compilation of data in so-called "data-poor fisheries" to be the rate-determining step in an assessment. Currently, there are no standard protocols for sharing data, parameters or algorithms in Australia.

Interpretation

G18 Risk management is usually carried out by reducing the likelihood of an undesirable outcome.

The likelihood of an undesirable outcome can be reduced by applying additional controls to the source of an impact (*e.g.* reductions in catch, by-catch reduction devices, spatial or temporal closures). Within these options, there are two distinct strategies to reduce this likelihood. Firstly, the frequency of an event can be reduced (*e.g.* less fishing effort), or, secondly, the impact per event can be reduced (*e.g.* implementation of by-catch reduction devices). Both strategies can be applied simultaneously if required.

These strategies are also the primary risk management approaches used in engineering and occupational health and safety.

G19 Risk management may, in some cases, be carried out by reconsidering the consequence of an outcome.

In some cases, given that the consequences of outcomes are value-based, an alternative strategy might be to reconsider the consequences of an outcome. The only occasion when you change the consequence is when the threshold of acceptability has been revised.

For example, initially it may have been considered acceptable to have 10 seals caught in a fishery each year, but after reconsideration, it has now been determined that 50 seals is now acceptable. This change to the acceptable consequence could be the result of new scientific research and a subsequent shift in public opinion (or just a shift in public opinion).

Standards such as biological limit reference points provide agreed thresholds of unacceptable outcomes. It would clearly compromise the utility of such standards if they were altered in an *ad hoc* manner and this is actively discouraged.

G20 Within a multi-species fishery, directed management of an indicator species is an effective strategy to manage species at equal or lower risk than the indicator species.

Similar to terrestrial environmental management approaches, risk management of a multi-species fishery can be facilitated by the identification of an “indicator” species. This species has a higher likelihood of being impacted by the fishery than other species which are co-caught (e.g. Newman 2006). The risk to all co-caught species should therefore be upper-bounded by the species at greater risk because that species is the most vulnerable to fishing gears and/or is the least productive. A challenge with this approach is the identification of the species at greatest risk. This may be problematic unless sufficient information is available.

Note that an indicator species is not necessarily a ‘keystone’ species that plays some crucial ecological role. It may, however, be that the indicator species is iconic and is therefore associated with additional social values. In some cases, the species at highest risk may be subject to the provisions of threatened species legislation. Such provisions will give additional authority to management.

G21 Managers should identify the factors that can cause decision-making processes to fail and develop risk management strategies to avoid these factors.

Decision-making processes within agencies may sometimes fail for a number of reasons, but these reasons are often associated with agency strategies becoming misaligned with stakeholder views, and those stakeholders representing their views directly to a Minister. This is particularly an issue in data-poor situations where the evidential basis for decisions will be weaker. Risk management strategies which may ameliorate this situation include: getting prior Ministerial commitment to decisions and preparing briefs that warn of the likely issues; legislated decision-making processes that capture and deliberate on all relevant issues (such as environmental assessments); improved consultative and co-management processes; early recognition that some strategies are likely to fail and develop alternative approaches.

8. BENCHMARKS

8.1. Background

The scores presented in the tables below are based on a self assessed benchmarking exercise designed to allow each organisation to rate how well they are currently (2008) meeting the benchmark. Scores are ranked from green to red with green being the highest, yellow the medium and red the lowest. The guidelines linked to each benchmark are also identified with the benchmarks (e.g., G20).

All efforts were made to accurately capture the current research and the management strategies used by these agencies and governments. However, any comments made are those of the project team and should not be used to infer current or future government policy for any jurisdiction.

Issues were only addressed in one benchmark, for example if the risk management system does not include social and economic components this should only be applied in benchmark 4.

Each benchmark was scored as follows:

- Red – no evidence of policy
- Light Red – some evidence of policy and partial implementation
- Yellow – policy in place; evidence of implementation
- Light Green – policy in place; evidence of substantial implementation
- Green – policy in place; evidence of full implementation
- Clear – policy not applicable;

The following benchmarks, which have an associated score and commentary, were developed by researchers from this project in consultation with staff from the agencies in Table 12:

Table 12. Summary of the agencies consulted for the benchmarking exercise.

Jurisdiction	Agency or Agencies
Commonwealth (CTH)	CSIRO Marine Research Bureau of Rural Sciences Australian Fisheries Management Authority
New South Wales (NSW)	NSW Department of Primary Industries
Northern Territory (NT)	Department of Regional Development, Primary Industry, Fisheries and Resources
Queensland (QLD)	Department of Primary Industries and Fisheries
South Australia (SA)	Primary Industries and Resources SA South Australian Research and Development Institute
Tasmania (TAS)	Tasmanian Aquaculture and Fisheries Institute Tasmanian Department of Primary Industries and Water
Victoria (VIC)	Department of Primary Industries
Western Australia (WA)	Department of Fisheries, Western Australia

8.2. Benchmark Summary

Figure 17 provides a summary of the scores for each jurisdiction as self-rated by the scientists, managers and co-investigators from those jurisdictions.

Bmark	Comm	NSW	NT	QLD	SA	TAS	VIC	WA
1	G	LG	LG	LG	G	LG	LG	G
2	LG	Y	LG	LG	G	Y	G	G
3	G	LG	LG	LG	G	G	LG	G
4	Y	Y	Y	Y	LG	Y	LG	Y
5	Y	Y	Y	Y	LG	LG	LG	LG
6	Y	Y	LG	LG	G	LG	Y	G
7	LG	LG	Y	G	G	LG	LG	LG
8	G	G	LG	LG	Y	LG	LG	G
9	G	LG	Y	Y	G	LG	G	G
10	G	Y	Y	LG	G	LR	LG	G
11	G	Y	LG	Y	G	LG	G	Y
12	LG	LG	G	LG	LG	G	G	G
13	LG	Y	Y	LG	G	LG	Y	LG
14	G	LG	G	LG	G	LG	G	LG
15	G	LG	Y	LG	G	LG	G	G
16	LG	Y	Y	LG	G	LG	LG	Y
17	G	G	G	LG	G	G	G	G
18	G	LG	G	LG	G	G	LG	G
19	G	LR	Y	LG	G	Y	LG	LG
20	N/A	G	G	LG	G	G	LG	G
21	LG	LG	Y	LG	LG	G	G	LG
22	LG	LG	G	Y	LG	LG	LG	LG
23	G	G	G	LG	G	G	G	G
24	N/A	R	G	LR	Y	N/A	LG	G
25	G	LG	LG	LG	G	LG	G	G

Legend:

R	Red	No evidence of policy
LR	Light Red	Some evidence of policy and partial implementation
Y	Yellow	Policy in place; evidence of implementation
LG	Light Green	Policy in place; evidence of substantial implementation
G	Green	Policy in place; evidence of full implementation

Figure 17. A summary of the benchmark scores for each of the jurisdictions. The benchmark numbers are associated with full descriptions in the following tables.

8.3. Responses to the Benchmarks

8.3.1. Benchmark 1

The risk management strategy fits within a broader management regime which includes clear objectives, indicators and performance targets.

Jurdn	Score	Justification
CTH	G	The risk management strategy for the Commonwealth is captured by two significant policies: the Commonwealth Fisheries Harvest Strategy Policy and its associated Guidelines; and Ecological Risk Management (ERM) framework. The first policy sets qualitative and quantitative objectives and reference points and presents an explicit process for controlling harvests of key commercial species under catch or effort to meet biological and economic performance targets. This policy applies to all Commonwealth fisheries, except those managed under multiple domestic jurisdictions or that have an acceptable alternative scientific process for determining international catch and effort. The second policy is focused on applying Ecological Risk Assessments (ERAs) in the risk management of all elements of fisheries including the broader impacts of fisheries on non-target species, habitats and ecosystems. There is research (see Benchmarks 9 – 10) that aims to put some of these ERA methods into the same performance-based framework as the HSP. It is recognised that it can be difficult to align indicators and reference points with prescribed performance targets/objectives for data poor fisheries.
NSW	LG	The Environmental Impact Statements (e.g. NSW Department of Primary Industries 2001; NSW Department of Primary Industries 2004a) included detailed risk assessment methods (Astles *et al.* 2006) which were applied during the development of the Fishery Management Strategies (FMS). At a more generic level an overall Resource Assessment Framework (Scandol 2004) was developed which outlines the NSW DPI's resource assessment objectives, indicators and targets (also see (Wild Fisheries Research Program 2006; Scandol *et al.* 2007). No Fishery Management Strategy was completed for the recreational fishery or the charter boat fishery and the FMS for the commercial fisheries are now somewhat out of date.
NT	LG	There are management plans for most fisheries with objectives, indicators, trigger points and management actions and there is accounting for recreational and Indigenous fisheries. Risk assessments are completed for all export fisheries as required. Annual status reports are undertaken for each fishery. A variety of methods and approaches are used though there appears to be no single documented framework that draws all the parts together.
QLD	LG	There are management arrangements for each export fishery that incorporate recreational species and include objectives, indicators and targets. Risk assessments are undertaken to prioritise issues for research and management for most export fisheries and recreational fisheries. A variety of methods and approaches are used (including varying levels of formality and documentation) though there is no single framework in place.
SA	G	There are management plans for each major fishery with objectives, indicators, targets and limits. A variety of assessment methods and management approaches are applied which are commensurate with the size and value of each fishery. Detailed stock assessments are undertaken regularly (every 1 – 3 years) for all major species. Catch, effort and catch rates are monitored for species with low catch, value or risk.
TAS	LG	There are management plans for each major fishery with objectives, indicators and targets, and rules for recreational fishing. Annual status reports are undertaken for each fishery and risk assessments have been completed for all export fisheries. Management objectives are reviewed every five years. A variety of methods and approaches are used though there is appears to be no single documented framework that draws all the parts

Jurdn	Score	Justification
		together. Some objectives could be better clarified.
VIC	LG	The Victorian *Fisheries Act* 1995 and associated regulations set the overarching regime for the sustainable management of Victorian fisheries, including clear management objectives. Sitting underneath this legislative framework, there are well articulated policies and specific structured management arrangements including Management Plans for many fisheries (e.g., rock lobster, eel, abalone, three recreational estuary finfish fisheries, giant crab and some inland recreational fisheries). Management arrangements for the larger bay and estuary finfish fisheries include planning for both the recreational and commercial sectors. Management Plans include objectives with associated strategies, actions, summary of information requirements, performance indicators, a schedule of actions and identification of the entity responsible for these actions. There are some gaps in these plans and allocation of fisheries resources among competing user/interest sectors is in most cases not explicit. The Management Plans use the concept of risk in various ways, including as a probability measure in quantitative contexts (Abalone Management Plan). There is an overall risk framework used to prioritise policy, compliance, research and management actions both within and between fisheries. Improvements to the implementation of this process are expected to come with further stakeholder consultation. The recent Fishery Status Report (Fisheries Victoria, 2008) provides a summary of the performance of each major fishery against targets.
WA	LG	Risk management is an integral part of the planning for research, management and compliance. All high value fisheries have management plans which identify the objectives, indicators and performance targets. All fisheries are being moved into the Integrated Fisheries Management Framework (IFM) – essentially an allocation policy between the commercial, recreational and Indigenous sectors. IFM reports have been completed for Rock Lobster and Abalone. Management plans for the smaller fisheries are in various stages of completion and implementation will be challenging for all fisheries.

8.3.2. Benchmark 2

The risks to harvested species are assessed using a formalised risk management system based on a recognised peer-reviewed framework (G1, G2).

Jurdn	Score	Justification
CTH	LG	All Commonwealth fisheries have been assessed using the ERAEF method. All fisheries were assessed at Level 1 (SICA) and target and bycatch species from key Commonwealth fisheries such as the Northern Prawn Fishery, (Stobutzki *et al.* 2001a; Stobutzki *et al.* 2001b) were subject to Level 2 (PSA) analyses (Smith *et al.* 2007b). Recently many of the same species have also been analysed with Level 3 assessments using the SAFE method (Zhou *et al.* 2007; Zhou *et al.* 2008; Zhou *et al.* in review). Additional Level 3 risk assessments include those undertaken with the quantitative stock assessments for quota species as well as ecosystem models (Atlantis, In Vitro and Ecosim for the SE and NW Australian ecosystems). There is a need to complete further analysis on some data poor fisheries (e.g., Coral Sea Fishery) should a suitable methodology be proven.
NSW	Y	A peer-reviewed risk framework (Astles *et al.* 2006) was used for the Environmental Impact Statements and the EIS's themselves were also peer-reviewed before finalisation. The Fishery Management Strategies integrated the results of the risk assessments into future plans for the fishery, but the risk assessments are not part of the ongoing resource assessment processes. Risk-based reasoning is used during discussions at the annual Resource Assessment Workshop (Wild Fisheries Research Program 2006) but these are not formalised (although they are well documented).
NT	LG	The management plans and environmental assessments make explicit reference to various

Jurdn	Score	Justification
		risk assessment frameworks including quantitative stock assessments. The National ESD Reporting Framework was used for snapper (with Queensland) and Aquarium Fishery risk assessments (Beatty 2008). Research presented in Stobutzki (2001b) and Milton (2001) was used in the assessment of Northern Australian sharks and rays (with Queensland). Some export risk assessments don't use a peer-reviewed framework but contain extensive information and analysis. A compliance-based risk assessment has been done for Spanish mackerel, mud crab and offshore snapper fisheries. There is no separate risk assessment for the recreational fishery, though the recreational catches are considered within the assessment of particular species.
QLD	LG	The management arrangements and environmental assessments make explicit reference to various risk assessment frameworks including quantitative stock assessments, and ERAs using the National ESD and ERAEF systems. The National ESD and Commonwealth ERAEF methods were tested against different fisheries and comparative notes developed. Not all harvested species have a risk assessment or specific management plan (e.g., bêche-de-mer).
SA	G	Each fishery has, or is, undergoing a risk assessment using the National ESD approach (e.g. Sloan 2006) although the detailed explanatory notes of these assessments have not been published. The SA *Fisheries Management Act* 2007 requires ecological risk assessment to be conducted as part of developing Management Plans. The National ESD risk assessment framework (Fletcher *et al.* 2002) is used to conduct these assessments and includes social and economic impact assessment.
TAS	Y	Export license risk assessments have been submitted for 10 fisheries and management plans have been prepared for all fisheries. The environmental assessments and management plans make explicit reference to various risk assessment frameworks including quantitative stock assessments. However there is no formal risk management system in place which requires a specific process to be applied. Risk assessments for the export fisheries do not appear to strictly adhere to one of the recognised peer-reviewed frameworks.
VIC	G	The risk assessments of Victorian fisheries, based upon the National ESD Reporting Framework, are undertaken by Fishery Management Advisory Teams (FMATs) to determine policy, compliance, research and management priorities within and across fisheries. Detailed ecological risk assessments (ERAs) have been undertaken for all significant fisheries, and those of concern). The results will be published by mid 2009.
WA	G	All commercial fisheries have been assessed using the National ESD Reporting Framework. The Framework is and based on the AS/NZS 4360 risk management standards. Copies of each report have been made available on the web.

8.3.3. Benchmark 3

There is a clear linkage between the legislative and policy objectives of an agency and the risk management system in place (G3).

Jurdn	Score	Justification
CTH	G	The FMA has an objective for the ecologically sustainable development (ESD) of Commonwealth fishery resources and all Commonwealth fisheries are subject to Part 10, 13 and 13A provisions within the *EBBC Act*. AFMA is committed to addressing the ecological component of ESD. This strategy is augmented with the Commonwealth Fisheries Harvest Strategy Policy (2007) (HSP) which incorporates the relevant requirements from the *Fisheries Management Act* 1991, the *Fisheries Administration Act* 1991 and the *EPBC Act* 1999 and provides for implementation of operational rules to set

Jurdn	Score	Justification
		catch and effort controls. Formal harvest strategies under the HSP have now been adopted for almost all Commonwealth fisheries, including for small and data poor fisheries.
NSW	LG	The Fishery Management Strategies and Environmental Impact Statements are based on requirements within the NSW *Fisheries Management Act* 1994, the NSW *Environmental Planning and Assessment Act* 1979 and the Commonwealth *EPBC Act* 1999 and contains policy objectives that are tied to the resource assessment system. The *Fisheries Management Act* refers directly to risk in terms of threatened species but does provide for risk management through FMS's, Share Management Plans and the Total Allowable Catch Committee.
NT	LG	The *Fisheries Act* 1988 contains clear policy objectives for sustainability of fish stocks, fisheries and marine ecosystems. Not all fisheries have management plans but those that don't have regulations in place to ensure sustainability. Endangered species are managed according to the *EPBC Act* (1999), and as listed under the *Territory Parks and Wildlife Conservation Act* (2001). The integration of the risk assessments into the management plans for mud crabs is underway.
QLD	LG	The *Fisheries Act* 1994 has a clear objective to sustain fishery resources with socio-economic benefits. Environmental assessments required for export approval have been done using either the National ESD or ERAEF approach. Quantitative risk analyses have been undertaken for key recreational and commercial species (e.g., pink snapper, Spanish mackerel, eastern king prawn, spanner crab, mullet, tailor) but no ERA has been applied to the whole recreational fishery (nor is this considered a good idea).
SA	G	The SA *Fisheries Management Act* 2007 has a clear objective for the ecological sustainable development of fisheries resources. Management plans must assess and address the risks of the fishery to the ecosystem including non-target species, and assess the risk of ecological factors that may impact the fishery. Management plans also include performance indicators and reference points to monitor the status of the fishery.
TAS	G	The *Living Marine Resources Management Act* 1995 (*LMRM Act*) permits the Minister to do what is required to sustain fishery resources with socio-economic benefits including the use of licences, management plans, TAC's, aquatic reserves and scientific surveys. The Act contains only broad objectives but the DPIW's policies are in line with these objectives. Five management plans have been implemented (for the Abalone, Giant Crab, Rock Lobster, Scalefish, Scallop fisheries) and draft management plans are for a number of minor fisheries with interim sets of rules (Commercial Dive and Jack Mackerel) and one set of general fisheries rules.
VIC	LG	There are very clear legislative and policy objectives for Victorian Fisheries which are operationalised in detail by a holistic risk-based approach that derives allocations of DPI resources and prioritises policy, compliance, management and research projects and services. Existing structured management will be updated using the outcomes of the risk assessments as appropriate.
WA	G	The "Policy for the Implementation of Ecologically Sustainable Development for Fisheries and Aquaculture within Western Australia" (Department of Fisheries 2002b) provides an explicit link between the legislative and policy frameworks in WA with the ESD Reporting Framework and the role of risk assessments within that framework.

8.3.4. Benchmark 4

The risk management system incorporates social and economic components (G1, G3).

Jurdn	Score	Justification
CTH	Y	Economic objectives are clearly identified within the *FMA* and social issues are captured within the principles of ESD. The HSP uses, where possible, B_{MEY} and F_{MEY} as target reference points. B_{MEY} is calculated explicitly in the Northern Prawn Fishery and some SESSF species, while proxies for B_{MEY} are used in the SESSF and several other fisheries in accordance with the HSP. Alternative economic indicators are required for data-poor fisheries. AFMA's Ecological Risk Management Framework does not include social and economic components by design. As the Commonwealth does not have jurisdiction over recreational fisheries, allocation issues are focused upon within sector rather between sector issues, though resource sharing is an important issue in the Eastern and Western Tuna and Billfish Fisheries. Collection of economic data is limited (ABARE conducts annual surveys for some fisheries). There is little formal inclusion of social components within the risk management system, nor current research.
NSW	Y	Social and economic components were included in the Environmental Impact Statements and the Management Advisory Committees capture socio-economic considerations. The socio-economic analyses that have been undertaken are not part of an ongoing formalised risk assessment process.
NT	Y	Legislation recognises the need for stakeholder rights to be taken into account but there is limited social and economic content in the assessments (as this was not required for export approval). Stakeholders including commercial, recreational and indigenous fishers and green groups have been included in decision making processes (MAC meetings) and recent Aquarium Fishery risk assessment workshop. There is a clear commitment to engage with stakeholders via management committees in the stock assessment and management planning processes. There is significant variation in this benchmark between fisheries.
QLD	Y	Legislation recognises the need for social and economic components to be taken into account but there is limited social and economic content in the assessments (as this was not required for export approval). The management advisory committees that provide advice to DPI&F on appropriate management arrangements are likely to capture socio-economic issues. There are good consultation processes in place for capturing social values. Limited work has been done to look at relative economic risks, though new programs are being considered.
SA	LG	Legislation recognises the need for social and economic components to be taken into account and there is some social and economic content in the export assessments (although this is not required for export approval). There is an annual economic assessment for each major fishery but no specific social data are collected – plans are underway to establish a program to collect and analyse social data. Management plans include socio-economic research priorities and some harvest strategies include social and economic objectives (e.g. Sloan 2005; Noell *et al.* 2006). The risk assessments being conducted as part of Management Plan development under the new Act are full ESD assessments (utilising the National ESD Reporting Framework developed by Fletcher *et al.* 2002).
TAS	Y	Maximising economic value or economic efficiency in the industry was deliberately left out of the objectives during the development of the *LMRM Act*. However, the Act allows for the facilitation of sustainable economic development. Socio-economic assessments are regarded as a research priority (DPIWE 2005b). A cost-benefit analysis is required whenever a change to a management plan is proposed to analyse the potential socio-economic impacts of regulatory changes (e.g., commercial dive fishery).
VIC	LG	Social and economic considerations are central to the management of fisheries in Victoria

Jurdn	Score	Justification
		under the 'Share, Secure, Grow' model, through which Fisheries Victoria implements the three principles of Ecologically Sustainable Development. The risk assessment framework explicitly considers socio-economic threats both posed by the fishery and to the fishery. It considers appropriate responses (policy, management, compliance, research) where warranted. In addition, structured management arrangements consider social and economic issues. Some fisheries – for example the Anderson Inlet Fisheries Reserve Management Plan (2006) – include specific strategies to maintain or enhance levels of satisfaction with recreational fishing opportunities, with an identified performance indicator. Rock Lobster and Giant Crab Fishery Management Plans indicate that performance management of the social and economic dimensions of the fishery will be further developed. There are restricted social and economic analysis of management options and a recognised need for more effective stakeholder input in the risk management system.
WA	Y	A draft policy exists for explicitly dealing with socio-economic issues and full implementation could require significant time and resources. A risk matrix is used for research prioritisation and this includes socio-economic components. Although the National ESD Reporting framework component trees contain elements for social and economic dimensions of fisheries these were not completed (as they were not required to meet *EPBCA* requirements). The ESD Reports do however include extensive reporting of the governance arrangements of each fishery and socio-economic performance indicators. Fishery management papers contain detailed reports on the social and economic dimensions of the fisheries.

8.3.5. Benchmark 5

The risk management system incorporates assessments based on the principles of Ecosystem Based Fisheries Management and harvest strategies that include performance indicators for monitoring biodiversity.

Jurdn	Score	Justification
CTH	G	AFMA pursues the ecological component of ESD (as an equivalent to EBFM) as its overarching framework for Commonwealth fisheries management (Department of Agriculture Fisheries and Forestry 2007). As noted in Benchmark #3, the ERMF is a key component in the implementation of ESD and includes bycatch and protected species management. Only Level 1 assessments have been undertaken for some data poor fisheries but the results have been used in multi-species fisheries to help identify a suite of key species to monitor within the harvest strategy. The AFMA observer program monitors discard rates in key fisheries. Some Level 3 risk assessments (such as results from Atlantis models) include indicators for biodiversity, and CSIRO has completed extensive modelling work on indicators for the ecosystem effects of fishing (Fulton *et al.* 2005a). Observer programs are limited in most small fisheries and the HSP focuses on target species.
NSW	Y	Ecotrophic modelling of NSW coastal waters has been conducted using Ecopath with Ecosim and CSIRO Atlantis model. Fishery Management Strategies do acknowledge the EBFM work (NSW Department of Primary Industries 2007) and in some cases state that no performance measure is available for the impact of fishing on biodiversity (NSW Department of Primary Industries 2003). An observer program is underway for the line fishery to better understand the diversity of sharks harvested in this fishery. Other programs exist within the NSW Government to monitor biodiversity (such as the Monitoring Evaluation and Reporting Program – which includes an aquatic component).
NT	Y	Issues such as discarding, provisioning and ghost fishing are dealt with by the ERA's and various research projects but there are no documented performance indicators for biodiversity. A qualitative performance indicator for identification of threatening

Jurdn	Score	Justification
		processes for ecosystems exists in various DEWHA reports (Department of Environment and Heritage 2004; Beatty 2008). An Ecopath model is being developed for the Gulf or Carpentaria and for Darwin Harbour.
QLD	Y	Issues such as discarding, provisioning and ghost fishing are dealt with by the ERAs and various research projects. A major recently completed collaborative research project (CSIRO, DPI&F, AIMS, Queensland Museum) has developed trawl fishery risk indicators for benthic communities of the Great Barrier Reef Region (Pitcher *et al.* 2007). These are being assessed by DPI&F for implementation for monitoring benthic biodiversity where considered achievable within resource constraints. A number of projects exist for ecosystem modelling (e.g., Barramundi dynamics have been modelled with Ecosim, also see Gribble (2001) and Pitcher *et al.* (1997)) and various habitat monitoring projects are underway. The Long Term Monitoring Program (LTMP) and observer programs are collecting byproduct and by-catch data.
SA	LG	Components of EBFM are in place including, ecotrophic modelling (sardine fishery), flexible environment-based multi-species management, performance indicators incorporating river flows (Sloan 2005), by-catch assessments and mitigating interactions with TEPS. Biodiversity objectives exist but there are no specific performance indicators that directly measure biodiversity, other than by-catch trend monitoring (e.g. Sloan 2005). There is currently no system to integrate all aspects of EBFM. Using a bioregional approach which accounts for all cumulative impacts would be a possible strategy.
TAS	LG	A review of the *LMRM Act* 1995 found no ecosystem-based objectives in the legislation (DPIWE 2005a). EBFM objectives are being incorporated into management strategies with issues such as discarding, by-catch, and TEPS are dealt with in the export RAs. An Ecosim model is under development. No evidence was found of quantitative indicators for biodiversity although the draft lobster plan has indicators for protected species.
VIC	LG	The Victorian risk assessment framework is based upon the ESD reporting framework and closely aligns with the key concepts and components of Ecosystem Based Fisheries Management. The ecological impacts associated with byproduct and discard species and interactions with TEPS has been the focus of ecological risk assessments – particularly for fisheries requiring *EPBC Act* certification. A bycatch and TEPS assessment has been undertaken for the giant crab fishery and as part of a broader ERA for the rock lobster fishery. The risk assessments, and *EPBC Act* assessments, have found that Victorian fisheries pose a low or minimal threat to biodiversity. As such explicit strategies to monitor “biodiversity” have not been implemented across the board. Impacts on biodiversity are regularly reviewed through the risk assessment cycle. Some Management Plans (e.g., the Mallacoota Inlet Fisheries Reserve Management Plan), specify the need for fish habitat assessment projects which will provide information on the habitat associations of both target species and fish of “biodiversity significance”. Interactions with threatened species are recorded as required under State and Commonwealth legislation.
WA	LG	All assessment reports made detailed reference to either the principles of ESD, EBM and EBFM. WA Department of Fisheries contains a research group dedicated to ecosystem and habitat research. Significant publications have been prepared for the general public and science/policy experts on these subjects. FRDC funded research on appropriate biodiversity indicators for some fisheries is underway (e.g., Gascoyne prawn fisheries). Monitoring programs are in place for composition of target species and for by-catch species in the lobster, trawl and scallop fisheries and recreational surveys (and the charter boat logbook) record all species harvested by anglers. Research surveys are studying differences in the biota between trawled and un-trawled areas. WA Department of Fisheries is currently leading a major study to assist in the implementation of EBFM as part of the WA Marine Science Institute (WAMSI). This includes the development of cost effective, fishery independent methods to survey biodiversity and fish community structure.

8.3.6. Benchmark 6

The geographical scope of risk assessments correspond to the distribution of species (through collaborative mechanisms where necessary) (G8).

Jurdn	Score	Justification
CTH	Y	Provisions exist for the establishment of joint authorities to manage shared stocks within the Australian Fishing Zone and a number of these exist (e.g., Joint Authority Northern Shark Fishery, Torres Strait Protected Zone Joint Authority). Australia is party to the UN Agreement on the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks as well as a member of several Regional Fisheries Management Organisations (CCSBT, CCAMLR). In general there are working relations between the Commonwealth and the Australian states, but the risk assessments are based upon fisheries, which are likely to have been defined by target stocks, fishing methods or the nuances of the Offshore Constitutional Settlement. More co-operation between jurisdictions is needed when quota reductions are required or complementary management arrangements need to be developed. Better approaches are required to deal with cumulative risks across fisheries.
NSW	Y	The *Fisheries Management Act* 1994 allows for joint authority with other jurisdictions for fisheries management. Collaborative resource assessments do exist with Commonwealth and Queensland but are not always updated frequently. NSW DPI sends representatives to various management and research forums for both Commonwealth and Queensland fisheries and there are joint projects with Queensland on spanner crabs, snapper and eastern king prawns. Commonwealth and Queensland representatives attend the annual Resource Assessment Workshops in Sydney.
NT	LG	The *Fisheries Act* 1988 allows for joint authority and a number exist with Commonwealth (NTFJA), WA, Qld and Indonesia e.g., Demersal fishery has management arrangements between NT, Qld and Indonesia and joint assessment with Timor Reef fishery. FRDC has funded a project on spatial distribution of snapper. Red snapper management currently uses precautionary TAC quota to allow for lack of Indonesian catch data. The Gulf fisheries also present significant challenges for assessment and management, particularly because of the recreational catches in NT and Queensland waters.
QLD	LG	The *Fisheries Act* 1994 allows for joint authorities and collaborative assessments do exist with the Commonwealth, NSW, NT, and PNG (e.g., Gulf of Carpentaria black-tip sharks, Torres Strait prawns, spanner crabs, tailor, sea mullet, Spanish mackerel). Joint assessment and monitoring programs have been undertaken for some species (e.g., spanner crabs, NE Queensland tiger prawns) and have been initiated for others (e.g., eastern king prawns, pink snapper, Gulf of Carpentaria red snapper and sea mullet). All risk assessments were undertaken on the management unit rather than the underlying stocks (i.e., based on fishery, not specifically risk to fish stock). Gaining adequate long term support for such projects from other jurisdictions can be challenging.
SA	G	The SA *Fisheries Management Act* 2007 allows for joint authority and some collaborative assessments exist with the Commonwealth, Victoria, Tasmania and WA (e.g., southern rock lobster, giant crab and abalone). Abalone stocks are assessed at a spatial scale appropriate for their life history.
TAS	LG	The *LMRM Act* 1995 allows for joint authority and collaborative assessments do exist with Commonwealth (under the Offshore Constitutional Settlement Agreements), SA and Victoria (e.g., lobsters, abalone, giant crabs). It has been acknowledged that species distribution in Tasmania is geographically diverse but all of the species-based performance indicators are Tasmania-wide. There is an increasing emphasis in spatial aspects of fisheries (particularly abalone).
VIC	Y	The *Fisheries Act* and OCS arrangements provide for single authority or joint authority management of fisheries that cross jurisdictional boundaries, and collaborative

Jurdn	Score	Justification
		assessments of some species/stocks do exist with the Commonwealth, Tasmania, NSW, and SA (e.g., giant crab, abalone). No joint assessments have been undertaken, noting there are few examples where this is required.
WA	G	Due to the large size of WA, most stocks are fully contained within WA. When cross-jurisdictional issues have been identified (such as mackerel and shark) then joint research projects and data collaboration efforts have been developed with NT and SA with the aim of having stock based assessments (e.g., FRDC1998/159 for mackerel). Cumulative impacts of multiple fisheries are being addressed through risk assessment, management by bioregions and, for some fisheries, through the EBFM and IFM frameworks.

8.3.7. Benchmark 7

Risk ratings that use quantitative methods to estimate likelihoods (such as mathematical modelling), clearly document all assumptions and incorporate uncertainties within the results (G4, G5).

Jurdn	Score	Justification
CTH	LG	There has been a move to implement Tier 1 and 2 assessments (the stock synthesis models) using the Stock Synthesis 2 framework for species taken in the SESSF. This is a well tested and documented environment and avoids the issues with specific hand-coded models for each fishery. Most assessments are subject to extensive sensitivity testing to model assumptions and data. There have been big improvements in getting inputs ready for assessment and processing outputs (such as graphs and tables). Fitting complex population models is an art (particularly the weighting of the likelihood and penalty functions) and there are trade-offs between re-evaluating the models versus maintaining consistency between years. Well-documented quantitative assessment methods are used in several other Commonwealth fisheries.
NSW	LG	The lobster, eastern king prawn and school prawn population models have been documented and are peer-reviewed. There is recognition that the abalone model is not as well documented as it could be, but the model is only one component of the assessment of this fishery. A number of quantitative assessments for data poor species have also been published (e.g. Stewart *et al.* 2005; e.g. Stewart *et al.* 2008).
NT	Y	The need for improved documentation of mathematical models was identified in the project interviews. A lot of analyses are performed in Excel spreadsheets and S+ scripts that are re-used. Systems could be better documented. There is a need to have the documentation better linked to the risk ratings.
QLD	G	Advanced modelling programs for stock assessment including extensive data standardisation, uncertainty analysis and management strategy evaluation. All stock assessments are detailed in reports that are externally peer-reviewed (e.g. Allen *et al.* 2006).
SA	G	Thorough documentation exists for all quantitative assessment models and standardised scripts are used to analyse catch and effort data (including calculation of most performance indicators and determination of any activated trigger points). All stock assessments explicitly consider levels of uncertainty. For some fisheries, such as sardines, a lower TACC is set to reduce stock risk and uncertainty associated with the harvest strategy.
TAS	LG	Most standard R scripts and models are documented – though it is acknowledged that there is some room for improvement. A backup copy of all assessment information and data are stored after each year's assessments so that analyses can be defended if required at a future date.

Jurdn	Score	Justification
VIC	LG	The quantitative risk analyses undertaken for the rock lobster and abalone stock assessments are well documented. Monte Carlo methods are used to estimate the quantitative uncertainties associated with model fitting and parameters (via Bayesian methods). It is unclear what consideration has been given to model structure uncertainty.
WA	LG	A variety of quantitative models are used in WA and documentation is improving. When resources are available, then more complete analyses are done (which better quantify the associated uncertainties). All surveys are documented and repeatable. Methods are kept simple and straight forward and unnecessary complexity is avoided.

8.3.8. Benchmark 8

Risk ratings that use qualitative analyses to estimate likelihoods clearly document the reasoning and assumptions behind all expert judgements employed (G4, G5).

Jurdn	Score	Justification
CTH	G	Risk assessments completed for the ERMF are extensively documented and most are now publicly available. Each element of the scoping and SICA analyses is justified on the basis of either published facts or expert opinion. Unlike most other ERA methods, there is explicit consideration of the confidence of a risk determination which facilitates the application of risk assessment for the prioritisation of research. The documentation of the ERMF is extremely thorough, though the full application of the method can be demanding.
NSW	G	EIS risk ratings are clearly documented in EIS (e.g. NSW Department of Primary Industries 2006) and Astles *et al.* (2006). Stock status determinations for all key commercial species are documented in the Resource Assessment Workshop notes, are available on an intranet and are published every second year in the Status of Fisheries Resources (e.g. Scandol *et al.* 2008).
NT	LG	The Snapper and Northern Australian sharks and rays risk assessment is well documented. The documentation for the mud crab and offshore snapper risk assessments provide detailed justification where appropriate. The documentation for the Aquarium Fishery risk assessment is not as extensive but this is because all the risks were found to be low. Many other export submissions don’t use a peer-reviewed RA method but contain extensive documentation.
QLD	LG	A number of detailed ecological assessments have been published for *EPBC Act* export requirements with well documented reasoning using ERAEF (Blue Swimmer Crab ERA 2007, East Coast Otter Trawl 2004, & East Coast Shark Fishery Assessment 2005) or NESDRF (Roelofs 2004b; Roelofs 2004a; Department of Primary Industries and Fisheries 2005; Snape 2005; Zeller *et al.* 2006). It is recognised that the documentation in some of the risk assessments could be improved and, in some cases, needs to be updated with new information available.
SA	Y	The ecological assessments completed and published for *EPBC Act* export requirements included well documented reasoning. However detailed notes on the reasoning and assumptions used in the assessments were not included in published versions. Future assessments of risk will incorporate transparent reporting/justification for likelihood and consequence ratings using the National ESD Reporting Framework (Fletcher *et al.* 2002).
TAS	LG	The export risk assessment submissions do not use a peer-reviewed RA method but do contain all the documentation regarding the risks to the ecological sustainability of each fishery.

Jurdn	Score	Justification
VIC	LG	The qualitative risk analyses undertaken for the fisheries document the justification for likelihood and consequence rankings with detailed risk assessment tables.
WA	G	All qualitative assessments have been fully documented with the reasoning described in detail. There are some concerns that the results maybe overly dependant on specific expertise that was available during the assessments (which has the potential to compromise repeatability).

8.3.9. Benchmark 9

The risk assessment has consistent cross-fishery estimates of the likelihood of adverse outcomes based upon available biological and ecological information (G4).

Jurdn	Score	Justification
CTH	G	The semi-quantitative nature of the Level 1 (SICA) and Level 2 (PSA) methods provides a good basis for consistent cross fishery estimates of likelihood. The fully quantitative Level 2.5 and Level 3 (SAFE) assessments should be fully consistent, though in practice these more complex methods will require expert judgements that will likely be encoded in the model structure and the parameters used.
NSW	LG	The EIS's were all developed by a single core group. However some inconsistencies in EIS risk ratings developed as the method evolved over the seven year period that EIS's were produced. There are some inconsistencies in the application of rules for stock status ratings that could be improved with more clearly defined rules (Wild Fisheries Research Program 2006).
NT	Y	An informal process exists for determining the type of assessment technique for determining the risk of current harvesting on stocks. As a general rule, an assessment model is built if reliable age-structured or catch rate data is available and risk based or weight-of-evidence approach used for some data-poor fisheries. Recognition of recreational and Indigenous sectors in reporting. Recreational surveys (using the NRFIS template) are being redone in 2009 but comprehensive Indigenous catch information was last compiled for the NRIFS in 2000/01 (DPIF&M 2006). A pilot study was undertaken in 2008 to assess methodology determining Indigenous catch for sharks, rays, barramundi and mud crab. Results are currently under review.
QLD	Y	An informal process exists for determining the type of assessment technique to use to determine the risk of current harvesting on stocks. As a general rule, an assessment model is built if reliable age-structured or catch rate data is available, otherwise either the ERAEF or National ESD methods are used. The quantitative assessments and ERAs are undertaken by discrete teams within DPI&F working collaboratively.
SA	G	Each fishery has been assessed, or is being assessed, using the National ESD Reporting Framework. Appropriate stock assessment techniques are used to determine the risk of current harvesting levels on stocks. Fishery-dependent information is collected for all species. Surveys are used to monitor absolute or relative abundance of several valuable species. Other fishery-independent data are collected for large fisheries. Stock assessment models are used for data integration where appropriate.
TAS	LG	Fishery Advisory Committees (FACs) assist in the progress of the management of the abalone, crustacean, scalefish, scallop and recreational fisheries. TAFI determines the type of assessment technique for evaluating the risk of current harvesting pressure on stocks. An assessment model is built if time and money permits and there is reliable catch rate data available otherwise the weight-of-evidence approach is used for data-poor fisheries. At present there is no overall cross-fishery risk assessments that use the same approach.

Jurdn	Score	Justification
VIC	G	There is both a within fishery and across fishery risk assessment process for Victorian fisheries based upon the National ESD Reporting Framework, which result in largely consistent cross-fishery estimates of likelihood. There is a recognised need for different expert teams to conduct each of the within fishery risk assessments. The required consistency is provided through detailed risk assessment guidelines documentation and result tables and oversight of the entire process by a single project leader.
WA	G	The risk assessments were completed in the most consistent manner feasible using the one methodology. There is good comparability of the risks of species by fishery. For example, there are consist risk ratings of scalefish between the demersal and trawl fisheries.

8.3.10. Benchmark 10

A program exists for continuing investment in research, development, training and implementation of risk-based approaches for the assessment of data-poor species (G5).

Jurdn	Score	Justification
CTH	G	AFMA, in partnership with CSIRO, have invested extensively in the development on ecological risk assessment methods and harvest strategies suitable for data-poor species. A MOU exists between AFMA and CSIRO for continued research on ERAs and up-dates scheduled every 3 – 5 years. Extensive investment was made in developing harvest strategies for data poor fisheries; but some challenges exist with respect to implementation and MSE-based reviews of such strategies. A new DAFF/BRS project “Reducing Uncertainty in Stock Status” will likely make use of level 2.5 ERA methods to infer fishing mortality rates and stock status, as well as develop and test other risk-based approaches to stock status. AFMA and CSIRO have engaged in training of both managers and some stakeholders in stock and risk assessment methods.
NSW	Y	A program exists for research and development on an assessment framework (Scandol 2004) and there are developments underway to improve the integration of risk ratings into the assessment program. There are no specific risk-based research programs currently underway with the exception of this project (which is lead by NSW DPI).
NT	Y	There is investment in the use of the National ESD Reporting Framework and other risk-based approaches for risk assessment but there are no current programs to increase the capacity in risk management (with the exception of this current project).
QLD	LG	Both the DPI&F teams responsible for ERA and quantitative stock assessments have training programs and have a key strategic role. The ERA team has trialled and documented a number of risk assessment methods. Some risk and stock assessment work appears to have only been partially completed as resources have been re-prioritised to other tasks.
SA	G	Units responsible for quantitative stock assessments are well resourced and have a long term role in the fishery. There is succession planning for human resources including the identification and development of staff with key skills. There is also investment in the development of qualitative risk assessments (e.g., partnerships on Pacific fisheries research). From a policy position, the National ESD Reporting Framework has been adopted as the standard tool for conducting risk assessment across all SA fisheries.
TAS	LR	Risk assessment training was undertaken by Rick Fletcher with a workshop for scallops. A number of TAFI scientists contributed to Commonwealth assessments and draft SICA reports for the Bass Strait Scallop Fishery. There are no current programs to increase the capacity in risk management or progress towards the implementation of a full risk management system.

Jurdn	Score	Justification
VIC	LG	The Risk-based Fisheries Resource Assessment Framework is an integral component of the planning process and is used to prioritise agency responses across policy, management, compliance and research. This process integrates the individual fishery risk assessments (completed by the FMATs) and therefore implicitly deals with the issues associated with data poor fisheries. Training and mentoring in the process is provided. Further training opportunities are given to staff to develop skills with these tools. Improving understanding of the framework and processes across the agency, in addition to risk-based prioritisation of projects and services strengthens the framework.
WA	G	The WA Department of Fisheries continues to be an international leader in the application of risk assessments for data-poor species and the key role of risk assessments is recognised by all staff. There are numerous “risk-champions” with the agency.

8.3.11. Benchmark 11

There is an explicit policy acknowledging the trade-off between the fisheries catch and cost of management (G6).

Jurdn	Score	Justification
CTH	G	The Commonwealth Fisheries Harvest Strategy Policy makes this trade-off extremely transparent. Cost-recovery objectives in the *FMA* provide an instrument for encouraging commercial fisheries to support a harvesting pressure commensurate with the value of the fishery. The Atlantis modelling in the SESSF has also examined these trade-offs. AFMA uses a prioritisation model for Research and Development that assess catch-risk-cost tradeoffs in both the MACs and AFMA Research Committee, see benchmark 15.
NSW	Y	The *Fisheries Management Act* 1994 allows for the cost of management to be recouped from fishers under the share management plan but catch levels are not tied to shareholdings except for the single-species lobster and abalone fisheries. The assessment framework (goal 3, section 2) does explicitly acknowledge the need for cost-effective assessment techniques for lower value fisheries and that the prioritisation system of research be based on a cost-benefit approach. The target resource assessment class for each species considers the cost of research, but this is not a formalised policy but rather a prioritisation process.
NT	LG	Management was initiated in NT with limited knowledge and so a precautionary approach was taken from the outset with limits imposed by licensing, quotas, access limits and input controls. As catch history and research improves these constraints have been reduced for some fisheries but resource limitations have resulted in the precautionary approach being maintained for many.
QLD	Y	There is an evolving hierarchy of assessment methods based on data availability which is linked to fishery value (e.g., East Coast Trawl Fishery Five Year Research Plan 2006 to 2011).
SA	G	The majority of management and assessment costs are paid by the industry in a cost-recovery co-management arrangement which has resulted in a very tight connection between catch value and cost of management. Industry is increasingly making choices between stable lower catches with less research expenditure or higher catches with higher management and research costs.
TAS	LG	A number of risk assessments make explicit reference to cost-recovery strategies (Revill 2006) and there is a recognised culture within DPIW to allow only precautionary catch levels when the funding for research is unavailable. Co-management strategies have been piloted with Giant Crab research levee and with industry involvement for pre-season data collection in the Scallop Fishery (Harrington *et al.* 2008).

Jurdn	Score	Justification
VIC	G	Full recovery of attributable costs for commercial fisheries and aquaculture has been implemented in Victoria. Through the cost recovery process, industry has a say in the level of investments to be made. This investment drives projects and services such as State assessments and compliance. The impact of reduced investment in the analysis of data or compliance risk is recognised during development of management arrangements, leading to a more conservative approach and usually reduced fisher catch. Some target reference points (e.g., abalone production) provide quantitative threshold risk ratings (which would result in conservative harvesting). For data-limited fisheries efforts are being made to develop low cost data collection methods (such as research angler diary programs), but there is an acknowledgement that information is always likely to be limited and harvest controls based on such information are likely to be less sophisticated and more conservative.
WA	Y	Resources available for research and management are closely linked to the GVP of each fishery and there is cost-recovery policy for the major fisheries. There is no explicit policy which links catch and cost of management, but the catches of data-poor fisheries are purposefully constrained. Resources are generally allocated to research and management in high risk situations.

8.3.12. Benchmark 12

Some fisheries are being managed in a "data-poor" state and this management strategy has been formally determined to have an acceptable risk (G7).

Jurdn	Score	Justification
CTH	LG	Some of the smaller fisheries including Lobster and Trochus, have been assessed as low risk through the ERA due to their small effort levels and evidence from analogous fisheries and species. However, the term "acceptable risk" is not used to describe the management of these fisheries. Most fisheries have some high risks associated with them that are being managed (such as latent effort). The requirements in relation to risk management contained in the HSP applies to many fisheries that are "data poor". Development of harvest strategies under the HSP for small fisheries includes novel suggestions such as "move on" provisions which reduce potential impacts resulting from discarding. Other spatial management strategies are also used, and a range of indicators and trigger levels have been defined. These fisheries have a commitment to collect more information in a low-cost manner. Harvest strategies for data poor fisheries will be evaluated formally under the RUSS project.
NSW	LG	The target resource assessment class provides an indication of which species are believed to be acceptably managed in a data poor state. However, a number of species have a stock status of "undefined" which is assumed to be the "data-poor" state (e.g., bigeyes, diamond fish) but there is little to differentiate such species on a risk-basis (though the relevant life-history issues are documented).
NT	G	There are fisheries being managed in a "data poor" state for which the assessment has suggested no further research is required (e.g., Aquarium Fishery, Trepang Fishery). Others are kept in an underutilised state until further information is gained (e.g., the Demersal Fishery).
QLD	LG	There are fisheries being managed in a "data poor" state for which the management strategy has suggested no further research is required (e.g., eel fishery, coral fishery, marine aquarium fishery). The coral and marine aquarium fisheries are particularly diverse (e.g., 600+ species) and have undergone formal vulnerability/sustainability/ecological risk assessments to specifically determine species at ecological risk and priority management issues (see Roelofs 2008b; Roelofs 2008a; see Roelofs *et al.* 2008a; Roelofs *et al.* 2008b). As a minimum all these fisheries have been

Jurdn	Score	Justification
		subject to environmental assessment and the issues of high priority have been identified for additional management and/or research. Various species have been identified to be at negligible risk from fisheries.
SA	LG	The co-management framework allows fisheries to be managed in a data poor state based on risk levels. Industry haves the opportunity to assess cost-benefits of conducting research. Secondary and tertiary species caught in the Marine Scalefish Fishery (e.g., sand crabs, mud cockles) are being managed in a data-poor state. For these species, catch and effort data are monitored annually with reference points in place to identify changes that may warrant investigation. The Lakes and Coorong Fishery is a data poor fishery with a low annual GVP (approx $4.5M). The Management Plan for this fishery (Sloan 2005) sets out a risk management framework and a strategic plan for conducting research and stock assessment to address key information gaps across the fishery and for specific species. This approach has proved effective and assisted the fishery to gain MSC certification.
TAS	G	A comprehensive study was published on the assessment and management of a data poor temperate reef species – banded morwong (Ziegler *et al.* 2006). This study provides excellent coverage of how and why these species should be managed in the current data poor state including minimum data requirements and appropriate performance indicators. Other small fisheries for sea urchins and periwinkles have been approved for export on the basis of very precautionary management strategies.
VIC	G	Examples of fisheries managed in this state include sea urchin and eels. With marine and estuarine finfish fisheries there is the recognition that some species are managed in a data-poor state (the phrase “data-limited” is used). The risk based fisheries assessment framework reviews these arrangements and determines risk rating. The approach is considered to be cost-effective in these circumstances.
WA	G	The Marine Aquarium Fishery has either low or negligible risks for the primary species even though knowledge of these species was incomplete. The management arrangements for this fishery involve constrained numbers of licences and operating conditions. A similar deliberately conservative management approach is being used in the northern developmental Blue Swimmer Crab Fishery.

8.3.13. Benchmark 13

The minimum standards for data identified in Guideline G8 are being met for all harvested species (G8).

Jurdn	Score	Justification
CTH	LG	CSIRO has extensive databases of the biological parameters for target and bycatch species. The Commonwealth logbook program provides spatially and temporally resolved information on fishing activity and various surveys (either fishery independent or observer surveys in lightly fished areas) provide additional insights into the distribution and abundance of many species. That said, the sheer geographical scope of the AFZ suggests that the minimum data standards would be unlikely to be met for all harvested species. For low GVP fisheries, there are often limited data and the logbook information may be spatially/temporally patchy. Furthermore some species are reported sporadically within multi-species fisheries, While the commitment to obtain and “bank” additional information (particularly on life history characteristics), was a common theme within the small fishery harvest strategies, this must be balanced against the cost of obtaining such information. Also note that Level 2 ERAEF analyses have not yet been conducted for all small scale fisheries.
NSW	Y	In 2006/07 there were 42 species in the "undefined" exploitation status where the target resource assessment class was greater than the current resource assessment class. This

Jurdn	Score	Justification
		status would, in most cases, be a result of a lack of minimum standards for data (e.g., angel sharks, bonito, dogfish, hairtail). However the number of species with and “undefined” status is continually being reduced and is down from 78 in 2001/02. There is a lack of credible reported recreational catch statistics for many of the less common species.
NT	Y	Advanced stock assessment models have been produced for a significant number of fisheries (which clearly require certain standards of data). Status reports demonstrate agencies awareness of minimum data standards (e.g., coastal line fishery, offshore net and line fishery). There is a lack of credible reported recreational catch statistics for many of the less common species and IUU fishing from foreign fleets is still a large concern for some species. More work needs to be done on shark identification and bycatch in barramundi fishery. Not all species have adequate life history information.
QLD	LG	Advanced stock assessment models have been produced for a significant number of fisheries/resources (these clearly require certain standards of data). For other species, information consistent with such minimum standards was presented within the risk analysis for deepwater finfish (White *et al.* 2002). Reef fish web guide and deepwater fish field guide have been developed to improve species identification by fishers. A field guide for shark species identification is being introduced progressively to key commercial fishers.
SA	G	The approach taken recognises that need for information is determined by level of risk. There are recognised gaps in biological information for some secondary and tertiary species, where the risk to the stock of current harvest levels has been evaluated as being low (Jones *et al.* 2005; Steer *et al.* 2005). Extensive data have been collected on major species to support detailed stock assessment. Recreational surveys, adopting the NRFIS method, are currently being replicated at a State level to provide up-to-date recreational catch statistics for assessment models.
TAS	LG	There does appear to be explicit recognition of the need for minimum data standards for each harvested species, though in the case of the target species, such information is usually available. There are a number of species caught in small quantities which would not meet the minimum standards for data outlined in G8. An analysis of the minimum data requirements for temperate reef species is provided in Ziegler *et al.* (2006).
VIC	Y	The minimum standards for data are available for the target species (e.g., rock lobster, snapper, King George whiting, bream, eels), but, with the exception of the rock lobster and giant crab fisheries, are not likely to be met for all minor target, byproduct and bycatch species (in either the recreational or commercial fisheries). Joint research with the Commonwealth is filling in many of these gaps for bycatch species in the Commonwealth-managed offshore commercial fisheries.
WA	LG	There is extensive biological information available for most target species. Biological information on bycatch species is extensive but the minimum standards identified in G8 are not met for all species.

8.3.14. Benchmark 14

Risk management systems make explicit reference to the precautionary approach or principle when interpreting uncertain likelihoods (G9).

Jurdn	Score	Justification
CTH	G	The objectives of the FMA make an explicit reference to the precautionary principle and this principle is exercised in at least two distinct ways with the risk management system. In the SICA and PSA analyses, the highest level of risk that is still regarded as plausible is

Jurdn	Score	Justification
		chosen and carried through in these analyses – the precautionary approach is inherently applied. In the HSP, there are both quantitative interpretations of precaution (e.g., requiring at least 90% probability of remaining above biomass limits, and a limit biomass of 20%) and qualitative where lower fishing pressure is applied with lower knowledge assessments (relative to high data assessments). Harvest strategies for small fisheries also use explicit strategies which are precautionary – such as significant area closures and limited access. They also have various response levels associated with triggers such that progressively more data and more complex analyses are required for higher levels of catch. These strategies reduce the risk of overfishing which may be associated with any changes or expansion of the fishery by requiring a concomitant increase in data and knowledge.
NSW	LG	The *Fisheries Management Act* 1994 makes reference to the precautionary approach in workings of the TAC committee. The Environmental Impacts Statements used risk methods that explicitly recognised the precautionary approach. The Resource Assessment Framework (Scandol 2004) provides an interpretation of the precautionary approach and its use in assessment work.
NT	G	The National ESD approach used for all DEWHA assessments takes a precautionary approach when interpreting uncertainty. Stock assessments include probability profiles to address uncertainties for some species, and best/worst case scenarios for others.
QLD	LG	The NESDRF and ERAEF approaches have been used for a number of environmental assessments. Both methods acknowledge that uncertainty increases risk and ERAEF includes a confidence score. The deepwater finfish assessment (White *et al.* 2002) includes a risk matrix that allows for uncertainty.
SA	G	Management plans require a precautionary approach to be used in setting catch or effort levels (e.g. Sloan 2005; Sloan *et al.* 2007) and have reference points set at precautionary levels (Sloan 2005; Noell *et al.* 2006). Explicit consideration of uncertainty is provided in all stock assessments.
TAS	LG	A review of the *LMRM Act* 1995 found no direct reference in the objectives to the precautionary principle or approach (including within the definition of sustainable development, though reference is made to avoiding adverse effects of [fishing] activities on the environment). The concept and application of precaution is, however, clearly used in various policy documents (e.g., Policy Document for the Tasmanian Commercial Dive Fishery). Other actions of DPIW and TAFI clearly demonstrate the application of the precautionary approach e.g., the size limit for the giant crab fishery is set at a conservative level (Revill 2006), and clam and oyster catch is limited to 10% of perceived biomass until a longer catch history is established. The application of precaution is therefore more through planning and implementation rather than formal risk assessment.
VIC	G	The guidelines for within-fishery risk assessments state that (step 4) "In situations where there is a lack of data to be able to determine what the risk is, it is best to be precautionary." Insufficient data elevated risk rankings in a number of fisheries during the recent fishery risk assessment process A precautionary approach has been cited as a significant determining factor in the development of a number of new or amended Victorian fisheries regulations due to commence in March 2009, for example elephant fish.
WA	LG	The assessment protocol examined all relevant combinations of likelihood and consequence for a potential outcome and took the result with the greatest plausible risk (which is consistent with the precautionary approach).

8.3.15. Benchmark 15

Research, monitoring and management tasks are prioritised using a risk-type approach (such as multi-criteria decision analysis). Priorities are determined based on input from research, management and stakeholders. (G10).

Jurdn	Score	Justification
CTH	G	AFMA has a Strategic Research Plan (AFMA 2005b), and has applied gap analysis to its research needs (AFMA 2005a). Identified research programs in the Strategic Research Plan include: fishery stocks and biology; ecosystem-based fisheries management; evaluation and development. Within the gap analysis, the potential need for a risk management system for business practices was identified. Research priorities for specific fisheries are developed in consultation with the stakeholder-based MACs for the major fisheries (which will often take advice from research subcommittees). The AFMA Research Committee evaluates research proposals against the Strategic Plan and now uses a formal catch-cost-risk trade-off to determine research priorities.
NSW	LG	Research tasks are prioritised primarily on the difference between the current and target resource assessment classes (which are determined by research). Research is also prioritised by the Management Advisory Committees, the Fisheries Research Advisory Body (FRAB) and by strategic management decisions (such as the need for an observer program or and improved logbook program).
NT	Y	Research priorities are determined by research and management advisory committees (MACs) containing stakeholders for priorities within a fishery. Management tasks are driven primarily by MAC determinations and by multiple trigger points that exist for each fishery. There are good prioritisation processes within fisheries but the cross fishery prioritisation could be improved. All demersal fisheries are managed as a unit.
QLD	LG	Risk assessments are conducted using, amongst other steps, workshops that involved researchers, managers, industry representatives and fishery stakeholders. Research and management priorities were identified from these processes. Ongoing priorities are determined by a steering committee which consists of DPI&F fisheries managers, staff from Assessment and Monitoring, and members of the assessment unit. MACs also contribute to the prioritisation of research. MACs also contribute to the prioritisation of research. There are also SAGs (Scientific Advisory Groups) which advise DPI&F on stock assessment priorities. Completing this benchmark at a strategic level across fisheries would result in a ‘green’ score.
SA	G	Risk analyses are conducted for each fishery to prioritise issues based on input from research, management and stakeholders.
TAS	LG	Fisheries Advisory Committees operate for the abalone, crustacean, scalefish, scallop and recreational fisheries. TasFRAB is a centralised body of stakeholders, managers and scientists that, along with a Research Assessment Group (RAG), helps prioritise and find funding for research and development. These committees prioritise the decisions on the basis of expert input, negotiation and consensus. Risk-type logics are therefore integrated into decision processes rather than being applied via technical methods.
VIC	G	The ‘Across Fishery Prioritisation Framework’ is a leading example of how the risk assessment under-taken at a fishery-level (by the FMATs) can be integrated to prioritise departmental responses for policy, management, research and compliance. The approach uses rankable measures to score issues on the basis of capacity, guiding principles, FMAT risk ranking and species/fishery value ranking. There is clear input into this process from researchers and managers. Further stakeholder involvement will occur in future risk assessments as the process is refined.
WA	G	Multi-criteria methods are used to prioritise stock assessments (of which the results of the risk assessments are a component). Advisory Committees are used to capture stakeholder

Jurdn	Score	Justification
		input for a range of fisheries. There is a very effective working relationship between the management and science groups.

8.3.16. Benchmark 16

Research is prioritised with the objective of reducing the excessive uncertainty associated with a likelihood identified during a risk assessment (G11).

Jurdn	Score	Justification
CTH	LG	Level 1, 2 and 3 analyses within the ERAEF framework provide a "confidence" flag which enables high risk results which are the result of an uncertain likelihood (or in the case of SICA, consequence) to be quickly identified. Such outputs provide a clear indication of what knowledge gaps need to be filled, and can be fed into the broader research prioritisation mechanisms used in Commonwealth fisheries. Specific examples include the establishment of the Chondrichthyan Technical Working Group, and the recent research into the identification of dogfish species in the Western Deepwater Trawl Fishery. The current focus of this approach is target species and the approach does not yet encompass all bycatch and byproduct species.
NSW	Y	Research is prioritised based on, among other considerations, the difference between target and current resource assessment class. This can be regarded as a means to reduce uncertainty to what has been deemed an acceptable level for each species. The best example is the objective of reducing uncertainties associated with the identification of shark species which is being addressed through an observer program and shark identification kit. The linkages between these decisions and the risk assessments can, however, be somewhat diffuse.
NT	Y	Risks due to information gaps have been identified for some species and research projects initiated (e.g., grey mackerel – FRDC Project 2005/010, and post-release survival analysis). Fisheries undertook a commissioned stock assessment of the Mud Crab fishery in 2004 following a number of trigger points being activated. Reliance on external funding may result in some immediate priorities not necessarily being addressed due to the relatively low GVP of NT fisheries. Outcomes from the ERAs have also been directly used to prioritise research.
QLD	LG	Research is prioritised by a steering committee that takes inputs from stakeholders, managers and assessment scientists (MACs / SAGs into QFIRAC – Queensland Fishing Industry Research Advisory Committee). Research to reduce key uncertainties is usually prioritised by this committee although it was acknowledged that prioritisation can be reactionary rather than pro-active. Outcomes from the risk assessments are available for integration into these processes. This could be undertaken in a more strategic manner to optimise outcomes.
SA	G	Research is generally prioritised by a co-management committee consisting of stakeholders, managers and assessment scientists. At a strategic level, this process is assisted by the State FRAB. Investment is linked to the value/risks of the fishery. The new Fisheries Council of SA is also involved in cross-fishery prioritisation or research and management. A review has been undertaken of compliance involving risk assessments for prioritisation of compliance resources (Sloan 2005).
TAS	LG	Research is prioritised for each fishery by a FAC with advice from the RAG although it is not through a formal risk prioritisation format. Research to reduce uncertainty is given importance in the 5 year research planning program. Uncertainty has been reduced recently in several fisheries (Ziegler *et al.* 2006; Gardner *et al.* 2007; Neira *et al.* 2008). This approach has yet to be fully implemented.

Jurdn	Score	Justification
VIC	LG	Research is prioritised along with other activities using the ‘Across Fishery Prioritisation Framework’ (which will include issues of high risk resulting from an uncertain likelihood). Also, in the management plans, key uncertainties (or information requirements) are identified and used to prioritise research. Projects may also be dependent on co-investment from industry of external funders which may not be aligned with priorities arising from the fishery risk assessments.
WA	Y	In the ESD reporting method, uncertainty is captured by selecting the highest plausible risk. The uncertainty associated with a likelihood in a risk assessment is not as well documented is it could be. The degree to which uncertainty resulted in the generation of a moderate or higher risk could be explicitly specified which could then assist identify situations where additional research may be of benefit. Or the management is increased such that the uncertainty no longer generates an unacceptable risk.

8.3.17. Benchmark 17

Simple fishery assessment methods (such as catch curves and standardised catch rates) are used to assist in the understanding of data-poor stocks (G12).

Jurdn	Score	Justification
CTH	G	Such methods are fundamental to SESSF Tier 3 (catch curves) and Tier 4 (standardised catch rates) control rules within the harvest strategy framework in the SESSF and are also used as examples in the HS Policy Guidelines. However, many Commonwealth data-poor fisheries are sub-tier 4 and even simple fishery assessment methods may not be feasible. This has necessitated the application of even simpler “assessments”. For example, at the first trigger level a suite of indicators is used including: logbook summaries/analyses; assimilating anecdotal evidence; and seeking expert consultation. At the second trigger level there is a commitment to collect the necessary data which will enable the implementation of a SESSF Tier 3 or 4 style of assessment. The range of trigger levels is a key strategy in the HS for such fisheries.
NSW	G	Simple fishery assessment methods such as catch curve analysis have been adopted for a number of species (e.g. Silberschneider *et al.* 2005; Stewart *et al.* 2005; e.g. Stewart *et al.* 2008). Extensive software has been developed to visualise and report upon the length and age statistics of commercial landings (and these systems are being extended to other sources of data).
NT	G	Fishery status report and management trigger points are tied closely to catch and effort trends (including recreational sector). Both simple and complex model-based methods are applied by the assessment unit to each of the fisheries. There has been successful use of stock reduction analysis, length frequency analysis and yield-per-recruit analysis (e.g., Mud Crab, Demersal and Finfish Trawl fisheries).
QLD	LG	Both simple and complex model-based methods are applied by the assessment unit to the more data-rich species (e.g., Allen, 2006 #210; O’Neill, 2005 #218; Roelofs, 2004 #197}. White and Sumpton (2002) compiled key biological information for data poor species within the Deep Water Line Fishery assessment but this was interpreted as a risk rather than stock assessment. As the focus for the assessment group is comprehensive assessments, partial analyses appear to have a lower priority.
SA	G	There is extensive use of simple assessment methods such as yield per recruit (e.g., rock lobster fishery), standardised CPUE analysis (e.g., abalone), catch-curve and age-structure analysis (e.g., garfish) in data- poor and data-rich fisheries. Reference points for these performance indicators have been established (e.g. Sloan 2005; Noell *et al.* 2006; e.g. Sloan *et al.* 2007).

Jurdn	Score	Justification
TAS	G	Standardised catch rate analysis, age composition analysis, modelling of length frequency distributions by area (Ziegler *et al.* 2008), recruitment strength and simple evaluations of alternative harvest strategies (Gardner *et al.* 2007) are used.
VIC	G	Monitoring and assessment of marine and estuarine finfish fisheries (recreational and commercial) has involved extensive use of simple fishery and stock indicators (such as catch rates, size/age composition data and recruitment indices for key target species from research angler diary programs). Due to the highly variable recruitment and subsequent variable size/age structure in such fisheries, certain simple assessment methods (such as catch curve analysis of mortality) are applied cautiously. Size at age, trends and patterns in age composition (i.e., to infer recruitment) and fishery independent data are also used where the cost can be justified.
WA	G	Such methods were used extensively in Wise *et al.* (2007) which was one of the key documents leading to the recent reform in the Demersal Scalefish Fishery. Beche-de-mer Fishery MSY estimated with a logistic growth model.

8.3.18. Benchmark 18

Novel assessment methods that estimate the likelihood of populations being harvested at unsustainable rates are being developed and/or implemented (G13).

Jurdn	Score	Justification
CTH	G	The SAFE method (Zhou *et al.* 2007; Zhou *et al.* 2008) provides a novel strategy to compare the current fishing mortality rate against F_{MSY}. The method uses spatial information in datasets to estimate mortality instead of the usual temporal information. CSIRO has implemented MSE approaches for a range of major Commonwealth fisheries and has extensively tested the control rules in the HSP. However these systems are not necessarily applicable, possible and/or cost-effective for all data-poor fisheries.
NSW	LG	Novel approaches include EBFM modelling using Ecosim and CSIRO Atlantis model, and Bayesian analysis with model structure uncertainty (Ives *et al.* 2007), use of quality control statistics (Scandol 2003b; Scandol 2005) and productive collaborations with the UBC Fisheries Center (Forrest *et al.* 2008).
NT	G	Using geospatial statistics and fuzzy logic rule-based modelling for Demersal fishery (FRDC project 2005/047). FRDC supported the “GeneTag hook” project for Spanish mackerel. Fisher’s catch records are also being validated against buyer data. There is also a pilot GPS data logger project and a review of the research and development strategy is being considered.
QLD	LG	Stochastic stock reduction analysis has been done for pink snapper and tailor. The prawn assessments for the southern Queensland and Torres Straight have included model structure uncertainty and quantitative risk analysis. The assessment group is developing better algorithms and procedures for fitting models to data, but there doesn’t appear to be research aimed at data-poor species (or linkages to ERA methods) in particular. In-kind support exists for student research into the application of novel (quantitative) assessment methods.
SA	G	There is significant research and development of novel assessment methods for the commercial fisheries. These include the use of a continuous underway egg sampler in the application of the Daily Egg Production Method (DEPM) for sardines and new diver-based survey methods to estimate the absolute biomass of abalone stocks adjacent to Cowell in western Spencer Gulf.
TAS	G	TAFI is devising technological solutions for gathering data such as the automated

Jurdn	Score	Justification
		methods to count scallops and novel methods to improve the estimation of catch rates within the abalone fishery at small spatial scales. Other research includes micro-wire tagging of lobsters, micro-chemical analysis of octopus populations, and analyses on population mixing and habitat use by calamari.
VIC	LG	The Research Angler Diary Program is a novel low cost approach to monitoring the state of key target fish species in small recreational-only fisheries. Extensive new work has been done in collaboration with the Commonwealth to measure relative abundance of target, bycatch and byproduct species in the Commonwealth-managed SESSF (Walker *et al.* 2007) and to measure key parameters for a number of elasmobranch species (FRDC Project).
WA	G	There are a number of novel assessment methods being undertaken in WA including video monitoring, experimentation with BUVs (baited underwater videos), aging without otoliths and a research angler program.

8.3.19. Benchmark 19

Harvest strategy frameworks with explicit decision rules have been implemented. Harvest strategies must contain a process for monitoring and conducting assessments of the biological and economic conditions of the fishery, and rules that control the intensity of fishing activity according to the biological and economic conditions of the fishery (as defined by the assessment) (G14).

Jurdn	Score	Justification
CTH	G	The HSP is the most extensive implementation of such an approach currently in Australia. Extensions to small scale fisheries will address gaps for species caught in small quantities. The Commonwealth acknowledges the challenges of such an approach for multi-species fisheries and fisheries where a significant fraction of harvest is taken by another jurisdiction or another sector, as well as for International fisheries where HS policy is not formally required to be adopted.
NSW	LR	Fisheries Management Strategies do include processes for monitoring and assessment as well as a comprehensive set of rules to control fishing intensity. However, performance reports that outline the harvest strategy implementation are overdue for most fisheries. There is a regulatory requirement that overfished species are subject to a Recovery Program (such as been developed for sea garfish (NSW DPI 2005), but the program for mulloway has not been completed. Limited data are collected on the economic conditions of the fisheries.
NT	Y	The management trigger point system outlined for each fishery in the annual status report represents a version of the harvest strategy framework. The systems include processes for monitoring and assessment as well as a comprehensive set of rules to control fishing intensity. Economic trigger points exist although only limited data appears to be collected on the economic conditions of the fisheries.
QLD	LG	Harvest control rules have been developed and applied to spanner crabs and stout whiting. These rules have been tested with simulation modelling and are robust to key assumptions. Various other trigger points have been developed for data-poor species (e.g., sea cucumbers) and most have procedural responses such as reviews that may lead to strict harvest control rules being developed.
SA	G	Harvest strategy frameworks exist in most management plans with biological and economic considerations and explicit decision rules that account for both biological conditions and economic certainty. Many of the harvest strategies for the smaller fisheries have reference (or trigger) points based upon significant shifts in catch effort and/or catch

Jurdn	Score	Justification
		rates (e.g. Sloan 2005; Noell *et al.* 2006; Sloan *et al.* 2007).
TAS	Y	Fishery management plans include processes for monitoring and assessment as well as a comprehensive set of rules to control fishing intensity. This represents a version of a harvest strategy framework. DPIW is currently developing performance measures and a harvest strategy for rock lobster, abalone and giant crab (DPIWE 2007). Such rules will only be applied in the major fisheries. Novel harvest strategy methods (using a pre-season test fishery) are being piloted in the scallop fishery and this approach may be extended to the Commonwealth scallop fishery.
VIC	LG	Such frameworks have been applied qualitatively for data-poor species/fisheries, where once a trigger point has been activated then review processes are initiated using a 'multiple lines of investigation' approach. Management Plans and other documents for the marine and estuarine finfish fisheries indicate an intention to develop appropriate indicators (often recruitment related) and reference points. For the larger quota managed commercial fisheries (such as rock lobster and abalone), TACC setting process are responsive to the annual stock assessments and the economic conditions of the fishery. These plan have, or are developing, explicit decision rules.
WA	LG	The performance management system has clear coded guidelines about whether stocks are under excessive pressure (indicated by F), but explicit harvest control rules are not in place for most fisheries. The use of such rules is being expanded (e.g., abalone, pearling, western rock lobster) on a case by case basis. The trigger point system used in the abalone fishery seems to be working well.

8.3.20. Benchmark 20

There is explicit acknowledgement that a "weight-of-evidence" approach can be used for scientific determinations of resource status (G15).

Jurdn	Score	Justification
CTH	N/A	AFMA has made a conscious decision to move away from the weight-of-evidence approach as they found it created too much continual debate amongst stakeholders. Unlike many of the states, the Commonwealth no longer uses this approach for scientific determinations of resource status. Tier 1 and tier 2 assessments are fully quantitative and synthesise available information in a population model, whilst Tiers 3 and 4 isolate credible sources of information and apply a control rule to that information to generate a recommended biological catch. The HSP was developed to provide additional quantitative certainty to government and industry about harvest policies and interpretation of data, therefore a "weight-of-evidence" approach could be interpreted as a weaker (and more easily distorted) form of inference, particularly when TACs are required. That said, the components of evidence that constitute a Level 1 (SICA) or 2 (PSA) risk assessment are comparable to the information used in other weight-of-evidence assessments, and harvest strategies for small fisheries are broadly based.
NSW	G	The stock status determination is based on the "weight-of-evidence" approach in an RAW forum of experts.
NT	G	The mud crab assessment is an excellent example of employing the "weight-of-evidence" approach to analyse stock risk (Haddon *et al.* 2004).
QLD	LG	Stock assessments appear to pool data from many sources into a single complex analysis though there is a still a focus on quantitative determination of resource status using model-based assessments. There is no 'stock status' approach in place at present (currently being developed) but an alternative 'performance measurement system' is being used. A 'stock status' approach is under development for public reporting purposes,

Jurdn	Score	Justification
		taking into account the characteristics of systems implemented for NSW and Commonwealth fisheries resources.
SA	G	The weight-of-evidence approach is explicitly employed in all stock assessments. The suite of performance indicators in management plans used to monitor the sustainability of each stock also demonstrates this approach. For example, all recent abalone stock assessments refer to 'lines of evidence' for determining resource status (Mayfield *et al.* 2006).
TAS	G	The weight-of-evidence strategy is the explicitly recommended approach for data-poor multi-species scalefish fishery (Ziegler *et al.* 2006).
VIC	LG	Qualitative factors are used to substantiate stock status and risk in determining or reviewing management arrangements for marine and estuarine finfish fisheries. Such factors informed decisions to increase the size limit for recreational and commercial black bream fishing in the Gippsland Lakes in 2003, and to introduce stricter size and recreational catch limits for snapper in 2007. The periodic stock/fishery status reports for marine and estuarine finfish fisheries use weight of evidence approaches but they do not report upon all of the data-poor species.
WA	G	WA Dept of Fisheries has made significant progress in the application of this approach (e.g. Wise *et al.* 2007). This is used predominantly in the cases of data poor species.

8.3.21. Benchmark 21

Risk-based project management practices are applied to stock assessments (G16).

Jurdn	Score	Justification
CTH	LG	Processes for improving the efficiency of stock assessments have improved but there are still gaps in these processes with respect to data and publication management. Introduction of the multi-tiered approach has provided greater structure for what needs to be done. The shift to SS2 in the SESSF has simplified source control issues. Much of the input data are extremely heterogeneous being from different jurisdictions and computer systems (and often supplied by different data managers). This has an associated cost with the extract, transform and load processes. Information and code silos still exist.
NSW	LG	Research projects are centrally managed using customised project management software (to be migrated to Clarify). Lobster, abalone and prawn models all verified, and most published in peer-reviewed journals. Models are tested against zero catch and simulated data. A number of information silos still exist but these are being slowly addressed.
NT	Y	A validation system is used for modelling and internal reviews are undertaken. There is a good use of external expertise and consultants where appropriate. There is a centralised database with catch/effort with designated database manager. Process documentation could be improved. No structured project management policy is in place for stock assessments.
QLD	LG	Various quality control procedures are in place to maintain the quality of outputs, for example: comparing the output of models built in more than one software tool; multiple model structure checks; and multiple data sources including fishery independent data. There is internal peer review of code and external review of models as well as data quality checks. No structured project management policy is in place for stock assessments. There are some concerns as to the vulnerability of the process if key personnel left.
SA	LG	Various quality assurance procedures are in place to maintain the quality of outputs, e.g., there are mechanisms for validating data, checking all calculations (two independent analyses), running new models using old data and internal/external peer review of reports.

Jurdn	Score	Justification
		These processes are continuously being refined.
TAS	G	Models are often built in two separate software packages to test model validity and the models are peer reviewed in-house. A project has been undertaken to standardise data gathering processes to improve repeatability.
VIC	G	The regularly completed stock assessments for abalone and rock lobster have well established procedures for testing computer code and model outputs. The rock lobster model is peer-reviewed and as a general rule multiple scientists work together on each assessment. Calculations for catch rates use standardised scripts. There is recognition that a great deal of knowledge is held by key staff members and that loss of personnel would create transition challenges.
WA	LG	Documented quality control processes for data collection (e.g., the exploitation experiment) and assessments. External reviewers are used to assess models and assessments (either Australian or international). Test models are built in alternative packages, sensitivity analysis and zero-catch simulations are used. A more formal project management system is being introduced. Issues have been identified with respect to retaining expertise and the reliance on industry dependent data. There is a human resources strategy in place to help manage staff turnover.

8.3.22. Benchmark 22

The efficiency of the workflows associated with stock assessment has been improved by adopting appropriate technologies (G17).

Jurdn	Score	Justification
CTH	LG	Electronic logbook processes at AFMA are likely to improve the efficiency of data collection and entry in the long term. AFMA has some particularly sophisticated reporting software from their data warehouse (Hyperion). However, there still appear to be electronic communication issues and delays between the major institutions (including state fisheries) and email is still the dominant method of exchanging data. AFMA is aware of these issues and is investing in improved systems.
NSW	LG	Data management has been identified as a critical process bottleneck. Most data now resides in a managed central database. Standardised R/S scripts are being developed to improve speed and consistency of basic assessment work. Stock status information is generated using standardised SQL stored procedures and R/S scripts. Software standards have been set although not totally adhered to. An novel intranet (RAS or the resource assessment system, ref has been developed to facilitate the communication of information around the department and the standardisation imposed generated significant efficiencies when preparing the Status of Fisheries Resources Report (Scandol *et al.* 2008).
NT	G	Use a centralised database for catch and effort data and Oracle Discoverer for canned reports and data extraction/analysis. There is an acknowledgement that some data silos can be created by the use of technologies such as Excel. Data can be mobilised for any external stock assessment work that may be commissioned.
QLD	Y	Developments are underway to improve access by assessment scientists to centralized data from both commercial and recreational fisheries together with extensive fishery independent data collected by Queensland DPI&F. Excellent GIS capability exists within the Department.
SA	LG	Centralised Oracle database with a good system for extracting data and producing reports with standard and one-off queries developed by Oracle programmers. Performance indicators for some fisheries run using automated scripts. There is a Technologies

Jurdn	Score	Justification
		Committee of the Fisheries Council which will provide additional direction. Some research data are still isolated in Access and Excel files.
TAS	LG	Standard R scripts are used for the basic trend analysis. An Excel front end was developed for AD Model Builder but needs to be made more accessible. Access to commercial data needs to be more standardised and automated. A good database structure for recreational survey data allows matching down to individual fishers. Some recreational licence information is now entered online and renewals are tracked through a client identifier.
VIC	LG	Centralised databases have improved the efficiency and accuracy of commercial catch and effort reporting (including standardisation), but there is recognition that improvements can be made to accelerate the organisation of available commercial and/or recreational fishery and research information for assessments. IVR is being used in commercial rock lobster fishery catch and effort reporting and this approach may be applicable to other commercial fisheries. VMS and data loggers provide an opportunity to collect real-time data on catch and catch rates. Fisheries Victoria is currently undertaking a significant project to improve data collection and management practices associated with the recreational fisheries.
WA	LG	Data management has been identified as an issue for workflow efficiency. Reforms to data management systems are mostly complete though some data and information silos continue to exist. Improved reporting systems are also being developed and new data sources are being explored e.g., VMS. There is a move to daily log books for some data poor fisheries in order to solicit more information.

8.3.23. Benchmark 23

Recent decisions have been taken that manage risk by reducing the likelihood of an outcome (G18).

Jurdn	Score	Justification
CTH	G	Application of the harvest control rules with the HSP to generate a RBC is an example of managing risk by reducing the likelihood of overfishing. A Priority List of high risk and any identified protected (TEP) species will focus the Ecological Risk Management Strategy for each fishery. Other examples of recent decisions to manage risk include by-catch management plans, spatial closures and strategies to reduce impacts on TEP species.
NSW	G	The increase in shark catches in the line fishery has resulted in new competitive quota system being developed and implemented.
NT	G	Seasonal closure introduced in Mary River system for barramundi; voluntary buy-back of licences from the Coastal Net Fishery; 2006 increased size limits and penalties for mud crabs; compliance risk assessment for Spanish mackerel, mud crab and offshore snapper fisheries.
QLD	LG	The East Coast Beche-de-mer Fishery is managed through temporal and spatial closures (rotational zoning) to reduce risk based on analysis of declining stocks. The spanner crab TAC is reviewed biennially, with decision rules based on a risk assessment which includes economic considerations (such as the stability of the fishery).
SA	G	Catch levels were reduced in the Central Zone Blacklip Abalone and Northern Rock Lobster fisheries in response to consistently declining catch rates and/or biomass estimates. A change in minimum legal size for King George Whiting was introduced because of concerns about sustainability.
TAS	G	Catch quotas were reduced in response to recent declines in surveyed abundance in scallop fishery. Extensive preparatory biosecurity measures are in place in case of an

Jurdn	Score	Justification
		outbreak of the abalone disease that causes ganglioneuritis (including banning the use of abalone offal for trap bait). Spawning closures for striped trumpeter were introduced on the basis of a risk-type assessment.
VIC	G	The most thorough example of risk management is Fisheries Victoria’s response to the disease that causes ganglioneuritis in abalone, where extensive controls have been put in place to prevent the spread of the disease and enhance the recovery of affected populations. The recent increase in the minimum size limit for black bream in the Gippsland Lakes is another good example.
WA	G	The additional controls on the demersal scalefish fishery (for both the commercial and recreational sectors) are excellent examples of the effective application of risk management to fisheries. Publicly available documentation makes it clear that additional controls are required to reduce the risk to “high risk” species.

8.3.24. Benchmark 24

In a multi-species fishery, active management of indicator species is used as a strategy to protect weaker stocks (G20).

Jurdn	Score	Justification
CTH	N/A	The Commonwealth does not have an explicit policy on the use of indicator species, though for most of the multi-species data-poor fisheries, a representative range of indicator species was chosen for monitoring, which embraced the main target species (where applicable) and those considered at high risk from the results of the ERA and therefore being more likely to limit the fishing activity. Furthermore, the HSP recognises issues associated with the biodiversity-productivity trade off (s5.4) and notes that the biomass of all harvested species in a multi-species fishery must be above BLIM. This will have the same effect as an indicator species unless selectivity can be improved for the stronger stocks.
NSW	R	The EIS’s identify high risk species and performance goals exist in the FMS's of multi-species fisheries that include management of threatened species. There are, however, no management strategies that are primarily determined by the status of indicator species.
NT	G	Multi-species trigger points use a number of prominent “indicator” species (e.g., red snapper indicator for Finfish Trawl Fishery even though saddletail snapper catch is much higher, goldband snapper is also considered as an indicator species). There are also trigger points for bycatch and byproduct catches but only relating to total catch rather than “indicator” bycatch/byproduct species. This “indicator species” strategy is being explored for other fisheries.
QLD	LR	Conceptually there is support for the most at-risk species within a group of similar species acting as a surrogate indicator species for risk assessment purposes. This approach is being extended to management of higher risk species in Qld commercial shark fisheries, but has had limited application to other species. Fishery observer and long term monitoring programs are collecting data in major fisheries and analyses undertaken with a view to identify potential future indicator species (Roelofs 2004b). However, the complex tropical ecosystems and multi-species and multi-sectoral fisheries in Queensland waters may not lend themselves readily to this approach.
SA	Y	The indicator species approach has been used extensively in SA for multi species fisheries such as the marine scalefish and Lakes and Coorong fisheries (Sloan 2005; Noell *et al.* 2006). Catch, effort and catch rates of secondary species are monitored annually. By-catch surveys have been or are being undertaken in all major fisheries to support by-catch risk assessment.

Jurdn	Score	Justification
TAS	R	This was not regarded as a good idea by TAFI scientists and DPIW managers consulted during the guidelines workshop. In multi-species fisheries, such as the Scalefish Fishery, key species monitored are mainly based on historical catch and effort data – which is deemed appropriate. No specific indicator species have been identified to date.
VIC	LG	Resources are generally focused on the key target species. The most likely application of such a strategy would be in some marine and estuarine finfish fisheries. At present the management of these fisheries is focused on the target species as they are considered to be at highest risk from the fishery, therefore this approach is being applied by default. If new information were to indicate otherwise, a change of active management to an appropriate indicator species would be considered.
WA	G	Newman *et al.* (2001) provides an example where a species at higher risk is used as an indicator species within the management of a fishery. Indicator species used to manage the Metropolitan fishery and in the Pilbara region where species are caught by multiple fisheries. All bioregions have indicator species identified.

8.3.25. Benchmark 25

Managers acknowledge the issues associated with data-poor fisheries, and have strategies for effective administration of decision-making processes* e.g., *legislated decision-making processes that capture and deliberate on all relevant issues; consultative and co-management processes (G21).

Jurdn	Score	Justification
CTH	G	Both the HSP and the extensions for small fisheries recognise that a formalised management framework (with established responses) that has agreement from key stakeholders is an effective strategy for managing in a data-poor environment. AFMA has a range of consultative structures in place to ensure technical, industry, environmental and managerial concerns are captured in decision-making processes. Although it must be acknowledged that low GVP fisheries generally lack sufficient funding for complex implementation and review processes.
NSW	LG	All commercial fisheries have Management Advisory Committees which provide linkages between research, management, industry and other stakeholders. These processes should be able to capture and act upon key socio-economic issues which may compromise decisions in a data-poor environment.
NT	LG	There was an identified need to be more pro-active on identifying potentially controversial social issues to avoid “fire-fighting”. Recognised need for better alignment of research with management and policy needs, so that more research devoted to identified risks and controversial social issues.
QLD	LG	The Department is developing a hierarchy of assessment requirements for managing with varying levels of data. Managers understand the issues with data-poor systems and consult widely with research and industry before developing significant new management responses. All fisheries have MACs which provide a mechanism for industry input. Recent consultation for the management plan for the East Coast Inshore Fin Fish Fishery was particularly thorough.
SA	G	Levels of data collection and stock assessment are matched to catch levels and risks to stocks. SA is committed to a co-management and partnership approach to management of fisheries. SA is probably the most progressive in Australia in relation to this approach. Appropriate stakeholder representation and robust decision-making processes aim to develop consensus strategies for the development of fishery resources, including data-poor fisheries. Management plans for each fishery contain a suite of performance

Jurdn	Score	Justification
		indicators designed to identify any significant issues in the fisheries in a timely manner. The SA *Fisheries Management Act* 2007 establishes the Fisheries Council of SA. The Council is established as a high level expertise based advisory body for the Minister on fisheries management issues. The council includes membership from all key stakeholder groups.
TAS	LG	Managers understand the issues with data-poor systems and consult widely with research and industry before significant changes to policy or management. Flexibility in the current management system has benefits for data-poor species and the current arrangements with TAFI are recognised to be effective. A cost-benefit analysis is required whenever a change to a management plan is proposed. Co-management strategies are being developed with the scallop fishery (Harrington *et al.* 2008).
VIC	G	The existing structured management arrangements are a very transparent instrument that document the objectives, strategies and performance measures for the management of either a key fishery species or an area of water. These plans have been developed in collaboration with key stakeholders and in accordance with planning processes specified in the *Fisheries Act* (including extensive public consultation). The fact that these plans have been extended to some recreational fisheries is a concrete example of the flexibility and effectiveness of such planning processes for aquatic resource management. Decisions made on the management of the fisheries use a 'multiple lines of evidence' approach. This process incorporates all relevant qualitative and quantitative data (environmental, social and economic) and includes 'fit for purpose' consultative arrangements. Delegation of responsibilities through a formal co-management approach is being explored. At present co-management is restricted to consultative management.
WA	G	Although there are no formally co-managed fisheries in WA however there are extensive consultation processes in place. There is also widespread recognition amongst fishery managers that consultative processes need to be particularly effective in data-poor circumstances.

9. DISCUSSION

9.1. Australian developments in context

Australia has undergone a great deal of progress in recent years within the field of risk management for fisheries (Fletcher 2005; Astles *et al.* 2006; Hobday *et al.* 2007; Smith *et al.* 2007a). Much of this progress must be attributed to the policy initiatives such as ecologically sustainable development, ecosystem-based fisheries management and the legislative requirements of the *EPBC Act*. Risk is not just synonymous with a probability estimate in a quantitative stock assessment, but rather the concept is now applied to a huge range of potential impacts of fishing activity on biophysical systems. Many of these systems are notoriously “data-poor”, with little known about either the biophysical system or the interaction of the fishery with that system.

Risk management provides a decision-making framework in the absence of full information. Or in the eloquent words of one Australian researcher: “Information takes time and money to collect. In the absence of that information how do you make decisions? Risk management provides you with a framework for making those decisions”. A clear message to emerge from this project is that risk-based concepts has been and always will be used to make decisions in fisheries – what has changed is the scope of the assessments and the need for them to be explicit, transparent and accountable (Astles 2008);(Webb *et al.* 2008).

The Australian developments in ecological risk assessment are now being examined by other countries (Fletcher 2006; Campbell *et al.* 2007)[14] and institutions (e.g. the ICES 2007; e.g. the Marine Stewardship Council 2009) to progress the ecosystem-based management of fisheries. There is, however, a need to refrain from too much self-congratulation. Within and between jurisdictions, the application of such methods can be highly variable. Simply considering the application of risk-based methods to target, byproduct and discarded species (i.e., excluding habitats and ecosystems), some jurisdictions have completed highly consistent and detailed analyses across all their fisheries, whilst other jurisdictions have completed relatively simple assessments for their export fisheries only. Treatment of recreational fisheries has also been very patchy, with them usually considered as an additional source of fishing mortality upon a commercially targeted species. To our knowledge, there have been no detailed and publicly documented risk assessments of a jurisdiction-wide recreational fishery in Australia (and this may not necessarily be a valuable exercise). Preliminary attempts at a qualitative risk assessment of the recreational fishery in NSW were compromised by the constraints of the NRFIS (Henry *et al.* 2003).

The application of the risk-based methods is also variable between jurisdictions. The Commonwealth has been consistent in applying the tiered ERAEF, NSW have consistently used their QERA approach[15], and WA applied the method from the National ESD Reporting Framework (NESDRF). Risk assessors in Queensland managers have trialled and tested the ERAEF and the NESDRF. South Australia, Victoria, Tasmania and the Northern Territory appear to be committed to the NESDRF. Any Australian fisheries certified by the Marine Stewardship Council may well be assessed using methods derived from the ERAEF.

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[14] The Pacific Islands Oceanic Fisheries Management Project hosted a Ecological Risk Assessment Workshop in 2008 (http://www.ffa.int/gef/node/18, accessed 19 March 2009).

[15] There were subtle changes made to the risk assessment method in 2003, which makes the outcomes between certain fisheries difficult to compare.

Webb and Smith (2008) recommend that agencies "Apply to the extent possible a consistent approach to EBFM across all jurisdictions to coordinate management of shared resources and cumulative impacts, and to assist in national reporting". This is a well intentioned recommendation and fully supported by the project team, but it does seem to fly in the face of reality. Risk assessment methods have diverged in Australia and are unlikely to unify in the near future.

This is not necessarily a negative outcome. One of the strengths of scientific endeavour is the competitive spirit that exists between alternative ideas and the need to question assumptions and methods. Any new scientific methods require testing, peer review, and critical evaluation. Risk assessments are no different. The most influential method will be determined by history rather than identified by a document such as this.

It is important to note that there are both process and task outcomes (Robson 1998) associated with a risk assessment. Process outcomes will include the improved understanding gained by individuals about their fisheries and better communication between staff involved in such assessments. Process outcomes will be achieved regardless of the method used, as long as there are clear objectives for the exercise and effective facilitation. Gathering available information on the fisheries, and the biology and ecology of potentially impacted systems will, provided such information is well managed, have long term benefits for a management agency regardless of the other outcomes of the risk assessment.

Section 1.3 of this report indicates that the usual scientific interpretation of risk is that it should be associated with some "objective reality". Yet, in Australia, the task outcomes (i.e., the actual results) from risk assessments may themselves not be strictly comparable. A shared species that has been determined to be at "high risk" in one jurisdiction could easily be determined to have an alternative risk rating in another. This can come about for a number of reasons including differences in the context of the assessment, the methods applied, the individuals involved, and any policy or legislative differences that exist. Given that such risk assessments are completed in the context of jurisdiction's managerial objectives this is understandable – though the requirements associated with the *EPBC Act* do anchor the process at a national scale. The national guidelines (G1–4) attempt to resolve this issue by putting the technical, quantitative, repeatable, objective components of risk into the likelihood dimension of risk, and putting the science-informed policy and policy debate into the consequence dimension. This puts an important onus on two key players involved in risk management. Scientists need to focus on better, more consistent and objective methods that measure or predict the probability that certain actions will result in unacceptable outcomes (the likelihood). Policy-makers need to deal with the equally difficult task of integrating the results of uncertain science, various policy directives, complex legislative requirements and multifarious trade-offs to specify what benchmarks or reference points represent acceptable performance for a fishery (the consequence).

9.2. Perceptions of risk

Both Webb and Smith (2008) and this project found differences in the perception between researchers and managers. In this study, researchers were more willing to identify blockages in risk management at a policy or political level than managers. This can be explained simply. Managers have to deal first hand with the complexities of contemporary natural resource management, and will thus be more sympathetic to why such blockages occur. There is a natural tendency for people to defend their work and professions so it is unsurprising that managers are usually less critical of policy implementation than researchers (also see Hammond *et al.* 1983).

An add-on to this project was the social science study undertaken by Steven Gray from Rutgers University in New Jersey. This study used the survey instrument developed for this project (Appendix 9) with East Coast US fishery scientists and managers. A detailed comparison was then made of the language associated with "risk" between Australian and US fisheries professionals. This contribution, from a very different discipline, illustrates some interesting patterns within management agencies. Appendix 9 contains a full copy of the associated draft manuscript.

9.3. A better definition for data-poor species and fisheries?

The focus of this project was data-poor species and this proved to be a complex issue to communicate with agency officers. One question (5) asked in the interviews was "Do you identify fisheries or species as 'data-poor' and what criteria do you use to make this determination?" The answers were particularly wide ranging. In some cases, most notably the Commonwealth, agencies had identified issues with data-poor species and fisheries, and employed specialised staff to progress assessment and management. In other cases, issues with species which have little data were addressed through broader policies such as observer programs, bycatch reduction strategies, ecosystem modelling, surveys of recreational fisheries and spatial management. Some people thought "data-poor" was a useful term, others did not. A common reaction was that such species or fisheries should be termed "value-poor", but this definition does not sit easily with recreational fisheries or non-use issues, where the concept of "value" is so multifaceted.

The project team advocates that the concept of "data-poor" should be re-interpreted as a mismatch between data (and the systems associated with collection, management and interpretation) and the managerial systems to act upon the information derived from that data. The national guidelines all point in the same general direction, you can either get better data (guidelines G6, G8, G11), or implement management strategies that have a high probability of delivering acceptable outcomes with the data available (guideline G7). An alternative phrase to describe situations where this mismatch occurs could be "data-management disparity".

9.4. Harvest control rules and the weight-of-evidence approach

Guideline G15 advocated the use of a weight-of-evidence[16] approach. This guideline was readily accepted by most state fisheries agencies as a rational approach for interpreting the complex and sometimes contradictory information about the state of fish stocks. Responses to the workshop evaluation suggested a positive, but mixed reaction to this approach, with managers being less enthusiastic then scientists. The approach had particular appeal for the so-called data-poor stocks (Wise *et al.* 2007) or when a large number of species are to be considered (Scandol *et al.* 2007). In direct contrast, the Australian Fisheries Management Authority has, via the Commonwealth Harvest Strategy Policy (Department of Agriculture Fisheries and Forestry 2007), a requirement to use harvest rules (harvest control rules, see guideline G13) to determine recommended biological catches[17]. Such rules are also being applied in a range of circumstances, though certainly not exclusively, by state agencies (see benchmark 19). In contrast, the Commonwealth has made a deliberate decision to steer away from a weight-of-evidence approach for assessment and management (see benchmark 20).

This difference in the attitude and implementation of a weight-of-evidence approach for stock assessment reflects an important difference that exists in the management of Australian fisheries between the states and the Commonwealth.

States have almost exclusive jurisdiction over the management of recreational fisheries in Australia (Gullett 2008). In many cases, particularly for coastal and estuarine stocks, this fishery is a very

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[16] The weight-of-evidence approach is considered to be inclusive of "multiple lines of evidence" approach (though the former term is in more common use in Australian fisheries).

[17] Recommended biological catches can be interpreted as commercial catch quotas after other sources of fishing mortality have been taken into account. Note that implementation of the HSP is more complex than indicated here.

significant and poorly quantified source of fishing mortality. Although it is certainly feasible to develop harvest control rules for such fisheries, their implementation will be far more problematic than with a fishery that is dominated by a large and well regulated commercial fishery. The two key regulations used to control recreational fishing mortality – bag and size limits – are coarse regulatory instruments for controlling the total recreational fishing mortality, particularly if there is significant discard mortality or limited resources for compliance. Direct control of recreational fishing mortality using tags has, to our knowledge, only been used for Shark Bay snapper in WA (Department of Fisheries 2009). In many instances, over-zealous application of harvest control rules to a mixed-sector fishery is likely to result in an unintended reallocation between the sectors. Harvest control rules are excellent public policy for the management of fish stocks harvested by output controlled commercial fisheries and a very effective tool within the risk management toolbox. However, their application to the management of species with a large or dominant recreational fishery requires additional consideration. The Australian States have implemented harvest control rules, and examples include the abalone fishery in WA (Department of Fisheries 2002a) and the spanner crab fishery in Queensland (QLD DPI 2008). These are, however, both large single-species quota fisheries with a limited recreational component. Cadrin and Pastoors (2008) also provided valuable commentary on the experience of applying harvest control rules to fisheries in the US and Europe.

In many cases, the approach the states have used to either determine stock status, or initiate management actions, has been referred to as a weight-of-evidence or multiple lines of evidence approach. On the basis of these arguments, which will use a mixture of quantitative and qualitative reasoning, various management responses are initiated. There is an inherent flexibility in such an approach, which can provide both strengths and weaknesses. The strengths include that the reasoning can reflect the specific circumstance at hand. For example, an estuarine species may be exhibiting recruitment issues in one estuary, but not in others. Qualitative arguments can quickly identify such circumstances and act on them, whereas non-spatial model-based representations are not helpful. An additional strength is that such processes are likely to be cheaper and faster. Such weight-of-evidence arguments can be quickly prepared and acted upon as required. In contrast, the development and testing of harvest control rules will take time and resources – although the operation of established and agreed rules should be very efficient.

Flexibility is also a weakness of the weight-of-evidence approach. The lack of "hard-coded" responses and dependence on expert interpretation could cause less confidence in any conclusion and less commitment to any subsequent actions. The minor changes to decisions taken around the WA Demersal Scalefish Fishery (WA Department of Fisheries 2008) is an example of how a changing political climate has the ability to impact the short-term outcomes of a weight-of-evidence approach. This contrasts with the ongoing commitment to the Commonwealth Harvest Strategy Policy even after a change of federal government.

Harvest control rules and the weight-of-evidence approach are not a dichotomy. Rather they represent two extremes along a continuum of choices. There are circumstances where the former approach is highly appropriate, provides certainty to industry and government and is highly cost effective. In contrast, for some species and fisheries, a weight-of-evidence approach provides the necessary flexibility to interpret and act upon a complex biological and social-political situation. Just as harvest control rules and management strategy evaluation have received significant attention in the fisheries literature (Smith *et al.* 1999; Sainsbury *et al.* 2000; Gardner *et al.* 2007; Smith *et al.* 2007a; Dowling *et al.* 2008), it is time for researchers and managers to publish their experiences and recommendations for improving the weight-of-evidence approach[18] (for examples see Vern 1996; Ziegler *et al.* 2006; Wise *et al.* 2007), particularly for recreational fisheries.

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[18] For a non-fisheries example see Schipper, C. A., Smit, M. G. D., Kaag, N. H. B. M. and Dick Vethaak, A. (2008). A weight-of-evidence approach to assessing the ecological impact of organotin pollution in Dutch marine and brackish

9.5. The Robin Hood approach

Punt *et al.* (2002) recently completed a project entitled “Using information for 'data-rich' species to inform assessments of 'data-poor' species through Bayesian stock assessment methods”. Project investigators undertook sophisticated statistical modelling where the parameters and time-series of fishing mortality and recruitment variability were “stolen” from data-rich stocks and given to data-poor stocks in the form of prior probability distributions. The authors concluded that this approach enabled improved precision of key-outputs for data-poor stocks, but cannot turn a data-poor stock into a data-rich one.

The use of parameters from related species to undertake various assessment analyses is a logical idea, and such functionality exists in FishBase’s Life History Tool (www.fishbase.org). Bayesian statistics provides a more statistically detailed framework for undertaking such work, but at the expense of a more complex analysis and interpretation (though this may change with the availability of better tools).

An alternative approach to stealing from the rich and giving to the poor is via some type of meta-analysis. In this approach, statistical models from large numbers of data-rich stocks are developed and inferences from data-poor stocks obtained by interpolation (e.g. Goodwin *et al.* 2006). The classic model that uses this approach in fisheries science is Pauly’s equation for estimating natural mortality (Pauly 1980). Section 5.8.5 outlines contemporary developments in this field that are relevant for the assessment of data poor stocks.

There is, however, another “Robin Hood” message from this study. There are significant differences in the resources available for assessment and management of fisheries between the Australian jurisdictions (Australia has “vertical fiscal imbalance” between the Commonwealth and the states, Dollary 2002). Within agencies, differences also occur, particularly when cost recovery policies are in place. In such situations, commercial fisheries with a low GVP simply do not have large research and management budgets[19]. Although recreational fisheries are associated with significant amounts of expenditure and have various values associated with them, research and management is usually funded from consolidated revenue. In NSW and Victoria, general recreational fishing fees do generate significant amounts of revenue and some of this is available for research and management initiatives.

Most readers would agree that there are within and between jurisdictional disparities in the resources available for fisheries assessment and management in Australia, and this is particularly obvious for the so-called data-poor species. Many assessment and management systems in Australia are very simple for data-poor species mostly because there are few resources to do anything else. In some cases, this is deliberate government policy, in other cases it is just the reality of competing demands upon finite budgets. Therefore, a universal driver for fisheries assessments in Australia is the need to continually improve efficiency.

One general strategy to improve the efficiency of the resource assessment dollar is better co-operation, particularly between agencies (although there will always be within-agency issues to consider). There are numerable examples of multi-jurisdictional co-operation to improve fisheries assessments and management in Australia, but there are just as many examples of where this could be improved. Our observation is that fishery scientists and managers still think primarily in terms

waters; combining risk prognosis and field monitoring using common periwinkles (*Littorina littorea*). *Marine Environmental Research* **66**: 231-239., but there are a multitude of others in law, medicine and public administration.

[19] There are sound economic arguments for why this is good public policy. Furthermore, the ESD principle “Improved valuation, pricing and incentive mechanisms” is consistent with cost-recovery policies. (s6(2)(d), *NSW Protection of the Environment Administration Act* 1991).

of jurisdictional responsibility rather than the biological stocks. Given the statuary responsibility of governments, this makes perfect sense. However, this approach is often inconsistent with the notion of ecosystem-based fisheries management. These are issues that require ongoing consideration if Australia is to be committed to this policy. Responses to benchmark 6 identify a range of agency responses to this issue, but these comments reflect the positive examples and may not be fully representative of the underlying issues. The Australian situation must be contrasted with the US approach which has a focus on the management of target stocks.

This is the point where the Robin Hood analogy must be left behind. Rather than "stealing", the path forward is about better co-operation, communication and recognition of intellectual property. Any strategic attempt to develop better systems to improve multi-agency co-operation needs to recognise that top-down approaches will only be sustainable if there is officer-level support. This requires a better understanding of the incentives which drive people to act the way they do.

In some cases, such multi-jurisdictional solutions could be worse than the problem, but that should not stop the search for better ways for the small community of Australian fisheries scientists to work more co-operatively and efficiently. We outline one suggestion below, with the expectation that it will require significant consultation and revision.

9.6. A web-based system for life-history information

The internet is now accepted as the key mechanism to deliver information in society. All agencies use public websites to communicate government policies and journals now distribute their content electronically. Crucial web resources for Australian fisheries scientists are CAAB (www.marine.csiro.au/caab/) and FishBase and the (soon to be developed) AFIS (Fisheries Statistics Working Group 2006) which will report national statistics on commercial landings.

There needs to be a debate about whether another web-based system needs to be developed that directly addresses the needs of professionals working in stock and risk assessment. The objective would be a system that encouraged consistent approaches to aquatic resource assessment in Australia. Such a system should not be a black-box but rather a controlled forum for exchanging data, algorithms, ideas and results. The internet is probably the only cost-effective technology that has not been fully exploited for improving fisheries assessments in Australia. The web is a proven platform for information sharing and significant improvements are likely to occur into the foreseeable future.

The impediments to such an approach are likely to be associated with privacy, security, intellectual property, resistance to standardisation and resistance to change. Any multi-jurisdictional system would have to address these issues if it is to succeed. Without going into details, the most likely "low fruit" for such an approach would be systems to manage life-history information. Such information is not usually subject to privacy laws, and the intellectual property issues can potentially be addressed. An understanding of life-history processes lies at the core of assessments for data-poor species (section 5.8.5).

The initial recommendation is for additional consultation and design of a pilot system with the scope limited to the compilation and analysis of life history processes. This system would interface with CAAB and AFIS and complement the existing functionality available on FishBase and BlueNet.

9.7. Uncertainty and fisheries management

The management of any fishery is always based on some form of model of the fishery, whether it be a simple model in the mind of a manager, or a complex computer model developed by scientists.

Uncertainty in fisheries management is thus generally dealt with in terms of how it is incorporated into any model of the fishery. Francis *et al.* (1997) identified a number of uncertainty categories including model structure uncertainty (representing our lack of understanding about the true underlying dynamics of the system), process error (more subtle or external processes that appear as natural variability), parameter estimation uncertainty, error structure uncertainty, observation error and implementation error. The benefit of being able to categorise uncertainty in this way is that it allows each type of uncertainty to be dealt with differently by scientists and each have thus generated their own associated research and literature. For instance, model structure uncertainty has been dealt with by employing models that generate more conservative results (Walters *et al.* 2004: Figure 5.2), or in more valuable fisheries by employing highly complex modelling techniques such as Bayesian Model Averaging (Hoeting *et al.* 1999, Ives *et al.* 2007). Parameter estimation uncertainty has been dealt with through sensitivity analyses and the use of Bayesian priors (Ives *et al.* 2007). Process, observation and implementation errors have been dealt with by yet another set of techniques such as the incorporation of stochastic components representing into model runs and running the models many times (e.g. Quinn *et al.* 1999; e.g. Clark *et al.* 2004).

Despite this progress in dealing with such ‘known’ uncertainty there still remains a seemingly unfathomable depth to the uncertainty associated with fisheries management. In a now famous speech at a Defence Department briefing on 12 February 2002, Secretary of Defence Donald Rumsfeld stated that “… there are known ‘knowns’. There are things we know that we know. There are known ‘unknowns’. That is to say, there are things that we now know we don’t know. But there are also unknown ‘unknowns’. There are things we do not know we don’t know.” (Rumsfeld 2002).

The greater the complexity in a system the more likely there will be such ‘unknown unknowns’. In general, the more uncertainty incorporated, the more complex the problem of risk becomes (Francis *et al.* 1997). With highly complex ecosystems containing vast numbers of organisms with extensive connectivity and interactions coupled with equally complex social, economic and political systems that can change dramatically over time, there are few areas of management that contain such deep levels of uncertainty as natural resource management (De Young 1999). A common approach to such deep uncertainty is to delay management action in the hope of reducing uncertainty through research. Unfortunately, more information can sometimes actually increase uncertainty, as it can reveal more complexity than was previously understood. Allowing such high levels of uncertainty to continue can also result in a decline in social trust over time (Bammer *et al.* 2008). If conditions of low social trust prevail they can pose major challenges and additional costs to decision-makers.

The long-term commitment to risk management is a valid response to such deep uncertainty. Risk management can not only incorporate all available information but also involves extensive stakeholder participation that can deal with social trust issues by incorporating a more participatory approach to planning that engages local communities and stakeholders in more of the decision making process (Forester 1999). Greater stakeholder participation may also open up fisheries management to alternative thinking that can result in solutions that not only promote more sustainable fishing practices, but foster a society that is more cooperative and more resilient to uncertainty (e.g., by altering public perceptions and preferences).

9.8. Risk, public administration and recreational fisheries

There has been a significant body of research undertaken by social scientists on risk (Adams; Margolis 1996; Slovic 2000; Renn 2008). Much of this work is highly quantitative and aims to better understand psychometric responses to risk-based phenomena. Although such research could, one day, play a role in risk management for Australian fisheries, another branch of scholarship which looks directly at the role of risk within public administration is of more immediate interest (Fisher 2003; Rothstein *et al.* 2006; Fisher 2007).

The underlying issues discussed in this report derive from the challenge faced by administrators when regulating access to publicly-owned aquatic resources under the principles of ecologically sustainable development. The primary legal instrument currently being used to understand the nature of the potential impacts that maybe associated with this access is strategic environmental assessment (Marsden *et al.* 2002), within which the risk assessments play a key role. These assessments are used in conjunction with other instruments, such as management plans, to provide specific direction to regulators to minimise any subsequent environmental impacts from fishing and provide for the sustainability of the resource. This framework requires additional consideration over how the decisions associated with such assessments are actually taken.

It must be recognised that the strategic assessments and the associated management plans are, in almost all instances, developed, interpreted and implemented by public administrators. Readers of this report must now appreciate, that the decisions associated with the management of fisheries require the consideration of a complex range of uncertain biophysical phenomena embedded within a multifaceted socio-political environment. Realistically only public administrators within executive government have the resources to fully research, explore and deliberate on these decisions. Neither the legislature nor the judiciary would be practically able to do so (Fisher 2007 at 21). Also, many of these decisions inevitably involve a degree of discretion. Within a democracy this places a significant responsibility on public administrators, so they must fully understand the strengths and weakness of the primary method that is now being used to account for many of these decisions – risk.

Fisher (2007 at 33) identified two paradigms of risk regulation within public administration: the rational-instrumental paradigm and deliberative-constitutive paradigm. Within risk-based decision-making both of these paradigms are evident, though various emphases are given to different situations. In particular, in regulatory frameworks where objective and quantifiable phenomena are being managed, there is a weighting towards the rational-instrumental paradigm. In contrast, more complex socio-political issues are likely to be weighted towards the application of a deliberative-constitutive model.

Understanding these two paradigms of risk-based regulation in Australia is fundamental for tackling the next major challenge for risk management in fisheries – recreational fisheries. With the exception of WA and Victoria[20], there has been limited application of risk-based methods to recreational fisheries in Australia. Although the underlying fisheries ecology maybe identical, the administrative context of recreational fisheries management is significantly different from commercial fisheries. These fisheries do not export their product and any associated fishing licences (if they exist) are very different to a commercial licence.

The results of various judicial review and appeal mechanisms of public administration are key to understanding the use of various instruments for environmental decision-making. For example, the NSW case law associated with environmental impact statements has provided very clear guidelines about what is an acceptable impact assessment of a project (e.g., *Schaffer Corporation Ltd and Hawkesbury City Council*, 1992[21]). The two cases associated with export approvals under Part 13A of the *EPBC Act* 1999[22,23] shed little light on the adequacy of the associated risk assessments. If

[20] Victoria has undertaken risk assessments of all significant recreational fisheries, including fisheries which are entirely composed of recreational harvest such as the inland natives and inland exotics fisheries. Summaries of these risk assessments should be published in 2009.

[21] LGRA, Land and Environment Court of NSW. 77.

[22] Nature Conservation Council and Minister for Environment and Water Resources and Others (2007), AATA 1876.

[23] Humane Society International and the Minister for the Environment and Heritage (2006), AATA 298.

anything the cases simply reinforced the difficulties of managing cumulative impacts within existing jurisdictional arrangements.

If Australian authorities are to commit to the application of risk-based approaches in the management of fisheries they must continue to invest, not only into the technical aspects of risk assessments, but also the social aspects of risk communication. For commercial fisheries, with a well defined and accessible constituency, the current strategies will continue to be fruitful for the foreseeable future; for recreational fisheries, with a far more complex constituency, ongoing investment on improved deliberative models will be required. In many cases, managing the cumulative impact of both sectors is the key to better environmental outcomes.

The consequences of the United Kingdom's commitment to risk-based regulation in 2002 are now being addressed by scholars in the UK. The comments by Rothstein *et al.* (2006 at 1064) provide a stopping point for this discussion: "far from being the final move in the regulatory game, therefore, the establishment of risk as a central organising concept of regulation is more likely to open up new games."

10. BENEFITS

This project delivered benefits in three areas. Firstly, the guidelines developed present a very useful check-list for managers and scientists implementing risk management in fisheries. Though there is an emphasis towards data-poor situations, the guidelines are broadly applicable to many contemporary assessment and management issues. In the national workshops we noted that a structured discussion of the case studies using the guidelines would, in thirty minutes, often result in similar recommendations to those that the original agencies have spent months working on. Much of the documentation associated with risk management is particularly lengthy and complex, and the guidelines are an abbreviated overview of the sorts of strategies and tactics that are known to work for fisheries assessment and management issues around Australia. This benefit is consistent with that outlined in the original application:

> “These guidelines will enable assessment scientists and key managers to rapidly evaluate options for the assessment of data-poor species. Some guidelines may simply state, "don’t go there", others might suggest refinements to existing programs to reduce costs, progress inter-jurisdictional arrangements or adapt managerial interpretations. This will provide immediate benefit to agency officers tasked with assessing and managing data-poor species.”

Secondly, the benchmarks provided a comparison of how individual jurisdictions performed with respect to the guidelines. The original application stated “Each jurisdiction uses strategies (whether documented or not) to undertake the assessment of data-poor species. This project will objectively identify the strengths and weaknesses of those strategies within a national context.” The benchmarking exercise was designed to highlight these strategies. In actuality, both the strengths and weaknesses were discussed and debated in the interviews and workshops, but the final benchmarks as presented in this document tended to focus on the strengths. This is an unsurprising outcome in a public document. The benchmarks provided are, to our knowledge, the most detailed inter-jurisdictional comparison of risk management in Australian fisheries. The tables presented in section 8.3 would be extremely beneficial to any agency that wished to reconsider the assessment and management of data-poor species – from either a tactical or strategic perspective.

Thirdly, the project had process benefits for both scientists and managers. The national workshops gave officers within a jurisdiction a chance to: discuss issues with risk management in their jurisdiction; apply to guidelines to actual data-poor assessment and management issues (the case studies); have a structured discussion about how their jurisdiction performed with respect to the guidelines. The co-investigator’s workshop in Sydney and the development of the national guidelines provided an opportunity for inter-jurisdictional deliberation. These benefits are consistent with the original application’s comment that “These [workshops and benchmarking exercises] are valuable "process outputs" which will improve communication and linkages between individuals, agencies and jurisdictions.”

11. FURTHER DEVELOPMENT

If risk management is to reach its potential in Australian fisheries management, then there will have to be a commitment to understanding and communicating its success and failures. This is the basis of an adaptive learning and applies just as much the implementation of risk management as it does fisheries management. Professionals in fisheries would be short-sighted if they did not think that lessons learned from the application of risk management in other disciplines had no relevance to them.

Advocates of particular risk management methods need to continually improve the documentation and training resources associated with these methods. In the long run, it is likely that the most dominate risk management methods in Australian fisheries will be those with the clearest documentation, the least ambiguity in the steps to follow, and those with superior training resources (including people and materials). Consideration should be giving to the development of documentation and training resources by specialists in these fields rather than scientists.

The promising analytical developments such as the SAFE method (Zhou *et al.* 2008), ERAEF Level 2 and Forrest *et al.* (2008) are all dependent upon extensive databases of life history parameters. The wider application of such methods could be constrained by limited human resources unless there are ongoing commitments for more efficient and transparent meta-data management and the sharing of expertise. Suggestions for how this might be done are provided in the discussion (section 9.6).

The textbook of what is risk management in Australian fisheries should not be closed. In particular, risk management of recreational fisheries should be subject to additional research in public administration and social/political science. Risk management in commercial fisheries may benefit from the introduction of concepts from finance including portfolio management and insurance.

12. PLANNED OUTCOMES

Inter-jurisdictional co-operation: this project reviewed the extensive risk and stock assessment work undertaken for data-poor species in Australia. This review was not just of the peer-reviewed and grey literature, but also the individual experiences of over 61 scientists and managers. Using this semi-structured information, a series of national guidelines were drafted that aimed to capture the strategies that were actually working for the assessment and management of data-poor species. These guidelines, which were developed by the project team and the co-investigators, provided an opportunity for senior assessment scientists and research leaders to integrate their best ideas into the guidelines. These guidelines were subject to a benchmarking exercise in the workshops (see below) which encouraged further deliberation and consideration about how other jurisdictions addressed challenges which were, for all intents and purposes, the same as theirs.

Evaluation of strengths and weaknesses: each jurisdiction uses a range of strategies to undertake the assessment of data-poor species. This project considered the qualitative, semi-qualitative and quantitative assessments used by all Australian jurisdictions. These approaches were integrated into the guidelines which were then subject to a benchmarking exercise. Patterns within these benchmarks, supported by the large numbers of the examples provided, illustrate the strengths and weakness of various strategies to assess data-poor species (a concept which is considered in detail in the benchmarks). Strengths and weaknesses of the three main ecological risk assessment approaches used in Australia were also documented.

Development of national guidelines: the national guidelines were developed to improve the application of risk-based methods in the scope, implementation and interpretation of stock assessments for data-poor species. These guidelines are listed below (and developed in detail in section 5):

1. Risk should be determined by combining the likelihood and the consequence of an uncertain outcome that will adversely affect objectives.
2. All risk-based approaches in Australian fisheries should fit within the likelihood-consequence model.
3. Understand that consequences must have a frame of reference that, for a government agency, is determined by legislative and policy objectives.
4. Recognise that the estimation of the likelihood of an uncertain outcome is an objective task and the influence of human-values in such estimates should be minimised.
5. Appreciate that agency officers need to have the requisite skills in risk management to apply these approaches in research and management.
6. Recognise data poverty is a broader concept than simply not having enough data.
7. Acknowledge that the best response to data-poor fisheries is not always to collect more data, but in some situations it is better to implement management strategies that are robust to uncertainty and are able to achieve acceptable levels of risk.
8. Recognise that there are minimum standards of data for species that are subject to some type of risk or stock assessment.
9. Acknowledge that when interpreting risk assessments, adoption of the precautionary approach implies that when the likelihood of an outcome is uncertain and the environmental consequence of this outcome is serious or irreversible, then the interpretation of this likelihood should be the higher but still plausible estimate.

10. Appreciate that risk-like approaches can be used for prioritising and scheduling research, monitoring and management tasks. Such approaches are often closely associated with multi-criteria decision analysis.
11. Recognise how risk assessments can be used to prioritise research. In particular, where potential outcomes are high risk because of an uncertain likelihood, research can be used to clarify the risk.
12. Continue to apply fishery assessment methods that have a successful track-record in data-poor environments.
13. Harvest strategy frameworks with explicit decision rules provide an effective risk management framework for fisheries.
14. Develop and promote analyses that estimate the vulnerability of stocks, the productivity of stocks or the likelihood that stocks are being harvested at unsustainable rates.
15. When direct support for a model is unavailable, then scientific arguments should be constructed using a weight-of-evidence approach.
16. Individual scientists should apply risk management strategies to their own research and workflows.
17. Continue to improve the efficiency of the workflows associated with stock assessment by adopting appropriate technologies.
18. Risk management is usually carried out by reducing the likelihood of an undesirable outcome.
19. Risk management may, in some cases, be carried out by reconsidering the consequence of an outcome.
20. Within a multi-species fishery, directed management of an indicator species is an effective strategy to manage species at equal or lower risk than the indicator species.
21. Managers should identify the factors that can cause decision-making processes to fail and develop risk management strategies to avoid these factors.

13. CONCLUSIONS

This project had four objectives which were achieved by delivering the following outcomes.

Objective 1 was to review the use of "risk" within the scope, implementation and interpretation of stock assessments of data-poor species in Australia and, with lesser detail, within the international domain. Chapter 5 is an extensive review of the use of "risk" when scoping, implementing and interpreting assessments of data-poor species. As expected, many of the methods in use are the ecological risk assessments that have been done to meet *EPBC Act* and other statutory requirements. It would not have been sensible to limit this review to quantitative stock assessment methods (although these were considered in more detail in section 5.8). Examples were given illustrating how quantitative stock assessments are a subset of ecological risk assessments. The literature review included a brief description of the application of risk-based methods in other disciplines.

This literature-based review was augmented with an interview-based review of 33 scientists and 28 managers around Australia. This approach provided a practical understanding about what fishery professionals believed to be the assessment and management issues associated with data-poor fisheries. Although the details of these interviews are confidential, general patterns and issues were captured and presented within both the guidelines and the benchmarks.

Objectives 2 and 3 were achieved in conjunction with objective 4. This re-ordering was required to provide additional consistency and simplify the structure of the project. Objective 4 was to develop national guidelines that will assist jurisdictions to develop and apply risk-based methods to the assessment of data-poor species. These guidelines were developed by the project investigators in June 2008, and presented at a series of workshops through Oct – Dec 2008. The full set of guidelines is presented in Chapter 7. As described in original objective 4, these guidelines promote the adoption of nationally consistent standards but are cognisant of diverse institutional arrangements that exist.

Objective 2 was to define benchmarks to compare and contrast the use of "risk" within the scope, implementation and interpretation of stock assessments across all Australian jurisdictions. Again, the definition of assessment was broadened to include ecological risk assessment as this was the primary tool being used. These benchmarks were defined by the project team and the responses developed by the project investigators and the workshop participants (Chapter 8). The full responses to the benchmarks presented in this Chapter represent achievement of objective 4 "Using the review and the benchmarks, identify the strengths and weaknesses of the various applications of risk-based methods used to scope, implement and interpret stock assessments in Australia".

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15. APPENDICES

15.1. Appendix 1 – Intellectual Property

No patentable inventions or processes were developed as part of this work. The work presented in this report remains the intellectual property of the authors, and they should be acknowledged when citing this work.

15.2. Appendix 2 – Staff

Staff directly employed on this project were:

Dr James Scandol – Senior Scientific Officer (NSW Department of Primary Industries)
Dr Matthew Ives – Scientific Officer (NSW Department of Primary Industries)
Dr Matthew Lockett – Fisheries Technician (NSW Department of Primary Industries)

15.3. Appendix 3 – Glossary

Adaptive Management: a management process involving step-wise evolution of a flexible management system in response to feedback information actively collected to check or test its performance (in biological, social and economic terms). It may involve deliberate intervention to test the fishery system's response (FAO).

Component: a major area of relevance to fisheries with respect to ESD (e.g., target species, bycatch species, marine environment, resource use/allocation, employment, income, lifestyle/culture, governance).

Consequence: outcome or impact of an event (AS/NZS 2006).

Ecologically sustainable development: Using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased (National Strategy for Ecologically Sustainable Development, Council of Australia Governments, 1992).

Event: occurrence of a particular set of circumstances (AS/NZS 2006).

False-negative: also known as Type II error: the error of failing to reject a null hypothesis when the alternative hypothesis is the true state of nature. In other words, this is the error of failing to observe a difference when in truth there is one.

False-positive: also known as a Type I error: the error of rejecting a null hypothesis when it is actually true. Plainly speaking, it occurs when we are observing a difference when in truth there is none.

Fishery: A unit determined by an authority or other entity that is engaged in raising and/or harvesting fish. Typically the unit is defined in terms of some or all of the following: people involved, species or type of fish, area of water or seabed, method of fishing, class of boats and purpose of the activities.

Hazard: a source of potential harm, or a situation with a potential to cause loss or adverse effect (AS/NZS 2006).

Indicator: an instrument used to monitor the operation or condition of a physical system. A quantity that can be measured and used to track changes with respect to an operational objective.

The measurement is not necessarily restricted to numerical values. For example, categorical values may be used.

Likelihood: used as a general description of probability or frequency (AS/NZS 2006).

Management Objective: something that an organisation's efforts or actions are intended to attain or accomplish; purpose; goal; target.

Management Strategy Evaluation: involves assessing the consequences of a range of management strategies or options and presenting the results in a way that lays bare the trade-offs in performance across a range of management objectives (Smith *et al.* 1999).

MCDA: Multiple Criteria Decision Analysis – is a discipline aimed at supporting decision makers who are faced with making numerous and conflicting evaluations. MCDA aims at highlighting these conflicts and deriving a way to come to a compromise in a transparent process.

Objective: something that one's efforts or actions are intended to attain or accomplish; purpose; goal; target.

Operational objective: An objective that has a direct and practical interpretation in the context of a fishery and against which performance can be evaluated (in terms of achievement).

Outcome: a final product or end result.

Precautionary Approach: The principle 15 of the Rio Declaration states that "in order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall be not used as a reason for postponing cost-effective measures to prevent environmental degradation." (Garcia 1996). As Garcia (1996) points out, "the wording, largely similar to that of the principle, is subtly different in that: (1) it recognizes that there may be differences in local capabilities to apply the approach, and (2) it calls for cost-effectiveness in applying the approach, *e.g.*, taking economic and social costs into account." The 'approach' is generally considered a softening of the 'principle'.

Performance measure: A function that converts the value of an indicator to a measure of management performance with respect to the operational objective (can be a limit, a target a trend, etc.).

Precautionary Principle: where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, private and public decisions should be guided by:

(i) careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and

(ii) an assessment of the risk weighted consequences of various options

(Intergovernmental Agreement on the Environment, 1992)

Probability: a measure of the chance of occurrence expressed as a number between zero and one.

Reference Point: the value of an indicator that can be used as a benchmark of performance against an operational objective. A reference point indicates a particular state of a fishery indicator corresponding to a situation considered as desirable (Target reference point, TRP) or undesirable and requiring immediate action (Limit reference point, LRP).

Risk: the chance of something happening that will have an impact on objectives. It is measured in terms of likelihood and consequence (AS/NZS 2006).

Risk management: the process of evaluating and selecting regulatory and non-regulatory responses to risk. The selection process necessarily requires the consideration of legal, economic, and behavioural factors. (FAO Glossary).

Risk assessment: component of risk management which comprises all processes concerned with identification, estimation and qualitative and quantitative evaluation of risks. Risk assessment consists of hazard identification, hazard assessment, risk estimation and risk reduction (FAO Glossary).

Sub-component, sub-sub-component, etc: Further sub-divisions of the components.

Sustainable Fishery: A fishery that is consistent with ecologically sustainable development (i.e., a fishery that uses, conserves and enhances the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased).

Uncertainty: a lack of knowledge arising from changes that are difficult to predict or events whose likelihood and consequences cannot be accurately predicted (AS/NZS 2006).

15.4. Appendix 4 – Interview Survey Instrument

Development of national guidelines to improve the application of risk-based methods in the scope, implementation and interpretation of stock assessments for data-poor species

Survey Instrument

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 past five 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 (data poor) 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?

    Strengths:

    Weaknesses:

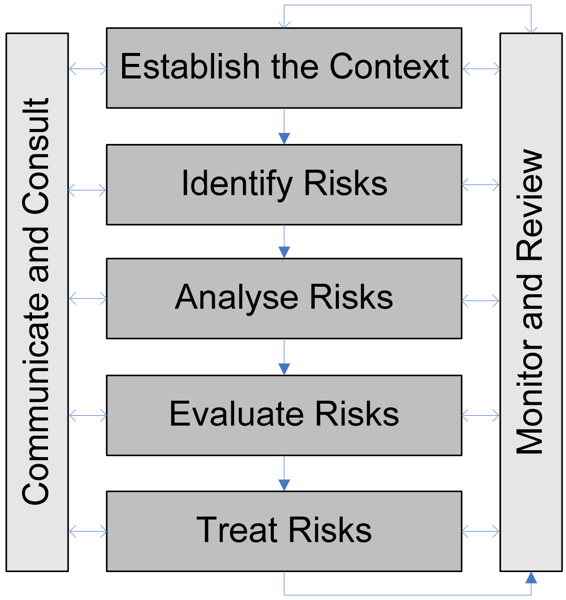
22. Are their any changes to this management/assessment interface on the horizon?

23. Is there anything more you want to add regarding all that we have just spoken about?

15.5. Appendix 5 – Workshop Guidelines Summary

Applying National Risk Guidelines

Page 1



Page 2

Defining Risk

G1: Risk should be determined by combining the likelihood and the consequence of an uncertain outcome that will adversely affect objectives.

G4: Recognise that the estimation of the likelihood of an uncertain outcome is an objective task and the influence of human-values in such estimates should be minimised.

Data Poverty

G6: Recognise "data poverty" is a broader concept than simply not having enough data.

G11: Recognise how risk assessments can be used to prioritise research. In particular, where potential outcomes are high risk because of an uncertain likelihood, research can be used to clarify the risk.

How we work

G5: Appreciate that agency officers need to have the requisite skills in risk management to apply these approaches in research and management.

G10: Appreciate that risk-like approaches can be used for prioritising and scheduling research, monitoring and management tasks. Such approaches are often closely associated with multi-criteria decision analysis.

G16: Individual scientists should apply risk management strategies to their own research and workflows.

G17: Continue to improve the efficiency of the workflows associated with stock assessment by adopting appropriate technologies.

G21: Managers should identify the factors that can cause decision-making processes to fail and develop risk management strategies to avoid these factors.

Page 1

1. Establish the context

G3: Understand that "consequences" must have a frame of reference that, for a government agency, is determined by legislative and policy objectives.

2. Identify Risks

G2: All risk-based approaches in Australian fisheries should fit within the likelihood-consequence model.

3. Analyse Risks

G8: Recognise that there are minimum standards of data for species that are subject to some type of risk or stock assessment.

G12: Continue to apply fishery assessment methods that have a successful track-record in data-poor environments.

G14: Develop and promote analyses that estimate the vulnerability of stocks, the productivity of stocks or the likelihood that stocks are being harvested at unsustainable rates.

G15: When direct support for a model is unavailable, then scientific arguments should be constructed using a "weight-of-evidence" approach.

4. Evaluate Risks

G2: All risk-based approaches in Australian fisheries should fit within the likelihood-consequence model.

G11: Recognise how risk assessments can be used to prioritise research. In particular, where potential outcomes are high risk because of an uncertain likelihood, research can be used to clarify the risk.

5. Treat Risks

G7: Acknowledge that the best response to data-poor fisheries is not always to "collect more data", but in some situations it is better to implement management strategies that are robust to uncertainty and are able to achieve acceptable levels of risk.

G13: Harvest strategy frameworks with explicit decision rules provide an effective risk management framework for fisheries.

G18: Risk management is usually carried out by reducing the likelihood of an undesirable outcome.

G19: Risk management may, in some cases, be carried out by reconsidering the consequence of an outcome.

G20: Within a multi-species fishery, directed management of an indicator species is an effective strategy to manage species at equal or lower risk than the indicator species.

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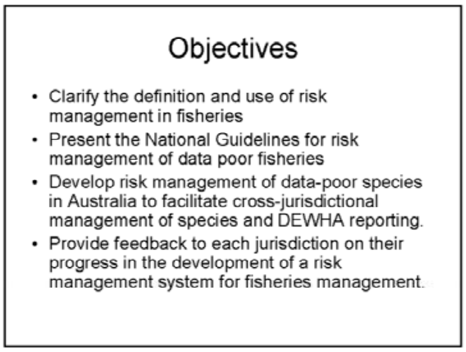
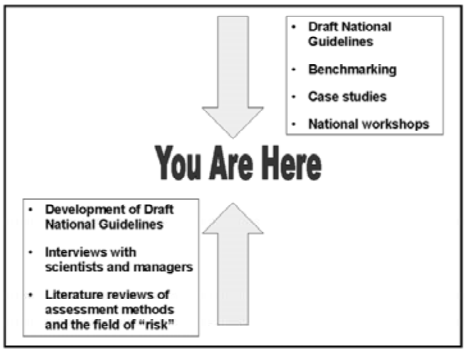
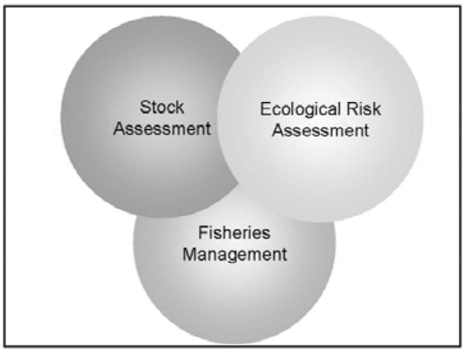
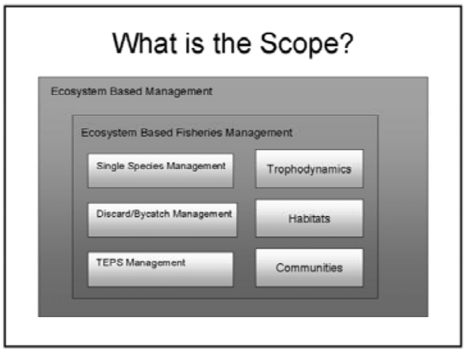
15.6. Appendix 6 – Workshop Presentations

Introductory Presentation









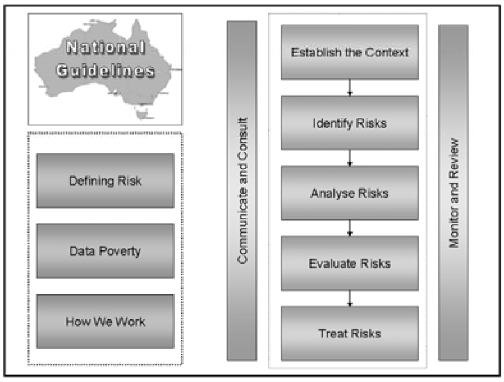
1

What is the Scope?

- In Scope
  - Low value target species
  - Bycatch species
  - Discarded species
  - Data poor recreational species
  - TEPS
- Out of Scope
  - High value target species with stock assessments
  - Habitats
  - Ecosystems
  - Socio-economics
  - The best ERA method

Is there a Problem?

- Yes
  - The ERAs are not perfect
  - We can't do stock assessments for everything
  - We could work smarter and faster
  - "Risks" need to be consistent
- No
  - We've done the ERAs
  - The only real assessment is a stock assessment
  - We do everything fine now



Defining Risk

- Risk is the combination of the likelihood and consequence of an uncertain outcome.

(Guideline 1)

	Consequence			
Likelihood	Minor	Moderate	Major	Extreme
Remote	1	2	3	4
Unlikely	2	4	6	8
Possible	3	6	9	12
Likely	4	8	12	16

Medical Risk Assessment

Likelihood

Level	Likelihood	Description
A	Almost certain	eg. will occur at least once a year or more often
B	Likely	
C	Possible	
D	Unlikely	
E	Rare	
F	Very rare	
G	Almost incredible	eg. once in 100,000 years

Consequence

Level	Description
1.	No medical treatment required
2.	Minor medical treatment required
3.	Hospitalisation required
4.	Minor disability resulted
5.	Major disability resulted
6.	Death resulted
7.	Multiple deaths resulted

Source: Paul Bullen Management Alternatives for human services, http://www.mapl.com.au/index.htm

Financial Risk Assessment

Likelihood

Level	Descriptor	Description
A	Almost certain	Is expected to occur in most circumstance
B	Likely	Will probably occur in most circumstances
C	Possible	Might occur at some time
D	Unlikely	Could occur at some time
E	Rare	May occur only in exceptional circumstances

Consequence

Level	Description
1.	Low financial loss
2.	Medium financial loss
3.	High financial loss
4.	Major financial loss
5.	Huge financial loss

Source: Bowden, A. R., M. R. Lane, et al. (2001). Triple Bottom Line Risk Management: Enhancing Profit, Environmental Performance, and Community Benefits. John Wiley and Sons. 314 pp.

2

OH&S Risk Assessment

Likelihood

Likelihood	Description
Very likely	It is expected to occur at some time in the near future (daily)
Likely	Will probably occur in most circumstances (weekly)
Possible	Might occur at some time (monthly)
Unlikely	Could occur at some time (six months to a year)
Highly Unlikely	May occur in exceptional circumstances (five years plus)

Consequence

Level	Description
Fatality	Death
Major injury	Extensive injuries, lost time injury >5 days , permanent disability (e.g. broken bones, major strains)
Minor injury	Medical treatment required, lost time injury from 1 – 5 days (e.g. minor strains)
First aid	First aid treatment where medical treatment not required (e.g. minor cuts and burns)
Negligible	Incident does not require medical treatment, property damage may have occurred

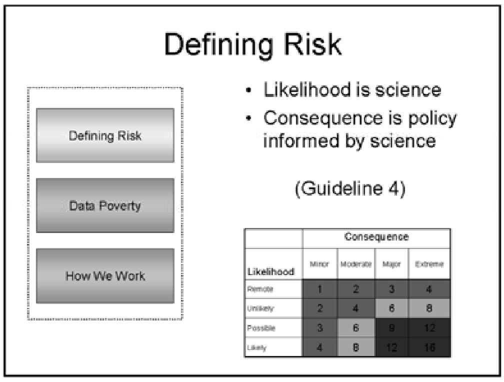
Source: http://www.safety.uwa.edu.au/policies/safety_risk_management_procedures

Pipeline Risk Assessment

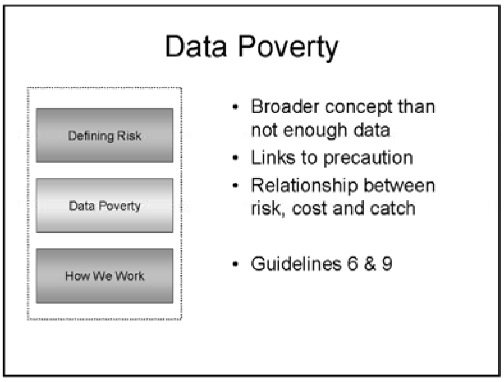
Risk score = (likelihood) x (consequence)
Likelihood = P1+P2+P3+P4

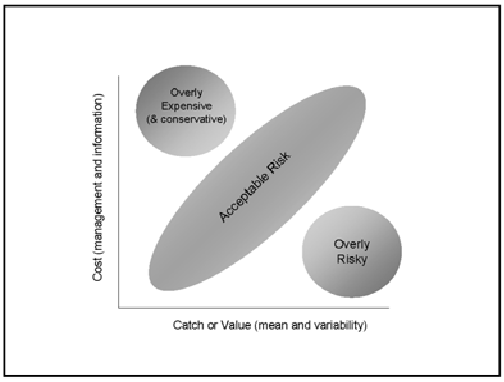
Equipment tag	Risk Score	Likelihood	Consequence	P1-external forces	P2-Corrosion	P3-Design issues	P4-Human error
Tank 101	154	77	2.0	22	19	25	11
Tank 315	146	76	1.9	21	24	22	9
Tank 655	235	49	4.8	14	17	16	2

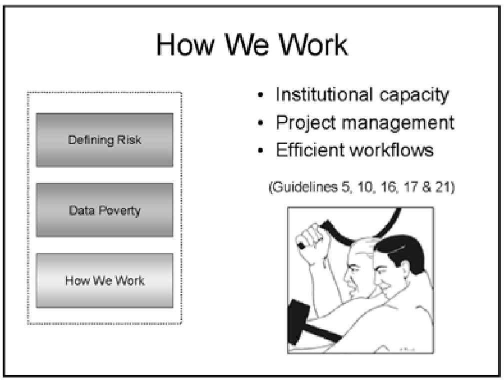
Source: Muhlbauer, W. K. (2004). Pipeline Risk Management Manual: Ideas, Techniques, and Resources. Gulf Professional Publishing. 395 pp.



Likelihood	Consequence: Minor	Moderate	Major	Extreme
Remote	1	2	3	4
Unlikely	2	4	6	8
Possible	3	6	9	12
Likely	4	8	12	16







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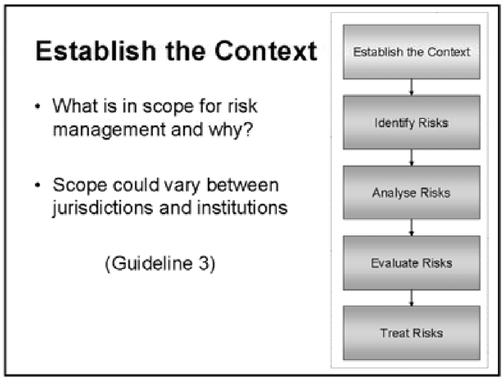
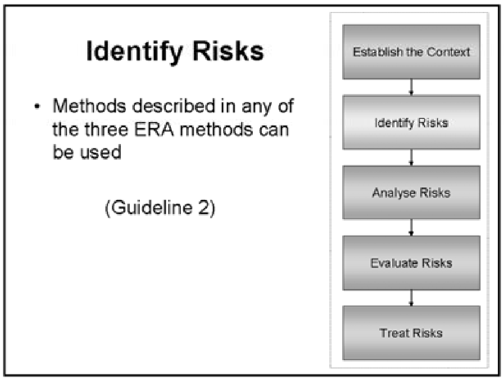
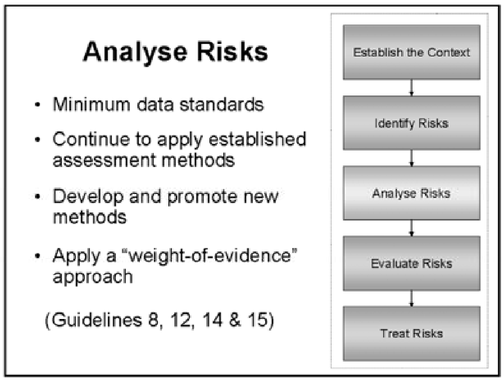
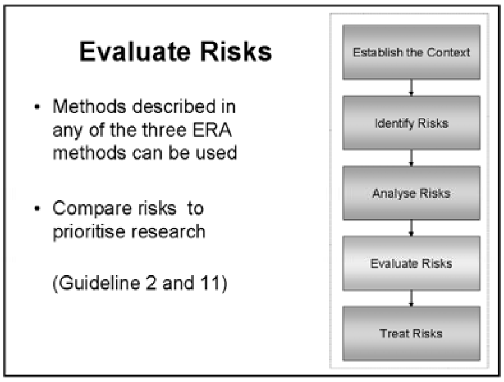
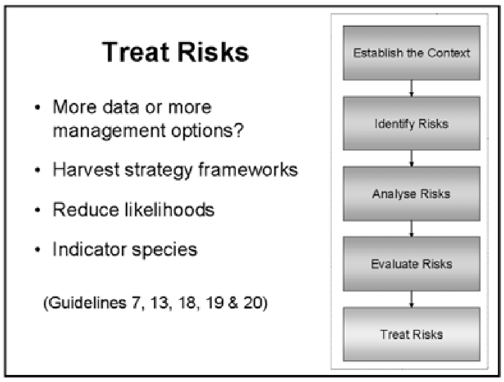

Establish the Context
• What is in scope for risk management and why?
• Scope could vary between jurisdictions and institutions
(Guideline 3)
Establish the Context
Identify Risks
Analyse Risks
Evaluate Risks
Treat Risks


Identify Risks
• Methods described in any of the three ERA methods can be used
(Guideline 2)
Establish the Context
Identify Risks
Analyse Risks
Evaluate Risks
Treat Risks

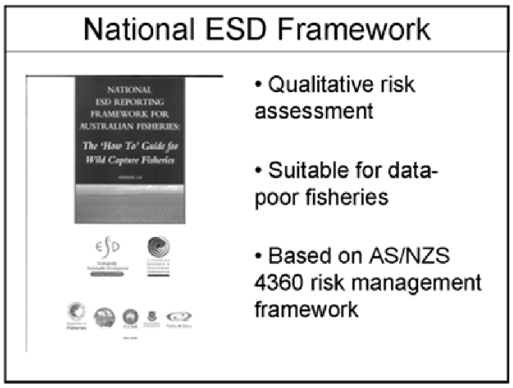

Analyse Risks
• Minimum data standards
• Continue to apply established assessment methods
• Develop and promote new methods
• Apply a "weight-of-evidence" approach
(Guidelines 8, 12, 14 & 15)
Establish the Context
Identify Risks
Analyse Risks
Evaluate Risks
Treat Risks

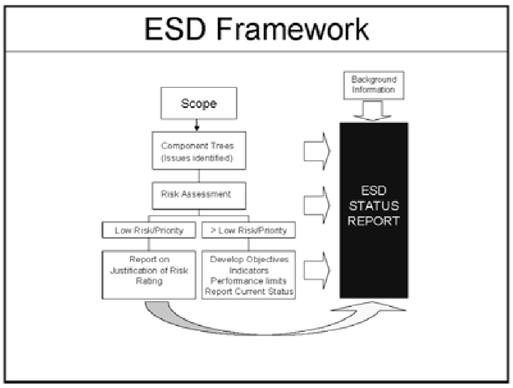

Evaluate Risks
• Methods described in any of the three ERA methods can be used
• Compare risks to prioritise research
(Guideline 2 and 11)
Establish the Context
Identify Risks
Analyse Risks
Evaluate Risks
Treat Risks

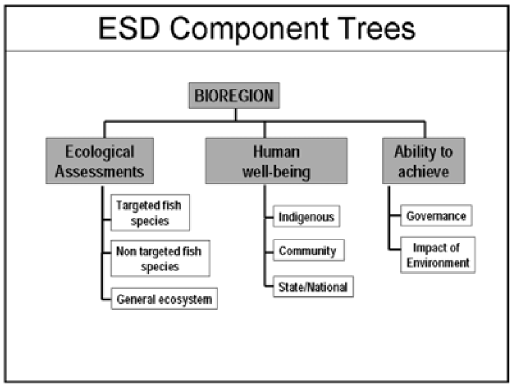

Treat Risks
• More data or more management options?
• Harvest strategy frameworks
• Reduce likelihoods
• Indicator species
(Guidelines 7, 13, 18, 19 & 20)
Establish the Context
Identify Risks
Analyse Risks
Evaluate Risks
Treat Risks

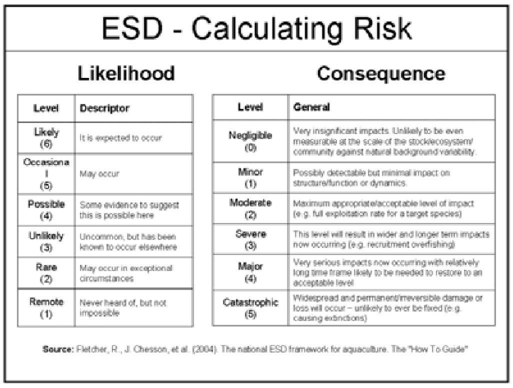
4

ERA Methods Summary Presentation









Level	Descriptor
Likely (6)	It is expected to occur
Occasional (5)	May occur
Possible (4)	Some evidence to suggest this is possible here
Unlikely (3)	Uncommon, but has been known to occur elsewhere
Rare (2)	May occur in exceptional circumstances
Remote (1)	Never heard of, but not impossible

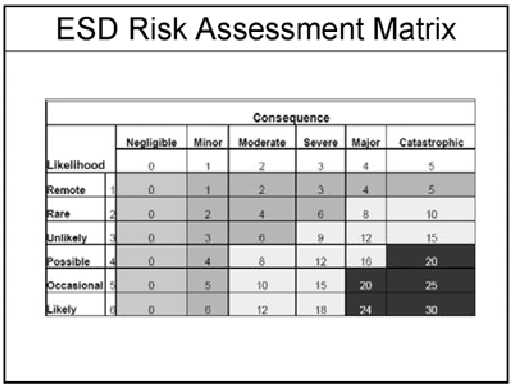
Level	General
Negligible (0)	Very insignificant impacts. Unlikely to be even measurable at the scale of the stock/ecosystem/ community against natural background variability.
Minor (1)	Possibly detectable but minimal impact on structure/function or dynamics.
Moderate (2)	Maximum appropriate/acceptable level of impact (e.g. full exploitation rate for a target species)
Severe (3)	This level will result in wider and longer term impacts now occurring (e.g. recruitment overfishing)
Major (4)	Very serious impacts now occurring with relatively long time frame likely to be needed to restore to an acceptable level
Catastrophic (5)	Widespread and permanent/irreversible damage or loss will occur – unlikely to ever be fixed (e.g. causing extinctions)

Source: Fletcher, R., J. Chesson, et al. (2004). The national ESD framework for aquaculture. The "How To Guide"

ERA Risk Rating: Impact on breeding stocks (C2 L5 MODERATE)

Red emperor and goldband snapper (Family Lutjanidae) have in common several life history traits – protracted longevity, slow growth, low rate of natural mortality, relatively large size and age at maturity – that make them more vulnerable to overfishing than other shorter-lived demersal fish species. These two species fetch high market prices and so are consistently targeted by trap and line fishers in the Kimberley region. In 2002, the median estimates of total spawning biomass of the two indicator species, red emperor and goldband snapper, in the Kimberley region were 54% and 41% of the estimated virgin levels, respectively. These levels were both above the recommended target level of 40% of the virgin spawning biomass and the breeding stock was considered adequate at the current catch levels. Whilst the estimated lower limit of the 95% confidence interval for the level of spawning stock biomass for goldband snapper was below the target level of 40% of the virgin spawning biomass, it was above the 30% limit reference point. The precise relationship between stock size and recruitment is unknown for each target species but assumed to be similar in form to other longer-lived lutjanid species.

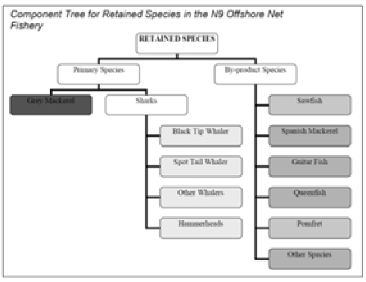
Given the vulnerable nature of each of the target species to over-fishing, it was considered that the NDSMF could be having a '**moderate**' impact on the stocks of each long-lived target species but the likelihood of this occurring was considered to be only an '**occasional**' outcome given the management in place. This resulted in a risk rating of **MODERATE**.



		Consequence					
		Negligible	Minor	Moderate	Severe	Major	Catastrophic
Likelihood		0	1	2	3	4	5
Remote	1	0	1	2	3	4	5
Rare	2	0	2	4	6	8	10
Unlikely	3	0	3	6	9	12	15
Possible	4	0	4	8	12	16	20
Occasional	5	0	5	10	15	20	25
Likely	6	0	6	12	18	24	30

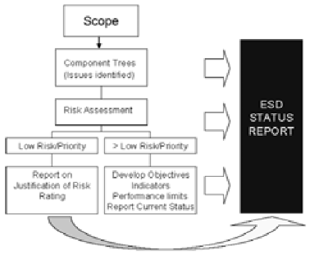
1

ESD Component Trees

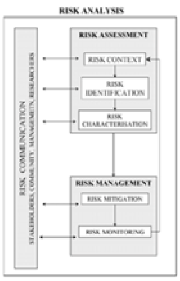


Source: Ecological Risk Assessment of Queensland-managed Fisheries in the Gulf of Carpentaria

ESD Framework



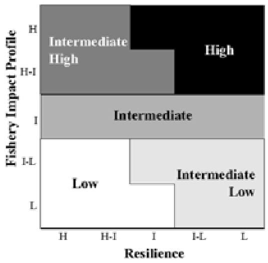
NSW QERA Method



Source (Astles, 2006 #1)

- Qualitative environmental risk assessment suitable for data-poor fisheries
- Based on AS/NZS 4360 standards
- Consequence set, risk = likelihood

NSW QERA Matrix



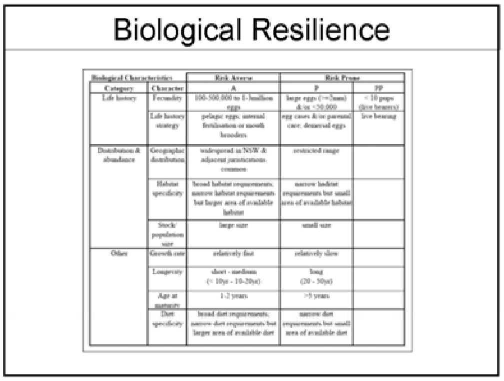
Biological Resilience

- Reproductive strategy
  - Fecundity, egg size and type, larval type
- Distribution and abundance
  - Range, habitat specificity, intensity
- Growth and longevity
  - Productivity, population turnover

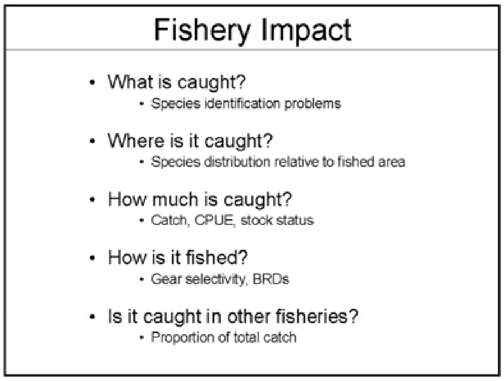
Biological Resilience

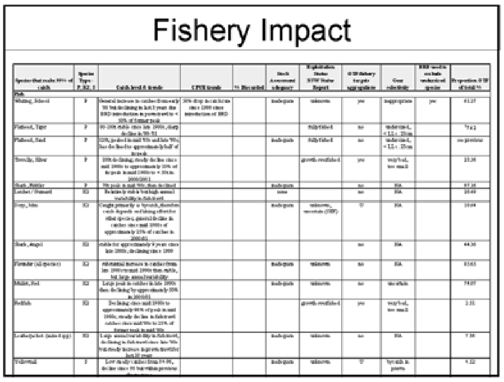
Species that make up 95% of landings	Species Type	Fecundity level	Reproductive/Life history strategy	Geographic distribution	Habitat specificity	Stocking size	Growth rate	Longevity	Size or Age at maturity
Fish									
Whiting, School	P	30-110	Larvae and eggs pelagic	Moreton Bay Q to SA including Tas	[illegible]		[illegible]	Short	[illegible]
Flathead, Tiger	P	1.5-2.5 mill	Larvae and eggs pelagic	[illegible]	[illegible]		[illegible]	Medium	[illegible]
Flathead, Sand	P	unknown	Larvae and eggs pelagic	[illegible]	[illegible]		[illegible]	Medium ?	[illegible]
Trevally, Silver	P	[illegible]	Larvae and eggs pelagic	[illegible]	[illegible]		slow	Long	[illegible]
Shark, Fiddler	P	[illegible]	Live bearing	[illegible]	[illegible]			Long ?	[illegible]
Latchet / Gurnard	B2	unknown	[illegible]	[illegible]	[illegible]			Medium ?	[illegible]
Dory, John	B2	unknown	[illegible]	[illegible]	[illegible]		rapid	Medium	[illegible]
Shark, Angel	B2	unknown	Live bearing	[illegible]	[illegible]			Long ?	[illegible]
Flounder (all species)	B2	unknown	[illegible]	[illegible]	[illegible]		unknown	Medium ?	[illegible]
Mullet, Red	B2	unknown	[illegible]	[illegible]	[illegible]		rapid	Short	[illegible]
Redfish	B2	unknown	[illegible]	[illegible]	[illegible]		slow	Long	[illegible]
Leatherjacket (mixed spp)	B2	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]
Yellowtail	[illegible]		Larvae and eggs pelagic	[illegible]	pelagic			Medium	[illegible]
Perch, Ocean	B2	[illegible]	[illegible]	[illegible]	[illegible]		slow	Long	[illegible]

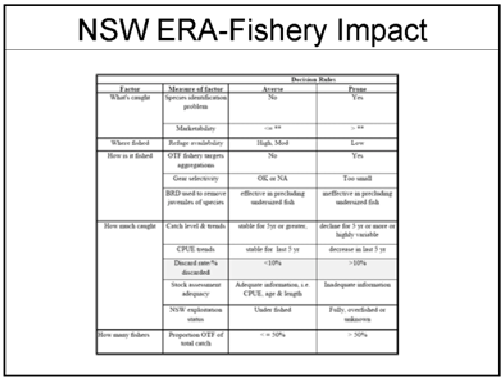
2



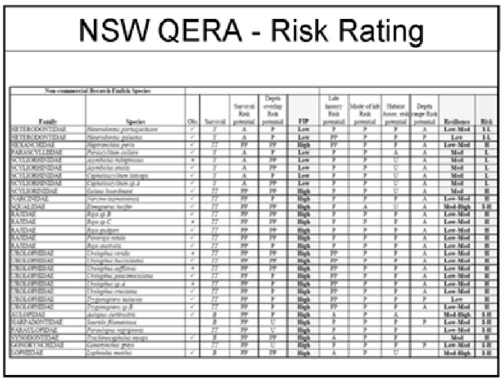
Biological Characteristics		Risk Averse	Risk Prone	
Category	Character	A	P	PP
Life history	Fecundity	100-500,000 to 1-3million eggs	large eggs (>=2mm) &/or <50,000	< 10 pups (live bearers)
	Life history strategy	pelagic eggs, internal fertilisation or mouth brooders	egg cases &/or parental care, demersal eggs	live bearing
Distribution & abundance	Geographic distribution	widespread in NSW & adjacent jurisdictions common	restricted range	
	Habitat specificity	broad habitat requirements; narrow habitat requirements but larger area of available habitat	narrow habitat requirements but small area of available habitat	
	Stock/ population size	large size	small size	
Other	Growth rate	relatively fast	relatively slow	
	Longevity	short - medium (< 10yr - 10-20yr)	long (20 - 50yr)	
	Age at maturity	1-2 years	>5 years	
	Diet specificity	broad diet requirements; narrow diet requirements but larger area of available diet	narrow diet requirements but small area of available diet	

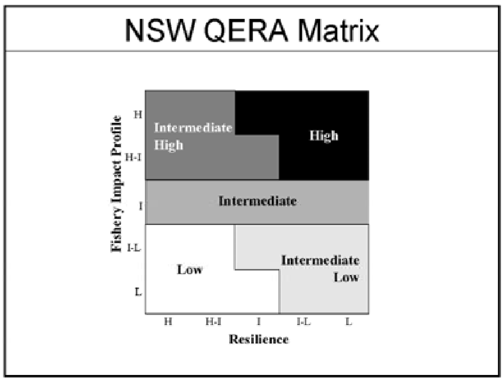




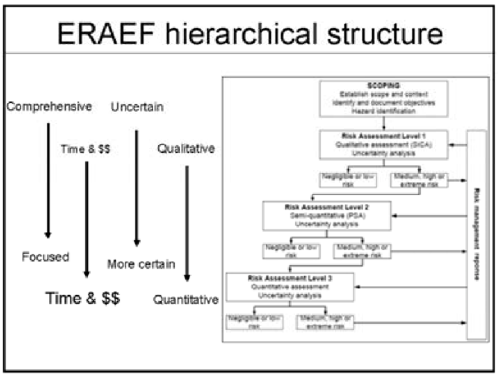


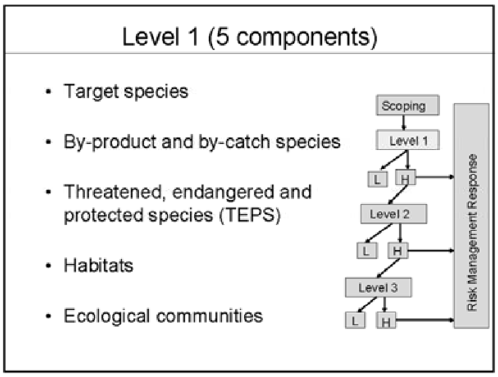
		Decision Rules	
Factor	Measure of factor	Averse	Prone
What's caught	Species identification problem	No	Yes
	Marketability	<= **	> **
Where fished	Refuge availability	High, Med	Low
How is it fished	OTF fishery targets aggregations	No	Yes
	Gear selectivity	OK or NA	Too small
	BRD used to remove juveniles of species	effective in precluding undersized fish	ineffective in precluding undersized fish
How much caught	Catch level & trends	stable for 5yr or greater.	decline for 5 yr or more or highly variable
	CPUE trends	stable for last 5 yr	decrease in last 5 yr
	Discard rate/% discarded	<10%	>10%
	Stock assessment adequacy	Adequate information, i.e. CPUE, age & length	Inadequate information
	NSW exploitation status	Under fished	Fully, overfished or unknown
How many fishers	Proportion OTF of total catch	< = 50%	> 50%

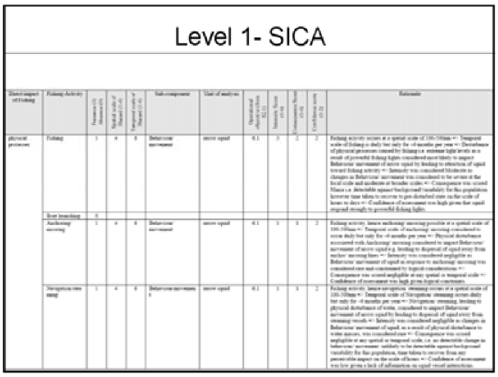


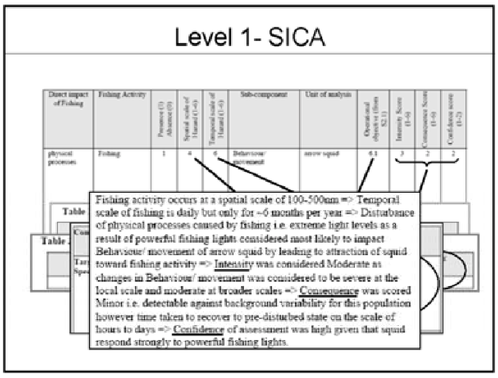


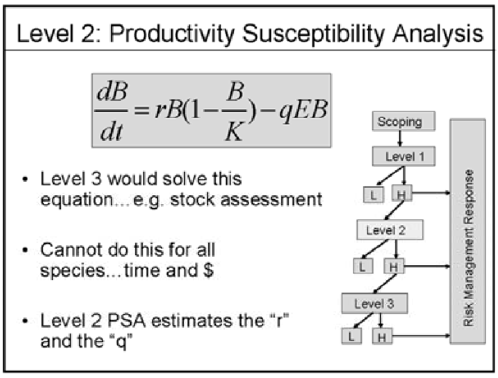

Hierarchical qualitative to quantitative risk assessment framework
Meets AS/NZS 4360 standards
Likelihood set, risk=consequence
ERAEF
Ecological Risk Assessment for the Effects of Fishing
Natural Heritage Trust
Australian Government
Australian Fisheries Management Authority
CSIRO


ERAEF hierarchical structure
Comprehensive
Uncertain
Time & $$
Qualitative
Focused
More certain
Time & $$
Quantitative
SCOPING
Establish scope and context
Identify and document objectives
Hazard identification
Risk Assessment Level 1
Qualitative assessment (SICA)
Uncertainty analysis
Negligible or low risk
Medium, high or extreme risk
Risk Assessment Level 2
Semi-quantitative (PSA)
Uncertainty analysis
Negligible or low risk
Medium, high or extreme risk
Risk Assessment Level 3
Quantitative assessment
Uncertainty analysis
Negligible or low risk
Medium, high or extreme risk
Risk management response


Level 1 (5 components)
Target species
By-product and by-catch species
Threatened, endangered and protected species (TEPS)
Habitats
Ecological communities
Scoping
Level 1
L
H
Level 2
L
H
Level 3
L
H
Risk Management Response


Level 1- SICA


Level 1- SICA
Fishing activity occurs at a spatial scale of 100-500nm => Temporal scale of fishing is daily but only for ~6 months per year => Disturbance of physical processes caused by fishing i.e. extreme light levels as a result of powerful fishing lights considered most likely to impact Behaviour/ movement of arrow squid by leading to attraction of squid toward fishing activity => Intensity was considered Moderate as changes in Behaviour/ movement was considered to be severe at the local scale and moderate at broader scales => Consequence was scored Minor i.e. detectable against background variability for this population however time taken to recover to pre-disturbed state on the scale of hours to days => Confidence of assessment was high given that squid respond strongly to powerful fishing lights.


Level 2: Productivity Susceptibility Analysis
$\frac{dB}{dt} = rB(1-\frac{B}{K}) - qEB$
Level 3 would solve this equation… e.g. stock assessment
Cannot do this for all species…time and $
Level 2 PSA estimates the "r" and the "q"
Scoping
Level 1
L
H
Level 2
L
H
Level 3
L
H
Risk Management Response

Level 2 - PSA

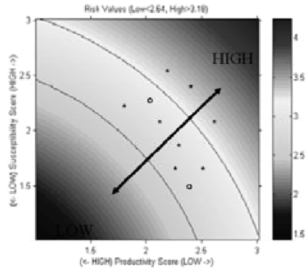
Productivity attributes

- Maximum age
- Age at maturity
- Size at maturity
- Annual fecundity
- Maximum size
- Reproductive strategy
- Trophic level

Susceptibility attributes

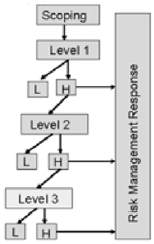
- Availability
  - Overlap with fishery
  - Global distribution
- Encounterability
  - Water column position
  - Depth range overlap
  - Adult Habitat
- Selectivity
  - Size at Maturity
  - Total records (+/-)
  - Post-capture mortality
  - Fate on discarding

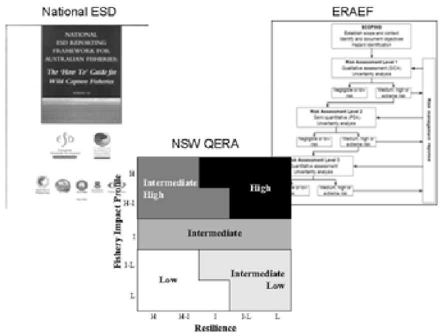
Level 2 - PSA



Level 3: Fully Quantitative

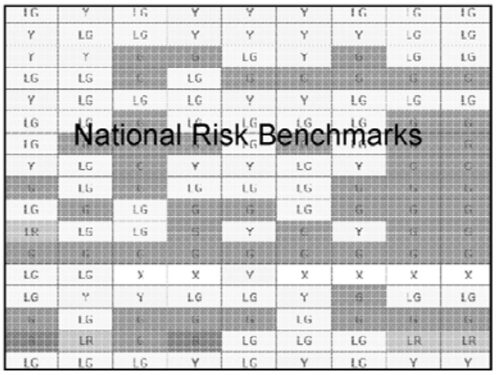
- Risk evaluated by fully quantitative in-depth scientific analysis
- Both time, data and expertise intensive
- Uncertainty incorporated into model structure and results
- e.g.
  - Quantitative stock assessments
  - Management strategy evaluations
  - Quantitative risk assessments (SAFE)
  - Ecosystem based modelling (e.g. Ecosim, Atlantis, InVitro)

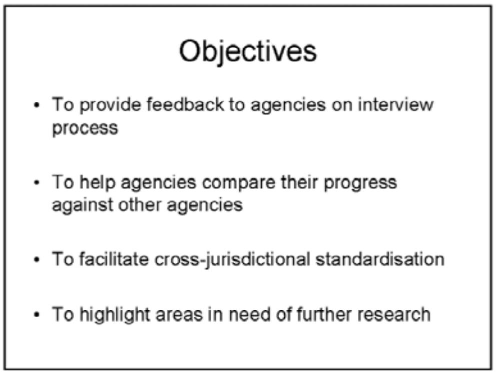


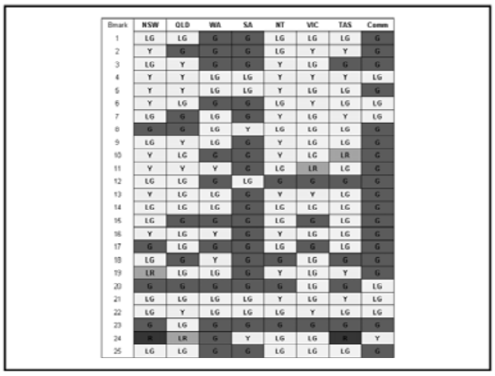


5

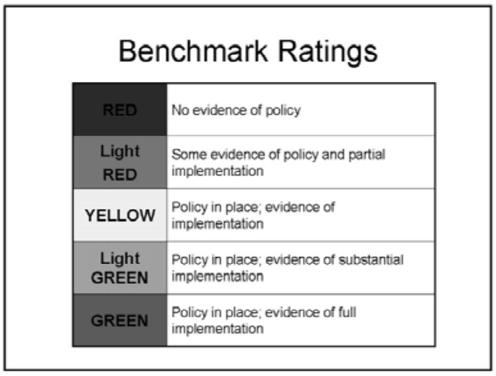
Benchmarks Presentation



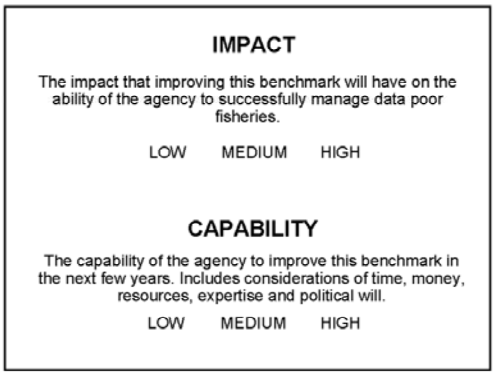


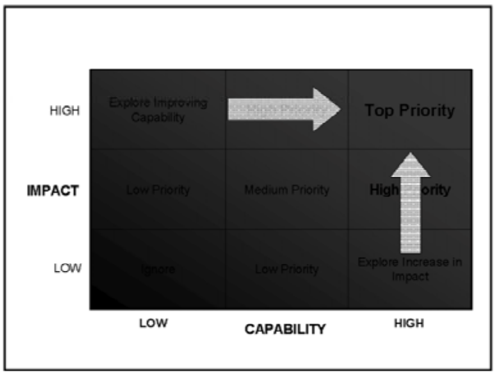


Bmark	NSW	QLD	WA	SA	NT	VIC	TAS	Comm
1	LG	LG	G	G	LG	LG	LG	G
2	Y	G	G	G	LG	Y	Y	G
3	LG	Y	G	G	Y	LG	G	G
4	Y	Y	LG	LG	Y	Y	Y	LG
5	Y	Y	LG	LG	Y	LG	LG	G
6	Y	LG	G	G	LG	Y	LG	LG
7	LG	G	LG	G	Y	LG	Y	LG
8	G	G	LG	Y	LG	LG	LG	G
9	LG	Y	LG	G	Y	LG	LG	G
10	Y	LG	G	G	Y	LG	LR	G
11	Y	Y	Y	G	LG	LR	LG	G
12	LG	LG	G	LG	G	G	G	G
13	Y	LG	LG	G	Y	Y	LG	G
14	LG	LG	LG	G	LG	LG	LG	G
15	LG	G	G	G	LG	G	LG	G
16	Y	LG	Y	G	Y	LG	LG	G
17	G	LG	G	G	LG	G	LG	G
18	LG	G	Y	G	G	LG	G	G
19	LR	LG	LG	G	Y	LG	Y	G
20	G	G	G	G	G	LG	G	LG
21	LG	LG	LG	LG	Y	LG	Y	LG
22	LG	Y	LG	LG	LG	Y	LG	LG
23	G	LG	G	G	G	G	G	G
24	R	LR	G	Y	LG	LG	R	Y
25	LG	LG	G	G	LG	LG	LG	G



RED	No evidence of policy
Light RED	Some evidence of policy and partial implementation
YELLOW	Policy in place; evidence of implementation
Light GREEN	Policy in place; evidence of substantial implementation
GREEN	Policy in place; evidence of full implementation



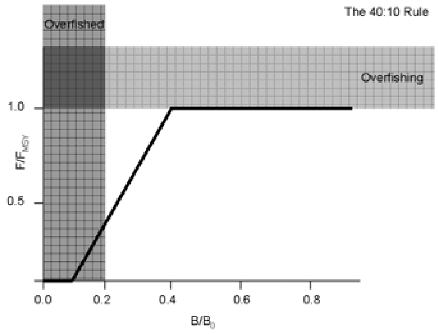


1

Data Poor Methods Presentation

Developments in Data-Poor Stock Assessment

- Rate versus state
- Life history – the fundamental link
- The Robin Hood approach
- New methods …

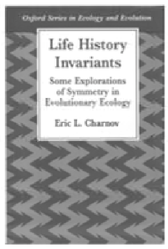


Rate vs State

- Overfishing versus overfished
- Current policy versus historical legacy
- Measuring F versus B
- F can be measured, F_{msy} can be estimated
- F_{msy} used as a limit reference point
- B cannot be estimated readily without recreational catches or contrasting data
- Indices of abundance will always be problematic or expensive or both

Life History – The Fundamental Link

- Growth, mortality, selectivity and recruitment are the key processes to understanding production
- ERA methods capture this information either qualitatively or quantitatively
- New stock assessment methods aim to leverage this approach into fully quantitative approaches



The "Robin Hood" Approach

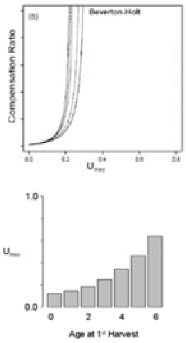
- Use data from "data-rich" fisheries to infer dynamics in data-poor species
- Linkages to meta-analysis
- Bayesian logic is ideal for this approach: data rich species provide priors for data poor species
- See Punt, Smith and Koopman (2002) Using information for 'data-rich' species to inform assessments of 'data-poor' species through Bayesian stock assessment methods FRDC Report 2002/094.
- Difficultly is that "data-poor" is often correlated with human resource-poor and expertise-poor

Forrest et al. (2008)

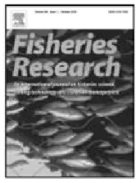
- Forrest, Martell, Melnychuk and Walters (2008). "An age structured model with leading management parameters, incorporating age-specific selectivity and maturity." *Canadian Journal of Fisheries and Aquatic Sciences* 65: 286-296.
- Enables estimation of the upper bound of U_{msy} (F_{msy}) from life history and selectivity parameters
- Enables estimation of U_{msy} (F_{msy}) if recruitment dynamics (shape and compensation) can be interpolated from a database of other species

1

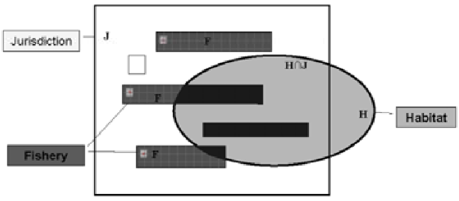
- No need for an informative time series of abundance
- Gives management a choice between decreasing F or increasing age at first capture to ensure F << Fmsy
- Clarifies issues with growth overfishing and recruitment overfishing



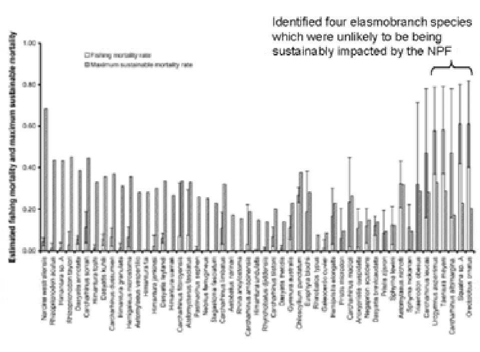
Zhou and Griffiths (2008)



- Zhou and Griffiths (2008). "Sustainability Assessment for Fishing Effects (SAFE): A new quantitative ecological risk assessment method and its application to elasmobranch bycatch in an Australian trawl fishery." *Fisheries Research* **91**(1): 56-68.
- Used the survey data, the contrast between fished and unfished grids in the NPF and estimates of natural mortality



- Used the survey data, the contrast between fished and unfished grids in the NPF and estimates of natural mortality
- With this information calculated
  - Maximum sustainable fishing mortality
  - Minimum unsustainable fishing mortality



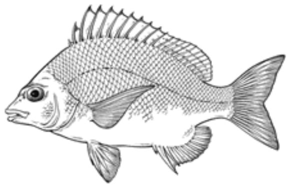
Final Comments

- Application of some sort of meta-analysis is unavoidable
- Improve management of life history data
- National sharing of data and expertise
- Some sampling issues may be intractable
- Resources will be allocated to habitat, ecosystem, social and economic issues

2

15.7. Appendix 7 – Workshop Case Study Examples

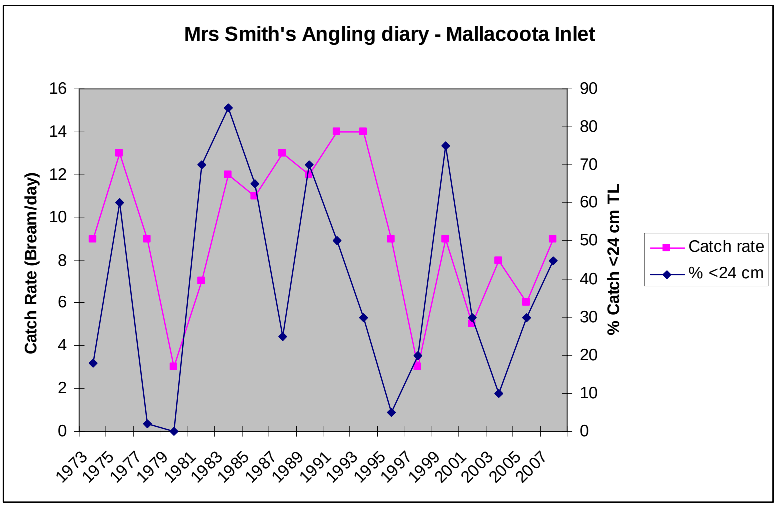
Mallacoota Inlet Black Bream Case Study



- Black bream (*Acanthopagrus butcheri*) is an endemic species which inhabit estuarine waters of southern Australia. Growth and recruitment of black bream is highly variable, factors contributing to this variability are unknown.
- Information from Victorian waters indicates life history parameters of:

Age at maturity	3 – 10 years (highly variable)
Maximum age, size	30 years, 65 cm, 4 kg
Size at maturity	Males 22 cm, Females 24 cm, MLL 26cm
Fecundity	300 000 – 3 million eggs

- Populations of black bream are confined to individual estuaries. Black bream are rarely found at sea, although some adult bream may migrate between estuaries (Hall, 1984). For management purposes populations are considered to be separate.
- The Mallacoota Inlet population is an important recreational fishery of black bream in Victoria. 2000/01 NRIFS data indicates that the estimated total annual retained catch of bream from Mallacoota Inlet was about 17 500 fish which represented about 40% of the total retained bream catch from the inlet that year. The commercial fishery in Mallacoota Lakes was closed in 2003, so harvest is now entirely from the recreational sector.
- The best available data to assess population status comes from a handful of detailed angling diaries, which show consistent trends, an example of which is shown below.

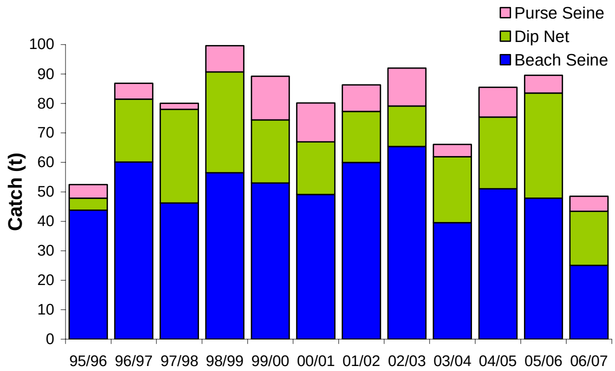


- These data indicate that population abundance is not influenced by changes in the fishery, rather it is directly related to juvenile abundance. The survival of black bream larvae appears to be heavily dependent on suitable salinity and water temperature conditions as well as food and habitat availability. There is no data on environmental conditions over time in Mallacoota Lakes, however it is assumed that the variability seen is a result of environmental variation from draught, flood or other events.
- Although the data suggests that the Mallacoota Inlet Black bream population is not largely effected by fishing effort, it is important that management responds to periods of low recruitment to ensure that fishing does not add undue pressure at those low abundance times. Therefore, to ensure sustainability of the population, managers need to develop some performance indicators or trigger points for managing black bream in the Mallacoota Inlet.

Garfish Case Study

- The southern sea garfish (*Hyporhamphus melanochir*) is caught almost exclusively by beach seine on the north-east coast (> 85%), but mainly by dipnets off the south-east and east coasts (70%). After years of relative stability in garfish catches at between 70 – 90 tonnes, production almost halved in 2006/07 to only 49 tonnes. Decreases were experienced for the both main fishing methods and in all major fishing regions. Beach seine and dipnet effort fell markedly compared to 2005/06 and overall effort for both methods remained relatively low compared to the reference period. Catch rates for beach seine and dipnet have also fallen, but since sea garfish is a schooling species, catch rate trends are unlikely to be sensitive indicators of abundance.
- There are three existing reference points for commercial catch and effort data:
  1. State-wide or regional catches outside the 1990/91 to 1997/98 range (56 – 92t);
  2. State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98;
  3. State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98.

  - Only the catch reference point was exceeded.
  - These existing reference points are proposed to be replaced with just one reference point for catch outside a recent reference range from 1998/99 to 2005/06 (66 – 102t).
  - The reference point for indications of stock stress has not been assessed (the last biological samples were collected in the mid 1990s).
- Industry members indicated that the catch declines during the 2006/07 fishing year were caused by a lack of fish stocks, although plenty of undersized fish were reported. The reason for this remains unclear given a relatively long period of apparent stability in the fishery and underlying fish stocks.
- Some industry members have also expressed concern about the effects of dipnets on the schooling behaviour of garfish. It has been suggested that intensive dipnet activity tends to cause schools to break up reducing opportunities to use beach seines to target the species and possibly affecting catch rates. Such interactions are localised and analyses at the spatial resolution of fishing blocks are unlikely to be sensitive enough to detect such impacts.



Commercial catch for garfish

Catch by Method	*N.E. Coast*	*E. & S.E. Coast*
Beach Seine	> 85%	
Dipnets		70%
Rec	?	?

Garfish life history

Age at maturity	F: 2 – 3 years
Maximum age	F: 8 years; M: 7 years
Size at maturity	F: 280 mm (?)
Maximum size	45 cm (unsexed) 0.5 kg
Fecundity	10,000 eggs
Size limit	250 mm
Bag limit	30

Spawning occurs over an extended period from October to February but reaches a peak in December

Landed Catch by Species 2006/07

	Catch (tonnes)
Scallop	4,294
Abalone	2,502
Garfish	49

15.8. Appendix 8 – Workshop Evaluation Form

FRDC Risk Project Workshop Evaluation

This information is being collected to assess the effectiveness of these workshops in meeting their objectives. The information collected will be compiled and included in the final FRDC report. Responses will be anonymous and individuals will not be identifiable.

Do you primary identify yourself as a: ☐ Fisheries Manager ☐ Fisheries Scientist

Proposed Guidelines

Principle 1 – Defining risk

The risk guidelines clarified my understanding of "risk management" for fisheries

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

Comments:____

I believe it will be possible for us to generate risk ratings for species that are consistent and comparable across fisheries and jurisdiction:

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

Comments:____

Principle 2 – Data poor fisheries

I was satisfied with the guidelines interpretation of a "data-poor species":

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

Comments:____

I see the need for a minimum level of information for stock or resource assessment:

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

Comments:____

Principle 3 – Scope, Implementation & Interpretation

I now better understand the role of risk in the prioritisation of research:

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

Comments:____

I believe the "weight of evidence" approach can be used to manage the fisheries that I am involved with:

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

Comments:____

Case Studies

Which case study (write name) did your sub-group use in the workshop? ____________________

The case studies were useful for illustrating the use of the guidelines:

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

Comments:____

____

15.9. Appendix 9 – Classifying the Risks in Fisheries Management

Classifying the Risks in Fisheries Management

S. A. Gray[1], M. C. Ives[2], J. P. Scandol[2], and R.C. Jordan[1]

[1]Rutgers University, Ecology and Evolution Graduate Program, 14 College Farm Road, New Brunswick, NJ 08901
[2]Wild Fisheries Research Program, NSW Department of Primary Industries, Cronulla Fisheries Centre PO Box 21, Cronulla NSW 2230

Abstract

The risks associated with the management of marine fisheries are attributable in part to the substantial uncertainties that exist within fishery systems. Adding to these uncertainties is the differences between individual's understanding of the concept of "risk". This paper examines risk identification as reported by fishery scientists and managers in Australia (AU) and along the U.S. Atlantic Coast (US) in an effort to: (1) define the risks identified by fisheries professionals (2) compare the identification of risk by professional group and by country and; (3) identify within a model of fishery management where these risks are located. Risk identification provides a way to identify where within agencies different types of risks are being managed, as well as to highlight areas of concern that exist across political, ecological, and social boundaries. In this paper, we identify three broad categories of risk, Unarticulated, Managed, and Institutional and 12 subcategories. These categories and subcategories are based upon 40 semi-structured interviews with fishery scientists and managers in two countries (US = 18 and AU = 22). We conclude that: (i) fisheries management risks can be broadly identified based on frequency of identification through interview data; (ii) The risks identified by individuals are reflective of the management system in which they operate, however significant differences were not found between professional roles within that system; (iii) investigations into the perceptions of the risks should be conducted routinely since conceptions are likely to change with new developments in the fisheries management environment; and, (iv) the risk of political influence may undermine other risk-based methods applied to fisheries and this is an area that would benefit from further research.

Introduction

Research into risk in fisheries management has grown in recent years, primarily because of the increasing realization that exploitation of marine resources may lead to stock collapses and, in some cases, commercial or biological extinction (Charles, 1998, Dulvy *et al.*, 2003, Hutchings and Reynolds, 2000, Roberts and Hawkins, 1999, Walters and Maguire, 1996, Worm *et al.*, 2006). Although risk within the fishery system has been widely acknowledged by researchers, a comprehensive understanding of the risks that are identified by the different professional groups involved is not well understood (Smith 1988). Methods of risk management are contingent on the types of risks being identified, which can change over space and time and vary between individuals and groups (Althaus, 2005, Delaney and Hastie 2007, Harms and Sylvia 2001, Peterman 2004). Past research has highlighted the importance of articulating definitions of potential risks within fisheries management while recognizing that perceptions may change by individual and by group. For example, in Peterman's (2004) study of standardized risk assessment procedures for fisheries, he stresses that "to avoid misunderstandings, fisheries scientists, managers, and stakeholders should always clearly state what they mean by the term risk" (p 1332). Additionally, in a comparative review of fishery scientists, management, and industry members from the United States West Coast groundfish fishery, Harms and Sylvia (2001) found a variation in the perception of the underlying resource between groups. They highlight the need for the alignment of the interests of industry, scientists, and managers when conducting effective science and management in order to achieve consensus about the perceived issues. Francis and Shotton (1997) stress 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 to deal with risks to the often conflicting (but rarely articulated) way in which risk is dealt with during management.

A number of quantitative (Groger *et al.* 2007, Hilborn *et al.*, 1993, Hilborn *et al.*, 2001, Pearsons and Hopley 1999, Puga *et al.*, 2005, Punt and Hilborn, 1997, Punt and Walker, 1998, Rosenberg and Restreno, 1994, Touzeau *et al.*, 2000, Walters, 1986) and qualitative (Astles *et al.*, 2006, Astles, 2008, Fletcher *et al.*, 2005, Francis, 1992, Hobday *et al.*, 2004) risk-based methods have been integrated into fisheries management as a way to mitigate potential undesirable outcomes associated with fisheries and as a means to prioritise scientific activity. These methods, however, usually limit their scope to the biological and ecological risks associated with fishing and fail to incorporate other risks recognised by scientists and managers such as those associated with the imperfect nature of the assessment and management processes. If the adoption of formalized risk methods in fisheries is to continue it is therefore important to: (1) identify the risks that are being articulated by professionals in research and management; and, (2) examine to what extent these perceptions vary in order to develop a risk-framework that incorporates all individual conceptions of the risks present. Understanding what risks are routinely identified may prove helpful and add clarity to the often ambiguous portrait of risk shown to be present in the fisheries management organisations where we conducted our interviews. Here we attempt to develop such a clarification by categorizing responses from semi-structured interviews with fisheries professionals in Australia and the United States into categories and domains.

Fisheries Management

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 and Wilson, 1996, McCay and Jentoft, 1996). Fisheries management in both Australia and the United States 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 U.S. 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 the fishery management process is expected to differ among management participants because the goals, priorities, values, and players in these areas differ (Adam *et al.*, 2000).

Australian Fishery Management

In Australia, federal legislation such as the *Fisheries Management Act* 1991 requires that marine fish are managed with the goal of ecological sustainability within the Australian Fishery Zone (AFZ) of 3 – 200 nautical miles. Australian fisheries resources within the AFZ are managed under both Commonwealth and State/Territory legislation. Management of these fisheries is usually carried out through the development of some type of management plan for each commercial fishing activity operating (FAO, 2003, Sainsbury *et al.*, 2000, Scandol *et al.*, 2005). Management plans specify major goals and objectives for a fishery and include management responses that are designed to achieve these goals and objectives, present performance indicators and trigger points, and highlight any research required. Developing management plans requires consultation with key stakeholder groups (e.g., commercial fishers, recreational anglers, non-governmental groups) through various types of consultative structures such as stakeholder-based advisory committees.

State and territory fisheries agencies, which also manage all inland fisheries and fisheries within three nautical miles of the coastline, have similar types of arrangements as the Commonwealth but have the additional responsibility of managing recreational fisheries. For a full description of fisheries management in Australia see McPhee (2008).

United States Fishery Management

The United States (US) fishery management system mirrors that of Australia's in several ways. In the Federal Exclusive Economic Zone (EEZ) within 3 to 200 nautical miles, management is guided by the *Sustainable Magnuson-Stevens Fishery Conservation and Management Act* 1976 (and most recently the *Re-Authorization Act* 2006). This legislation established eight multi-state regional councils to guide management to end overfishing through the development of Fishery Management Plans (FMPs). U.S. federal fishery legislation outlines the goals of fisheries management, which is to end overfishing by way of management measures including a variety of input and output controls tailored to each fishery. Similar to the Australian system, these plans are developed with considerable consultation with technical staff, fishery managers, independent scientists and stakeholder groups. FMPs serve as strategic plans that are meant to balance social and biological interests through an iterative process of development. This process is expected to result in a management plan that is ratified (or revised) by the United States Department of Commerce. The development of an FMP in the U.S. follows a similar format to that in Australia. First, the scoping process earmarks a species to be managed. Then FMPs are drafted and recommendations are made from technical staff about the status of a stock. After peer review of the draft FMPs, the plans are revised, and then ratified by regional councils before being proposed as a plan of action to the federal government. In the U.S., stakeholders (such as recreational and commercial anglers, fishing industry representatives and other key non-government organizations) are invited to participate in the process from the initial data collection phase, in the capacity of an advisory committee to the regional councils, and finally by commenting on proposed control measures.

Individual states within the U.S. have their own fisheries management arrangements as well as cooperative agreements between coastal states. Along the Atlantic Coast, the Atlantic Coast Marine Fisheries Commission (ASMFC) serves as a deliberative body, coordinating the conservation and management of the shared coastal (0 to 3 nautical miles) fishery resources. As with the U.S. federal management system, individual states and the ASMFC proceed with management through a blending of stakeholder consultation, scientific assessment of the fish stocks, and management decisions meant to achieve the social and biological goals of fisheries. The ASFMC, however, is not federally mandated by the *Magnuson Stevens Act*.

Differences in Australia and the United States

Despite the similarities in structure and approaches of the two nations there are a number of subtle differences between the two. A number of Australia's jurisdictions have policies for cost recovery (AFMA, 2004) where research, management and compliance costs are partially recovered from industry. This constrains funding for activities such as biological research, monitoring and compliance to reflect the economic value of the fishery. The American system has no similar formal mechanisms in place. Further, Australia's *Environment Protection and Biodiversity Conservation Act 1999* requires strategic environmental assessment of fishing activities to be approved by the Commonwealth Department of the Environment, Water, Heritage and the Arts before export permits for a fishery's products are issued. The U.S. has not established such stringent regulations on fisheries export. Finally, recreational fisheries management is performed by the states and territories in Australia with federal management organizations only addressing commercial fishing while in the U.S. both recreational and commercial fisheries are often jointly managed.

Methods

This project focuses on risk identification by fishery scientists and managers on the Atlantic Coast of the United States (15 states from Maine to Florida, including Pennsylvania) and in all 6 Australian states as well as the Northern Territory. All fisheries professionals interviewed were involved in the management or scientific assessment of fish stocks in both state (0 – 3 nautical miles) and/or federal (3 to 200 nautical miles) waters. In total, 40 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). In Australia, interview participants included 12 fisheries scientists and 10 fisheries managers while the U.S. Atlantic coast interviews consisted of 10 fisheries scientists and 8 fisheries managers ($n = 40$). The term fisheries ***scientists*** in both countries refers primarily to stock assessment scientists while the term ***managers*** 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 Delaney and Hastie, 2007 and Wilson *et al.*, 2002). 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; (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 patterns in the identification of risk within their professional schema and the third question was designed to elicit specific identifications of risk with which they might currently be engaged. Only the answers to these first three questions were used for this present study. The full interview was used as part of a separate project designed to develop national risk management guidelines for data poor fisheries. In all, the survey instrument included 24 questions with some questions more appropriate for managers (dealing with decision making) and others better suited for scientists (aimed at assessment and technical analyses).

Since the identification of specific risk categories within fisheries management is, to our knowledge, not well developed, the analysis in this paper focuses broadly on: (1) defining 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 within a general model of fisheries management. Individual participants in this study remained anonymous but each individual was identified as either a manager or scientist from either Australia or the U.S.

Analysis Methods

Participant responses were coded using a post-coding technique (Miller, 1983) to identify emergent themes. There were four steps to the coding process. First, project researchers discussed common themes based on field notes and interview experiences. From these discussions, general lists of re-occurring identifications of risk were developed. Second, researchers reviewed a sample of the transcribed interviews from both nations to verify the initial categories and identify additional subcategories (categories mentioned less often during interviews). Third, all transcribed interviews were then coded for the identification of risk by two different researchers. Finally, the results were discussed by the researchers until agreement was reached on the coding applied.

Quantitative comparisons were then undertaken between countries and between professions to determine to what extent the identification of risk varied between groups. Since 12 separate non-exclusive categories emerged through data analysis, the highest possible score for any categorization would be 40 (since N = 40), whereas the highest possible score for any one individual's identification of risk would be 12 (since 12 categories emerged). Finally, statistical methods were used to determine whether the scoring for each group were significantly different from each other.

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 (SPE); ecological (ECO); and social (SOC) since their answer explicitly mentions risk associated in his work with individual "species," "the environment" as well as "the fishers" respectively.

Risk Identification within a Generalized Fishery Management Model

Once the domains of risk were identified, they were placed within the Generalized Fisheries Management Model (GFMM) to determine where identifications of risk converged or diverged between the groups. Fisheries management involves similar steps in both countries (McCay and Creed, 1999, McPhee, 2008). In the GFMM we have broken the risks identified into three broad categories including uncategorized risks (which are undefined or broadly defined), managed risks (which are the ecological and socio-economic risks being managed) and institutional risks (which are the risks associated with the institutions developed to reduce the managed risks). These broad categories are broken down further into 12 subcategories, described in more detail below.

This process of systematic interpretation and arrangement of coded interview data has been shown to be a useful analytical tool when representing knowledge and perception about the status of marine resources (Ozesmi and Ozesmi, 2004, Rochet *et al.*, 2008).

Results

Qualitative Categories of Risk in Fishery Management

Fisheries management in Australia and the U.S. involves a system of scientists, managers and stakeholders contributing in various capacities to develop a plan of how marine fisheries are to be harvested. In a complex system such as fisheries (which involve multiple dynamic components interacting at various temporal and spatial scales), the identified categories are not exclusive because all categories are connected and influence each other to varying degrees. However for the purposes of this study to clarify the concept of risk, three broad categories and 12 subcategories of risk in fisheries management were identified (Table 1). An explanation of each of these categories and sub-categories follows.

Table 13. Summary of the risk coding instrument. Transcribed interviews yielded 3 main categories of risk in fisheries management and 12 subcategories. The ranking shows the risk category identified most often was the risk to the species being managed (SPE) and least often was the unarticulated risk (UNA).

Risk Category and Subcategory	Definition	Rank by Frequency of Response
I. Uncategorized Risk		
(a) Unarticulated **(UNA)**	Risk is mentioned in talking, but not often articulated. Risk is a "problem".	11
(b) Broadly Defined or Likelihood and Consequence **(BROAD)**	Risk is everywhere; it is the backbone of fisheries management. Fisheries management is risk management. Likelihood and consequence.	10
II. Managed Risk		
(a) Species or Stock Level **(SPE)**	Risk of a decline to a species/stock.	1
(b) Ecosystem Level **(ECO)**	Risk to the "environment"/habitat or ecosystem	6
(c) Economic, Social or Individual **(SOC)**	Risk to Industry/the economy. Risk to society or individual (someone's livelihood).	8
III. Institutional Risk		
(a) Legislative **(LEG)**	Risk of not meeting legislative objectives or requirements as outlined by law.	6
(b) Data Collection/Management **(DATA COL)**	Risk in the collection of data (not appropriate, misguided, biased, sparse).	3
(c) Data Analysis **(DATA AN)**	Risk in the methods used to analyze data (wrong methods, high degree of uncertainty in the output).	2
(d) Management Objectives **(MGT)**	Risk of not meeting management objectives. Not meeting management goals as outlined through legislation.	3
(e) Stakeholder Influence/Political Influence **(POL)**	Risk of biasing decisions in face of stakeholder pressure. Risk of politicizing the process and clouding judgment.	5
(f) Science-Management Interface **(SMI)**	Risk of inappropriate communication/understanding during the science and management interface.	10
(g) Implementation Uncertainty **(IMP U)**	Risk that management decisions will not have the desired outcome (risk of stakeholder compliance or management action not having the desired effect).	9

<u>I. Uncategorized: Risk is everywhere, informal or implicit</u>

The Uncategorized risks that were identified were divided into two main areas, namely unarticulated and broadly defined.

Ia. **Unarticulated risk**
The **Unarticulated** risk subcategory includes statements that alluded to risk being discussed in informal terms (e.g., risk is implicit, talked about) and did not involve the phrases *"risk is"*, *"risk to"*, *"risk from," or "risk in"* explicitly, nor was it clear that risk was found in any specific domain of fisheries management. **Unarticulated** risk was identified 22.5% of the time.

Unarticulated risk example:
"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." – U.S. Manager.

Ib. **Broadly defined** risk
In this category risk was identified as being either: 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). **Broadly defined** risk was identified by 35% of interviewees.

Broadly defined risk example:
"Risk is probability times consequence." – Australian Scientist.

<u>II. Managed risk: Risk to the biological and social systems being managed</u>

Managed risk refers to identified risks to the biological and social systems. Potential loss of productivity of these systems is arguably the impetus for institutional fisheries management in both countries (Hatton *et al.*, 2006). The risks associated with this category are defined generally and are best characterized by the acknowledgement that fisheries management is designed to reduce risks to the ecosystem, fisheries and society. When identifying this risk, many participants would discuss specific stock assessments or case studies that directly pertain to a particular managed species as a way to articulate risks that they had encountered in their work.

IIa. **Species/Stock-level** risk
Species/Stock-level risk was identified as the potential harm to the sustainability of a species or stock. Species or stock-level risk was mentioned by most (75%) of the study group.

IIb. **Ecosystem-level** risk
Ecosystem risks included harm to the general ecosystem including species beyond those targeted by fishers (such as by-catch), and habitat destruction from fishing gear. This risk was mentioned by 42.5% of the interviewees.

Ecosystem-level risk example:
"[There exists] a risk of ecological damage and risks to the entire ecosystem" – Australian Scientist.

IIc. **Social** risk
Any mention of socioeconomic, individual livelihood or individual risk was categorized in a third category as social risk. **Social** risk was identified somewhat less frequently at 40% and included 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 example:
"… 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." – U.S. Manager.

III. Institutional: Risks that arise from the practice of fisheries management

Institutional risks are those created through the formal processes of managing marine fisheries (i.e., trying to reduce biological and social risks). Institutional risks were divided into seven subcategories which reflect the management system established to address the managed risks found in the fishery system.

IIIa. **Legislative** risk: the risks of not meeting requirements as outlined in U.S. 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 later risk arises due to legislated objectives sometimes being ambiguous because of problems with normative or unscientific language and due to society's uncertain expectations for the environment (Duarte-Davidson *et al.* 2006). Participants that identified risk in this manner 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% of interviewees.

Legislative risk example:
"With the new Magnuson [Act] we have to develop recommendations to meet the letter of the law" – U.S. Manager.

IIIb. **Data collection** risk: the risk associated with the incorrectness of data collected for assessment work.
This risk is the first of two subcategories identified that are associated with the risk from the quantitative and qualitative methods employed to assess the status of the biological or social systems through data collection and data analysis. **Data collection** risk is the risk of gathering inappropriate, misguided, biased, or sparse datasets for risk/stock assessment work. It was identified by 55% of interviewees.

IIIc. **Data Analysis** risk: the risk associated with the correctness of scientific assessment work.
Data Analysis risk relates primarily to quantitative assessment work and refers to the risks associated with the methods used to analyze data, such as stock assessments. The risk is that such assessments may be incorrect or extrapolated beyond their utility and thus lead to incorrect advice being given to managers. **Data analysis** risks were mentioned in 62.5% of the interviews.

Data Collection and Data Analysis risk example:
"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
The risks associated with not meeting management objectives was identified by over half (55%) of the respondents. **Management objectives** risk differs from the risk of not meeting legislative requirements in that management objectives may be separate from legislative requirements. This could be the case when management objectives attempt to meet legislative requirements while taking into account current institutional requirements. Management objectives may also be in addition to legislative requirements as the later are usually quite general and require the specific details embodied in management objectives. Not meeting management objectives was usually discussed in terms of not simultaneously balancing biological and social interests.

Management objective risk example:
"Ultimately for fisheries the risk they should be concerned with is the risk of not meeting your management objectives as written in the legislation." – Australian Scientist.

IIIe. **Political Influence** risk: the risk associated with unbalanced political influences compromising current management objectives.
The fifth category of institutional risk involves risks associated with political influence over the decision-making process and was identified by 47.5% of the participants. This risk includes the mention of factors that influence or bias management decisions in the direction of a stakeholder group(s). The risk involved with this step is that of disproportional access in the management outcome to favour one stakeholder group at another's expense.

Political influence risk example:
"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." – U.S. Scientist.

IIIf. **Science/Management interface** risk: the risk associated with unbalanced political influences compromising current management objectives.
The risk of inappropriate communication or understanding during the science/management interface was mentioned by 35% of interviewees. These risks were primarily identified as those of misinterpretation or misunderstanding by managers of information provided by scientific assessments, including the levels of uncertainty presented in the scientific assessments.

Science/Management interface risk example:
"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" – U.S. Scientist.

IIIg. **Implementation uncertainty** risk: the risk associated with the management actions not producing management objectives.
Finally, the risks associated with implementation uncertainty was mentioned by 37.5% of participants. The risks associated with this last subcategory involved the risk that the management measure chosen did not have the desired effect on the fishery system. 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. Uncertainty obviously plays a large role in each of the risk subcategories mentioned above, however the uncertainty associated with this particular identification is specific to the effectiveness of management actions.

Implementation uncertainty risk example:
"There is a view that no matter what we do at the management table, Mother Nature will have a greater impact as to what happens." – U.S. Manager.

Overall Risk Identification

To determine trends and identify areas of divergence or convergence, coded responses for all groups were graphed by frequency by combining total manager and scientist counts for each country. This yielded a single score for each country in each category measured (Figure 1). Overall results indicate that the most often identified risk in fisheries management was that of the species or stocks being managed (75%). This was followed by the risks associated with the analytic methods used to determine the status of those stocks (62.5%); data collection for those analyses (55%); and the risks associated with management decisions (55%). The risks identified least often were in the subcategories of unarticulated (22.5%); broadly defined risks (35%); and the risks associated with the science-management interface (35%).

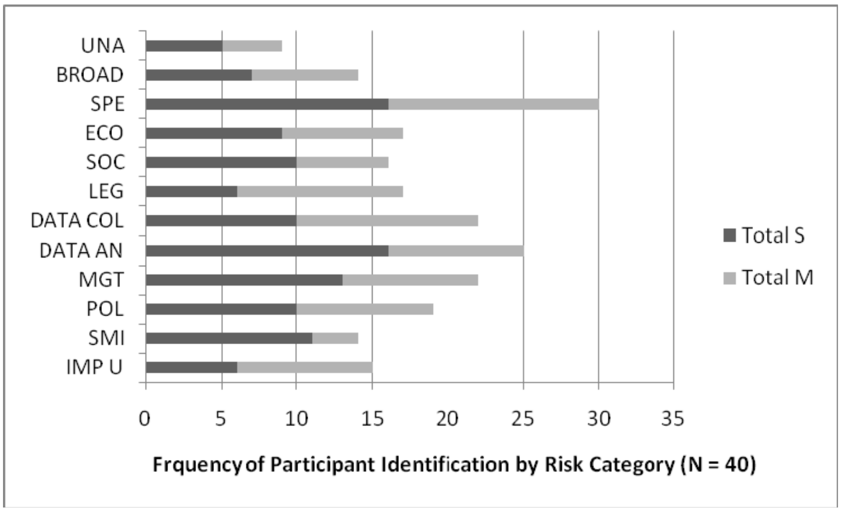


Figure 18. Frequency of coded responses to categories for all groups combined.

Comparison between Australia and the U.S. Atlantic Coast

Coded responses were also compared between Australia and the U.S. Atlantic Coast. The following ratios are listed as percentages (AU: US) for comparison since 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, AU scientists comprised 55% of AU total, US scientists comprised 54% of US total).

In the three main categories of risk, the American interviewees reported risk in more *Uncategorized* terms than did the Australian interviewees (Australian 5%:US 44%) while broad risk was identified more by Australians (45:22). *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 of significance indicates that Australians and Americans differ in the broad risk categories of Managed ($p < 0.001$; Fishers Exact Test – FET) and Institutional risk ($p = 0.003$, FET), however, Unarticulated risk yielded negligible difference ($p = 0.14$, 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 (Figure 2A and 2B). The following ratios are listed as percentages by professional role in management, which varies proportionally: (Scientist: Manager). *Uncategorized risk* found similar scores between scientists and managers with unarticulated (23:22) and broadly defined risk (32:39) yielding comparable results. *Managed* risk also showed some similarity with species (73:78) and ecosystem (41:44) scores alike, although scientists recognized more often social risks (45:33). *Institutional* risk yielded somewhat divergent results 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 (50:27) more often. Overall, scientists and managers responses were not found to be significantly different in their identifications of Unarticulated ($p = 0.081$, FET), Managed ($p = 0.144$, FET) or Institutional risk ($p = 0.08$, FET).

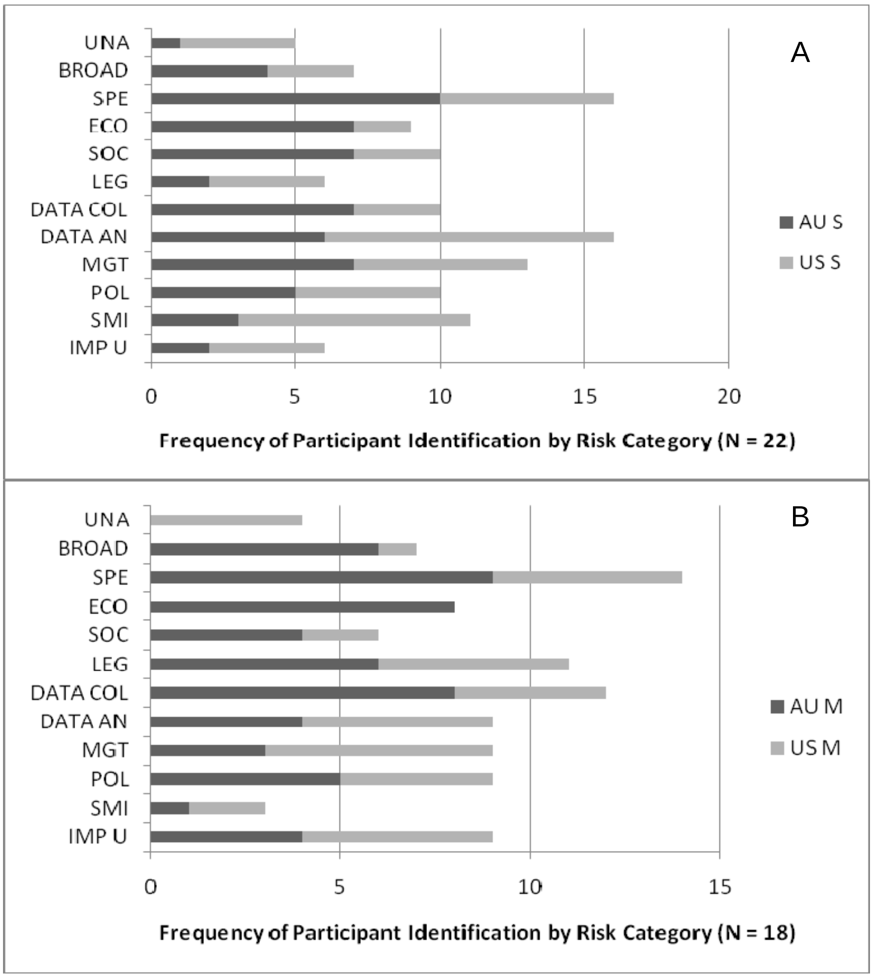


Figure 19. Frequency of coded responses to categories for Australian and US: A Scientists; B Managers.

Risk within the Generalized Fishery Management Model

Results from scientists and managers were combined to measure the total number of participants who identified each type of risk. These 12 categories were then placed in an order fitting the GFMM (Figure 3). Unarticulated or broadly defined risk is listed first since potential, perceived, or actual loss is often the impetus for management of natural resources. The managed risks to the biological and social systems that are addressed by the management system are then listed as these risks pertain to the generally agreed upon goals of fisheries management. Finally are the institutional risks that are the risks involved in the very processes by which marine fish are formally managed.

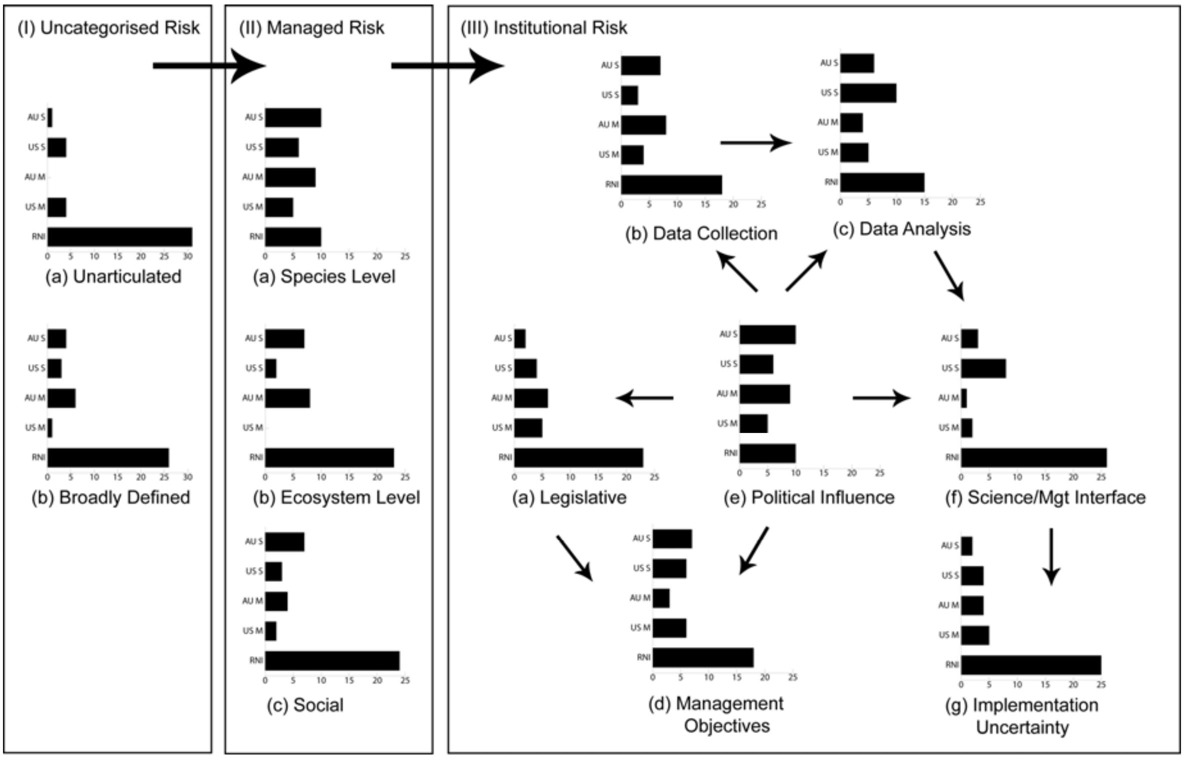


Figure 20. Identified categories risk overlaid upon a generalized fishery management process model. Charts indicate the count of identified risk categories by group. The most frequently identified risk categories were: (IIa) species-level; (IIIc) data analysis; (IIIb) data collection and (IIId) management objectives.

Discussion

Possibly the most important finding from this study is that each category and subcategory was identified by each of the two national groups and the two professional groups. This indicates that although variation in risk identification was found among groups, the risks that must be addressed in the management of fisheries were identified to some extent by all groups. Differences in risk identification are most likely attributable to subtleties that exist on finer scales of fisheries management in both countries as broad comparisons did not yield statistically significant differences. For example, the U.S. overall identified risk more often in uncategorized terms than did Australians. This is possibly due to Australia's recent integration of qualitative risk-based frameworks (Astles *et al.*, 2006, Astles, 2008, Fletcher *et al.*, 2005, Hobday *et al.*, 2004) into assessments following the export requirements of the Department of the Environment, Water, Heritage and the Arts. This strategic assessment process promoted risk management in fisheries and defined risks (at least to some extent) in quite explicit terms. Americans also mentioned institutional risks such as legislative risks, more often than Australians. This is possibly attributable to recent developments within the U.S. system such as the 2006 Re-Authorization of the *Magnuson's Stevens Act*.

Beyond species, ecosystem-level and assessment phase risks, it is interesting to note that the risks of not meeting management objectives and the risks associated with political influence are identified frequently regardless of professional role or nation. The risks associated with political pressure have multiple points of influence within institutional risk (as shown in Figure 3). They are also difficult to isolate within one step of the management process as there are many possible designs of systems for enabling stakeholder participation. While participatory management is considered to increase transparency, accountability, and robustness of management decisions by incorporating stakeholder knowledge and concerns into the process (Kaplan and McCay, 2004), it has also been shown to change support and direction of management decisions and contribute to unfavorable or "risky" outcomes (Dudley, 2008). Further, political influence may have the power to decrease the efficacy of other risk-based methods since the risk arising from investment in a more participatory process may marginalize risk management applied in other areas – such as increased data collection or data analysis. 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 little data is being collected and few or no standardized procedures exist.

As fisheries continue to move towards formalized methods to address issues associated with the potential impacts of marine fishing, it is important to define the risks that various stakeholders bring into this debate (Francis and Shotton, 1997, Harns and Sylvia, 2001). This paper provides a categorization of risks from the perspective of fishery management 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, tackle and bait shop owners, and non-governmental organizations. For example, through an analysis of interview data with commercial fishermen, Smith (1988) concludes that commercial fishermen's perceptions of risk arise primarily from "non-fishermen" (e.g., sports fishermen, economists, politicians, biologist, 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 further refine how other groups involved (beyond those engaged in professional management) articulate and perceive risk in fisheries.

Interview-based analyses, such as those presented here, are subject to a number of possible biases (Fowler 1984; Converse *et al.* 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 minimized by the fact that the questions were designed for a larger study and both interviewee and interviewer were unaware that this information would be used for a categorization of risk. However, interviewer bias could have occurred since U.S. 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. Even though each respondent was told that the interviews would be anonymous, their answers could have been biased by the respondents' awareness that they were being taped and thus may have tailored their answers to reduce any possible risk to their job or professional standing.

Conclusion

The complexity found within fishery systems has long been acknowledged but is rarely taken into consideration in routine fishery management decisions (Dudley, 2008, Garcia and Charles, 2008). Therefore it is important for professionals to work toward understanding shared identifications of the different conceptions of risks so that divergent and convergent concepts can be articulated. Refining the definition(s) of risk from the perspective of the groups involved adds clarity to an ambiguous construct that might otherwise prove difficult to manage (Francis and Shotton, 1997). The primary lessons learned from this study can be summarized as follows:

(i) Risks in fisheries management can be broadly categorized based on the frequency of identification through interview data.

(ii) The risks identified by individuals are reflective of the management system in which they operate, however significant differences were not found between professional roles within that system.

(iii) Investigations into the perceptions of the risks should be conducted routinely since conceptions are likely to change with new developments in the fisheries management environment.

(iv) The risk of political and stakeholder influence may undermine other risk-based methods applied to fisheries and is an area that would benefit from further research.

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