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Review and refinement of an existing qualitative risk assessment method for application within an ecosystem-based management framework

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The adoption of risk-based methodologies is considered essential for the successful implementation of an ecosystem approach to fisheries and broader aquatic management. To assist with these initiatives, one of the qualitative risk assessment methods adapted for fisheries management over a decade ago has been reviewed. This method was updated to ensure compliance with the revised international standards for risk management (ISO 31000) and to enable consideration of ecological, economic, social, and governance risks. The review also addressed the difficulties that have been encountered in stakeholder understanding of the underlying concepts and to increase the discipline in its application. The updates include simplifying the number of consequence and likelihood levels, adopting graphical techniques to represent different consequence levels, and discussing how changes in uncertainty can affect risk scores. Adopting an explicit "weight of evidence" approach has also assisted with determining which consequence scenarios are considered plausible and, where relevant, their specific likelihoods. The revised methods therefore incorporate the conceptual elements from a number of qualitative and quantitative approaches increasing their reliability and enabling a more seamless transition along this spectrum as more lines of evidence are collected. It is expected that with continued application of these methods, further refinements will be identified.

Keywords: consequence, ecosystem approach, fisheries, likelihood, qualitative assessments, risk analysis, risk assessment, risk management, stock assessment, weight of evidence.

Introduction

Taking an "ecosystem" approach for the management of natural resources is increasingly recognized as most appropriate because it considers all relevant ecological, economic, social, and governance issues to deliver holistic community outcomes (FAO, 2002, 2003, 2012; Bianchi and Skjoldal, 2008; Bianchi *et al.*, 2008). With such a wide scope, an extremely large and diverse set of issues can be identified which often generates concern among managers, especially those with limited resources (FAO, 2009, 2012; Link, 2010; Fletcher and Bianchi, 2014). The use of some form of risk assessment to at least filter the different types of ecological issues has therefore increased substantially over the past decade (e.g. Fletcher *et al.*, 2002; Fletcher, 2005; Patrick *et al.*, 2009; Hobday *et al.*, 2011; Zhou *et al.*, 2011; MSC, 2014). This trend is consistent with growing recognition that fisheries and aquatic management are just specific forms of risk management (Francis and Shotton, 1997; Fletcher, 2005, 2008).

Risk management involves the explicit consideration of risks in all decision-making processes with risk assessment core to this by providing evidence-based information and analyses to help make informed decisions of the adequacy of current controls in achieving objectives (IEC, 2009; ISO, 2009; SA, 2012). The lack of available information for many issues is often seen as an impediment to completing formal risk analyses, including the completion of basic stock assessments for data-poor species. However, with the ISO definition of risk updated to "*the effect of uncertainty on objectives*" (ISO, 2009), examining risk now includes the clear articulation of objectives and the level of uncertainty generated from having incomplete information (IEC, 2009; SA, 2012). Uncertainty can be explicitly incorporated within the analysis of risk by utilizing methods capable of using all available quantitative and qualitative data (IEC, 2009; Linkov *et al.*, 2009; SA, 2012).

Risk analysis, which is a critical part of the risk management process, involves consideration of the causes and sources of risk to achieving the objectives of an "organization" (which, in an aquatic resource management context, would include stakeholders and the relevant management agency). It also includes an examination of the magnitude of the potential consequences and the probability (likelihood) that those consequences will occur given current management controls (ISO, 2009; SA, 2012). One of the many qualitative risk analysis methods that conforms to these requirements is the consequence–likelihood (probability) matrix (IEC, 2009; SA, 2012). This C × L method is widely used as a screening tool in many fields, especially when a large number of potential risks may be identified (IEC, 2009; SA, 2012). This makes it highly suitable to cope with the large number of ecological, social, economic, and governance issues identified using an ecosystem approach. This method was first adapted for use in fisheries management within Australia over a decade ago (Fletcher *et al.*, 2002; Fletcher, 2005; Fletcher *et al.*, 2005) and has subsequently been applied in many other locations (e.g. Cochrane *et al.*, 2008; Fletcher, 2008; FAO, 2012). It has even been considered one of the ten "must be read" methods supporting the implementation of the ecosystem approach to fisheries (Cochrane, 2013).

Since its initial adaptation, this C × L method has been continually amended to better enable its use with ecosystem-based approaches for developing fisheries (e.g. Fletcher, 2008; FAO, 2012), regional-level, management-planning frameworks (e.g. AFMF, 2010; Fletcher *et al.*, 2010; MEMA, 2013), and for whole-of-agency risk-management systems (Fletcher *et al.*, 2012). Successive guidelines have included refinements that deal with the differing scopes of these frameworks and also address the difficulties often encountered with its implementation. This iterative process of improvement has resulted in many major enhancements being identified compared with the original published versions.

This review outlines the most significant updates made to each of the steps in the qualitative risk assessment process originally outlined in Fletcher *et al.* (2002) and Fletcher (2005). The key updates include (i) incorporating changes in the terminology and techniques now contained within the updated versions of the international standards for risk assessment and risk management; (ii) a summary of the main difficulties encountered when applying this methodology and descriptions of the refinements designed to improve clarity and consistency in terminology usage leading to an increased level of discipline and rigor when completing the analyses and evaluations; (iii) an expansion in the scope of the assessments to cover ecological, economic, social, and institutional components and their associated objectives to meet the requirements for full implementation of the ecosystem approach; (iv) an outline of how to integrate this methodology with the outputs generated from other assessment methods frequently used in fisheries management.

The outlined refinements, based on experiences gained in a wide variety of situations over the past decade (see references above), especially when embedded within a whole of agency risk management system, are expected to increase the efficiency, comprehensiveness, and robustness of the outcomes generated by the risk assessment process. This should improve both the timeliness and acceptance of any resultant management decisions, but most importantly, lead to better outcomes for aquatic natural resource managers and their respective communities.

Methods

The main activities undertaken in this review were to (i) examine the terminology that is used within the risk assessment documentation and compare this with the updated ISO standards, (ii) identify the key improvements that facilitate undertaking this form of risk analysis, and (iii) expand the scope of the methods to enable the assessment of the additional objectives covered by the ecosystem approach.

(i) *Terminology*: The qualitative risk assessment methodologies originally outlined in Fletcher *et al.* (2002) and Fletcher (2005) were based on risk management standard AS/NZ 4360 (SA, 2000, 2004). These international standards for risk management, risk assessment, and communicating and consulting about risk have subsequently been updated to ISO 31000 and ISO 31010 (IEC, 2009; ISO, 2009; SA, 2010, 2012). The specific methods and operational principles presented within fisheries and aquatic management risk assessment guidelines or presentations were therefore reviewed to ensure that the terminology, definitions, and techniques were fully compliant with these new standards (Table 1). Where appropriate, text from the various standards has been directly incorporated into the amended descriptions for each step in the risk assessment process. It should be noted, however, that alternative risk management frameworks and their definitions are available (e.g. ICES, 2013).

(ii) *Risk assessment techniques:* Based on considerable experience gained over the past decade from completing or facilitating assessments, undertaking training exercises, answering many queries, and developing a series of guidelines for different situations, the descriptions for each step in the risk assessment process have been updated. Areas where problems in the application of methods or interpretation of outcomes have most consistently been encountered were selected for specific examination. For each of these, the underlying basis for the errors or confusion was identified and descriptions of the refinements, which were developed to overcome these issues, were presented, together with examples.

(iii) *Objectives and scope of assessments:* The consequence tables were revised to ensure that they accommodated the broad range of objectives covered by the ecosystem approach (FAO, 2012). In addition to the set of ecological tables presented previously (Fletcher, 2005), an expanded set of consequence tables was compiled based on the common types of issues and high-level social, economic, and governance objectives frequently encountered across multiple country and fishery situations. The suite now not only allows for the assessment of risks associated with all aspects of the fishery but also extends to cover the factors affecting the internal governance and operations of the management agency and the industry.

Results

Risk assessment vs. risk management

The risk assessment process, which is an essential part of implementing a risk management system (Figure 1), includes three steps; risk identification, risk analysis, and risk evaluation. It is important to note that, while the other steps in the risk management process are not specifically covered in this review, they are all necessary to

Table 1. Definitions of risk management terms and their numbering as presented in the ISO 31000 (2009) plus notes on common issues to improve consistency of use within an ecosystem approach.

Standards, definition (and reference number)	Frequent issues
Risk (2.1) is the effect of uncertainty on objectives. It is often expressed in terms of a combination of the consequences of an "event" or "events" and the associated likelihood of the consequence actually occurring	This definition is much narrower than general public usage. It is commonly used instead of other more appropriate terms—threat, likelihood, vulnerability etc. It must be linked to meeting a specific management objective.
Context (2.9) defining the external and internal parameters to be taken into account when managing risk, and setting the scope and risk criteria	This includes the description of what is to be managed, the stakeholders that may be affected, the high level objectives to be achieved, the levels of acceptable impact (including their attitude to risk), and the timelines to assess risk. These must be established before completing a risk assessment
Risk assessment (2.14) includes the overall process of risk identification, risk analysis, and risk evaluation	
Risk identification (2.15) is the process of finding, recognizing, and describing risks. This may involve the identification of risk sources (2.16; the elements with the potential to give rise to risk), and/or events (2.17; their causes and potential consequences)	This step includes the identification of the issues, threats, impacts, and drivers that may affect the achievement of objectives—and therefore the risk. During this step, some of risk context elements may want to be re-examined
Risk analysis (2.21) is the process used to determine the magnitude or level of risk (2.23) which is expressed in terms of the combination of consequences and their likelihood	This is the most critical step, and it is therefore often thought of and incorrectly described as being the entire risk assessment step
Consequence **(**2.18) is the outcome of an event (2.17—which can include one or more occurrences of the event or even consist of something not happening) affecting objectives. It can be certain or uncertain, have positive or negative effects on objectives, and be expressed qualitatively or quantitatively	Most consequences will be described as different levels of impact for an asset. The separation points will be determined by what levels of impacts are considered acceptable for meeting the objective
Likelihood (2.19) is the chance of something happening and can be measured objectively or subjectively, qualitatively or quantitatively. It is used with the same broad interpretation as the term "probability" but less mathematical	This term is often misunderstood. It is not the likelihood of an event or activity but the specific likelihood a specific consequence actually occurring within the specified time frame.
Risk evaluation (2.24) is the process of comparing the results of a risk analysis with risk criteria (2.22; the reference levels against which the significance of a risk is evaluated) to determine whether the risk and its magnitude is acceptable or tolerable	Based on the risk score or level, this determines whether the current set of management actions needs to be change or increase, decrease, or remain the same

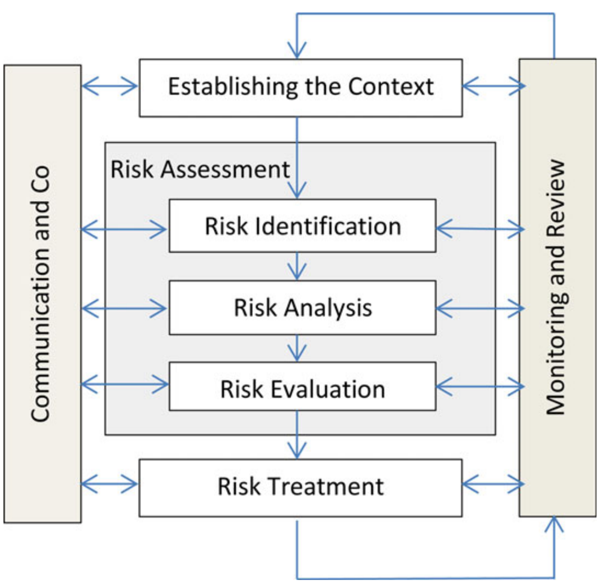

Figure 1. Position of risk assessment within the risk management process (modified from SA, 2012).

the overall success of the risk management process. Critically, unless the risk context, including the scope of management (which defines which activities, stakeholders and geographical extent will be covered), the objectives to be delivered, the time frame for the assessment, and what is considered acceptable performance have all been established, it is not possible to undertake a valid risk assessment. The various methods available to assist with the development of the risk context for a fishery or other aquatic activity plus the development of suitable risk treatments (the other two steps in the risk management process) are covered elsewhere (see FAO, 2012; Fletcher and Bianchi, 2014).

Definitions

Definitions of risk

Issue: The formal ISO definition of risk is now "*the effect of uncertainty on objectives*" (ISO, 2009). When applied to the ecosystem approach, a relatively high level should initially be taken by asking: "*What is the risk to meeting the agreed objectives for each asset (e.g. a fish stock or other ecological unit), outcome (e.g. food security, healthy community), system (e.g. management plan) from all the activities covered within the management system?*" (FAO, 2012).

As was previously identified by Francis and Shotton (1997), the word "*risk*" is used in a number of different ways. Many participants and stakeholders involved in risk assessment processes do not restrict their understanding or usage of the term "risk" to the international standards definition. The four most common alternatives being: (i) "*Threats*" such as too much fishing effort, or coastal pollution are often described as "*risks*". These are more formally described as the "events" or "risk sources" that can potentially generate a level of risk of not meeting an objective; (ii) rare or long-lived species are often described as being "*at risk*" rather than being more accurately described as "*inherently vulnerable*" to various risk sources; (iii) it is also common to hear that the "*risk*" of a stock collapse occurring is "*x*", rather than the more appropriate phrase that the "*likelihood*" of a stock collapse is "*x*" which generates "*y*" level of risk; and (4) finally, the maximum "*potential consequence*" that could eventuate in a situation can be incorrectly used as the level of risk irrespective of how small the likelihood is for that consequence level actually occurring.

While all these elements form essential parts of the risk assessment process, they should not be used as synonyms for risk. The lack of clarity generated from a high level of incorrect and inconsistent usage of these terms can add considerably to the confusion of participants, increasing the difficulties completing the risk assessment and potentially affecting acceptance of the outcomes.

Refinements: Given the increasing adoption of formal risk-based management and risk assessment methods in fisheries and aquatic management, it is recommended that consistency is increased by adopting the ISO terminology. The international standard definitions for each of the main terms used in risk management (ISO, 2009). The set of common issues for each of these that may be encountered when this method is applied are presented in Table 1.

Definition of likelihood and consequence pairs

Issue: Another common difficulty in terminology has been the incorrect understanding of how the term "likelihood" should be applied within the risk assessment process. It is often incorrectly assumed to refer to (1) the "likelihood" that a particular activity/event (i.e. catching a species, going fishing) will occur; or (2) the "likelihood" that a set of management arrangements is (or will be) adopted; or even (3) the "likelihood" that any level of consequence may occur. In a formal risk analysis context, however, the term likelihood should only refer to the likelihood that a specific consequence will occur (SA, 2012).

Refinements: The relevant guidelines have been modified to more clearly describe likelihood in the risk management context as—the conditional likelihood that a specific level of impact (consequence level) may occur within the defined time frame, given the current or proposed set of management arrangements either from an accumulation of small "events" and/or from a single large "event". This description emphasizes that the selection of likelihood and consequence levels must form a pair and they should not be chosen independently.

Risk identification

Overview description: Risk identification is formally defined as the process of finding, recognizing, and describing risks, which involves the identification of risk sources and events, their causes, and their potential consequences including those managed and not managed by the "organization" (ISO, 2009). The process of identifying risks must involve individuals who have relevant knowledge and this activity should occur within an appropriate environment that enables effective stakeholder participation (SA, 2010). To facilitate this outcome, a wide range of tools that assist with effective risk identification for an ecosystem approach are now available from the FAO EAF toolbox (FAO, 2012; Fletcher and Bianchi, 2014).

Issue: The high level of stakeholder engagement that occurs during risk identification for an ecosystem approach often results in a wide variety of matters being raised (de Young *et al.*, 2008; FAO, 2012). These can include stakeholders opinions of the desired state for the ecological assets (e.g. target stock and ecosystem health) the types of social and economic outcomes (e.g. food security, economic rent, safe working environments) stakeholders want the management system to deliver; and the effectiveness and efficiency of the governance system (e.g. administration, compliance, monitoring, research, etc.). In risk management terminology, these are the goals and objectives of the risk management activities (ISO, 2009) and they are part of establishing the risk context. It is common, however, that the risk identification workshops are the first occasions when the various components of the risk context are presented or openly discussed. If most stakeholders present do not agree with the management objectives or levels of acceptable impact that are presented, the risk analysis process will be problematic and the outcomes unlikely to be definitive. This may require additional consultative processes for their resolution.

Participants will also identify what they consider to be the threats, impacts, and drivers (e.g. too much fishing effort, the price of fuel, illegal fishing, unsafe working conditions) that may be affecting the assets to be managed and the outcomes they provide. These risk sources or events may be generating potential consequences for one or more objectives and therefore affecting the level of risk (ISO, 2009). Both of these types of matters are important, but to complete the risk analysis phase, they need to be sorted into their respective categories.

Refinements: The items identified during the stakeholder workshops can be clearly sorted into the two categories. The set of ecological assets and social/economic outcomes (goals and objectives) to be achieved are listed as columns in a table with each of the identified risk sources (impacts/threats/opportunities) to these objectives listed as rows (see FAO, 2012, www.fao.org/fishery/eaf-net, for more details). This approach has the advantage of illustrating that a single risk source/event can affect a large number of objectives and a large number of risk sources/events can often be affecting a single objective.

Risk analysis

Overview description: Risk analysis involves the consideration of the causes and sources of risk, their positive and negative consequences, and the likelihood that those consequences can occur (ISO, 2009). The potential consequences, likelihoods, and resultant levels of risk are all dependent on the effectiveness of the controls that are in place (SA, 2012). Undertaking risk analysis using the consequence–likelihood (C × L) methodology either involves multiplying the scores from qualitative or semi-quantitative ratings of appropriate consequence (levels of impact) and likelihood (levels of probability) of each of these consequences actually occurring from which a risk score and risk rating are calculated, or by directly assigning risk levels to each of the appropriate combinations of consequence and likelihood (IEC, 2009).

Determining the appropriate (plausible) combinations of consequence and likelihood scores should involve the collation and analysis of all information available on an issue. This will include (but is not limited to) the (i) inherent vulnerability of the ecological assets and the relative susceptibility of those assets to the various managed activities and other threats (risk sources/events) that may be affecting them; (ii) the level of uncertainty in the information available about the asset or the risk sources; (iii) the relative comprehensiveness and effectiveness of any current or proposed management systems in mitigating the effects of various threats or events; and (iv) the observed outcomes (lines of evidence) that results from these factors which, for captured species, often include the catch, size composition, and spatial distribution of effort (see example in Table 3). Based on the available information and the expert opinions from those involved (including stakeholders), the most appropriate combinations of consequence and likelihood levels that fit the situation for a particular objective are selected.

If more than one combination of consequence and likelihood is considered plausible, the combination that generates the highest risk score (or risk level) should be chosen as the final outcome (i.e. consistent with taking a precautionary approach). Given that this is the most critical part of the risk assessment process, a number of procedures have been identified over the past decade that can improve the discipline and effectiveness for completing this step and therefore the robustness of the outcomes. The key elements are listed below.

Structure of the analysis methods

Issue: The consequence and likelihood tables can be user-defined and therefore individually tailored for each particular objective and its associated level of acceptability (IEC, 2009; SA, 2012). The number of different levels can also be varied to suit the level of detail most appropriate for each situation. There is a trade-off in the number of levels used because each of the tables needs to have suitable non-ambiguous descriptions relevant to the specific objective. A larger number of levels can increase the precision of outputs, but it can also increase the level of disputes in choosing between adjacent levels. Using fewer levels will increase the coarseness of the assessment, which can also reduce stakeholder acceptance.

Refinements: The original six by six level tables described in Fletcher (2005) have been considered too complex for use in many situations, but especially with developing fisheries. A four category system was therefore established for use in the Pacific and Africa (Fletcher, 2007, 2008), but this simpler structure (Figure 2) has also been accepted for use with other types of fisheries (FAO, 2012). Other structures can be applied where this is appropriate or required (e.g. most Western Australian Government Agencies use a 5 × 5 system), with between three and five levels being the most common (IEC, 2009).

Using this simpler four-level system, the standard generic descriptions for likelihood and consequence levels are presented

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

Figure 2. Consequence × likelihood risk matrix. The generic descriptions of each of the consequence and likelihood levels are presented in Table 2. The numbers in the cells indicate the risk score values and the colours/shades represent the levels of risk as described in Table 8.

in Table 2. These generic consequence descriptions should be individually tailored to become specific for each objective and clearly delineate the maximum acceptable level of impact, which in a four-level system, is normally consequence level 2. It is also common to include a "zero" consequence level because this can assist deal with situations where large numbers of "insignificant" issues are likely to be raised. Having a zero level enables scoring combinations of a high likelihood of a negligible (0) consequence (negligible risk), which is simpler for many participants to comprehend compared with having to choose a very low likelihood of even a minor consequence level actually occurring.

Levels of data, uncertainty, and risk scoring

Issue: One of the biggest concerns in implementing the ecosystem approach is calculating the levels of risk for issues where there are minimal quantitative data. While risk is the effect of uncertainty on objectives, the process of undertaking risk analyses in situations where there are inherent uncertainties can cause a high degree of stress for some participants (including scientists).

Risk assessments are designed to make the most informed decision possible using all available information, even if this is limited (SA, 2012). It is important to recognize that not assessing the risk associated with an issue because there is a perceived lack of information essentially means that the current level of action or inaction is, by default, rated as acceptable. Where there are clear uncertainties, the highly disciplined approach outlined below can appropriately incorporate these into the justifications for the final scores that are selected. The justifications should include a suitably detailed narrative that refers to, and to the extent possible, is consistent with all available lines of evidence, including their levels of uncertainty (see Francis and Shotton, 1997, for a list of the different types of uncertainty).

Refinements: Evaluating the levels of risk associated with meeting an objective will inherently involve addressing uncertainties and variability that may occur in the future (SA, 2012). The level of current or future uncertainties associated with an issue can be included within the determination of the best combination of likelihood and consequence by incorporating all available lines of evidence and other information. The level of uncertainty can be conceptually depicted using the relative size of the "sphere" or range of plausible C × L combinations (Figure 3). As this sphere of uncertainty increases, this will result in progressively higher overall risk scores being selected.

To illustrate this concept, if the current level of impact on an objective was known with a high degree of certainty and precision to be fully within consequence level 2 (C2) (Figure 3, Sphere A). The appropriate qualitative risk score for this would be that it was "likely" (L4) to be a C2 consequence; which would generate a risk score of 8 which equates to a moderate level of risk (Table 8). If, however, for this same issue, less information had been available and the level of uncertainty increased, the sphere of plausible combinations could also increase potentially until the likelihood profile reached well beyond the boundary of the C2 into C3 (Figure 3, Sphere C). At this level of uncertainty, the more appropriate combination would be that it was possible (L3) for the level of impact to be at C3, which would generate a risk score of 9; which equates to a high risk (Table 8). With this outcome, additional data could be collected that reduced the uncertainty (and the size of the sphere) to an acceptable level (Figure 3, Sphere B). Alternatively, additional restrictions could be imposed that lowered the potential impact such that the "sphere" of plausible outcomes rose sufficiently

Table 2. Generic descriptions of likelihood and consequence using a four-level system modified from Standards Australia (2000), Fletcher *et al.* (2002), and Fletcher (2007).

Level	Likelihood descriptor
Generic likelihood levels	
Likely (4)	A particular consequence level is expected to occur in the time frame (indicative probability of 40–100%)
Possible (3)	Evidence to suggest this consequence level may occur in some circumstances within the time frame (indicative probability of 10–39%)
Unlikely (2)	The consequence is not expected to occur in the time frame but some evidence that it could occur under special circumstances (indicative probability of 3–9%)
Remote (1)	The consequence not heard of in these circumstances, but still plausible within the time frame (indicative probability 1–2%)
Level	**Consequence descriptor**
Generic consequence levels	
Negligible (0)	No measurable impact and no effect on meeting objective
Minor (1)	Measurable but minimal "impacts" that are highly acceptable and easily meet objective
Moderate (2)	Maximum acceptable level of "impact" that would still meet the objective
Major (3)	Above acceptable level of impact. Broad and/or long-term negative effects on objective which may no longer be met. Restoration can be achieved within a short to moderate time frame
Extreme (4)	Well above acceptable level of impact. Very serious effects on objective which is clearly not being met and may require a long restoration time or may not be possible

Note that the descriptions for each of the generic consequence levels need to be specifically tailored for each objective (see Table 7 for examples) and that inclusion of a zero level is recommended, but not essential.

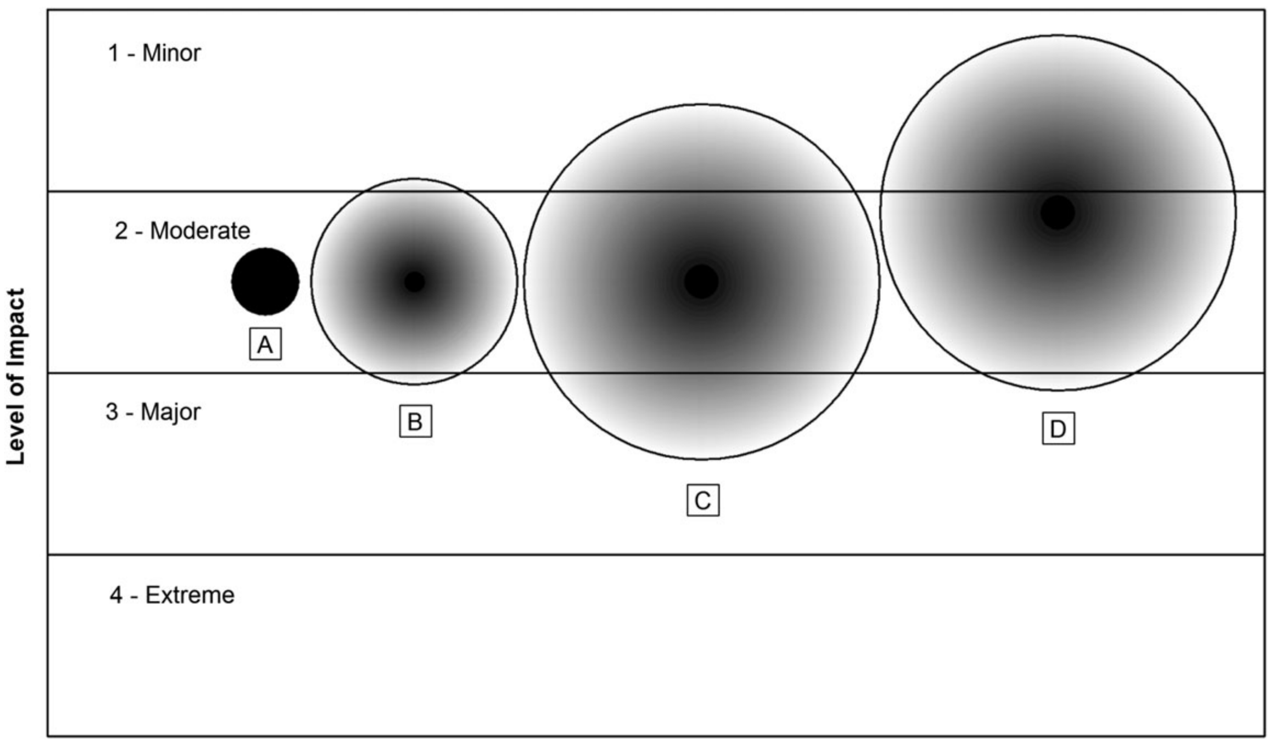

Figure 3. Pictorial representation of how uncertainty affects the sphere or range of plausibility for the same issue depending whether it is known with; high certainty (Sphere A), moderate uncertainty (Sphere B), or high uncertainty (Spheres C and D). The numbered levels on the impact scale represent the different consequence levels. The darker the region within the spheres represents higher likelihood; concentric bands could also be used for the different likelihoods (see text for details on resultant risk scores).

to be largely within acceptable levels (i.e. mostly above Level 3, Figure 3, Sphere D).

The use of this "sphere" or range of plausibility concept has been extremely valuable in getting participants to more clearly understand how qualitative risk analysis can be applied in a similar conceptual manner to more quantitative methods. An extension of this concept has been developed to increase the level of discipline applied when selecting the most appropriate C × L score combinations. This technique makes use of all available lines of evidence for an issue and is effectively a risk-based variation of the "weight of evidence" (WoE) approach that has been adopted for many assessments (e.g. Wise *et al.*, 2007; Linkov *et al.*, 2009).

The consistency or inconsistency for each line of evidence with the level of impact being within each of the consequence level scenarios is explicitly assessed. If all the lines of evidence for an issue are only consistent with a single consequence level (x)

then only a single C × L combination would be plausible. In this situation, the appropriate C × L combination would be that C "*x*" was "likely" (L4), which would essentially be equivalent to Sphere B in Figure 3. The more the different lines of data are consistent with different or multiple consequence levels, the wider the set of plausible combinations that would be generated. This would be equivalent to the larger spheres C or D in Figure 3.

Example**:** The commercial whiting fishery in Shark Bay, WA, provides an example of how WoE can be incorporated into this formal qualitative risk analysis approach. A preliminary assessment of this fishery examined the standard information on the biological characteristics (productivity) of this species and their potential susceptibility to the fishery (distribution vs. fishery boundaries), as used in the Marine Stewardship Council's pre-assessment framework (MSC, 2014), plus recent trends in catch and effort (Table 3). This level of information is common for data-poor fisheries both in WA and in many other areas of the world.

Using just these lines of evidence (Table 4), all four levels of consequence (depletion) would be plausible, but with different levels of likelihoods (Table 5). While the total catch and effort levels have been maintained at similar levels for at least 20 years (Jackson *et al.*, 2012), the boundaries of the fishery cover most of the species distribution in Shark Bay. These patterns could be consistent with stocks fished at light/acceptable levels (C1 or C2) or a stock that has been in a collapsed state for some time (C4). This catch history would not, however, normally be associated with a stock in transition (C3) because, over 20 years, this should either generate a trend of reducing catches for the same effort or an increase in effort would be needed to maintain catch levels (Caddy and Gulland, 1983; Hilborn and Walters, 1992). Hence, the stock is unlikely (L2) to be at a C3 level of depletion.

Adding the catch-history information to the biological/productivity characteristics of whiting, it is likely (L4) that the stock has been fished at moderate levels (C2). However, without any additional information, it is possible (L3) that it could either be lightly fished (C1) or, alternatively, it is possible (L3) that the stock could have already collapsed (C4) before the period examined and is not able to recover due to continued fishing pressure. With this amount of information and the corresponding level of uncertainties, there was a large set of plausible risk score combinations with the highest (C4 L3) equating (based on Table 8) to a high risk level (Table 5).

A more comprehensive assessment was completed for this fishery by including all the known lines of evidence (Table 4). This resulted in a revision to the plausibility and likelihood profiles associated with the four consequence scenarios.

The more detailed examination of the management arrangements recognized that there were only 12 commercial licences and only 5 active operators fishing across the whole of the 10 000 km^2 Shark Bay (Jackson *et al.*, 2012). Furthermore, these operators can only use beach-seine nets with a restricted length and mesh size

Table 3. Summary table of the information used to complete the two risk analyses of Shark Bay Whiting.

	Lines of evidence		
	Biology/productivity	**Susceptibility to the fishery**	**Outcomes**
Initial level of information	*Max age:* moderate—8 years *Age at maturity:* early—2 years *Reproductive strategy:* simple with high fecundity *Distribution:* around Shark Bay	*Distributional overlap:* 70% of total area within boundaries of the commercial fishery	
Additional level of information	*Distribution:* stock known to also be present in deeper waters of Shark Bay	*Management restrictions:* strong—only 5 licence holders currently operate, limitations on gear restricted to one beach-seine per crew with length and mesh restrictions. *Overlap in effective effort:* small proportion of beach area can actually be fished each year. Deeper waters not accessed. *Management effectiveness and compliance:* high compliance *Processor imposed:* catch limits per day for last 10 years	*Catch history:* stable catch levels for over 20 years *Effort history:* slight decline in effort over past 10 years *Market:* focus on high-quality product caps on daily catch levels *Catch composition:* most of catch is well above size at maturity

See Jackson *et al.* (2012) and Smallwood *et al.* (2013) for more information.

Table 4. The degree of consistency with the four levels of consequence for each of the different lines of evidence for Shark Bay whiting.

	Initial lines of evidence		**Additional lines of evidence**		
Consequence level scenario	**Potential overlap**	**Catch/effort**	**Management restrictions (effective overlap)**	**Catch size composition**	**Offshore distribution**
1	o	√	√	√	√
2	√	√	√	√	√
3	√	o	o	x	x
4	√	√	x	X	X

The biology/productivity information presented in Table 3 affected the interpretation of each of these different lines of evidence (see text for details). Legend: √, consistent; o, partially consistent; x, not consistent; X, inconsistent.

Table 5. Likelihoods (as indicated by Xs) for each of the consequence levels for the Shark Bay Whiting stock based only on the lines of evidence for biological/productivity, potential overlap/susceptibility, plus simple catch and effort (see Table 4).

Consequence Level	Remote 1	Unlikely 2	Possible 3	Likely 4	Risk score	Final risk level
1	X	X	X		3	
2	X	X	X	X	8	
3	X	X			6	
4	X	X	X		12	High

The final risk level is the combination that generates the highest risk score which, in this case (C4 × L3 = 12), equated to a high risk (Table 8).

Table 6. Likelihoods (as indicated by Xs) for each of the consequence levels for the Shark Bay Whiting stock that included the additional lines of evidence for total catch and effort plus management restrictions, effective effort levels, markets, and catch composition (see Table 4).

Consequence Level	Remote 1	Unlikely 2	Possible 3	Likely 4	Risk score	Final risk level
1	X	X	X		3	
2	X	X	X	X	8	MOD
3	X				3	
4					n/a	

The highest risk score combination was C2 × L4 = 8 which equates to a moderate risk (see Table 8).

with no access to deeper waters of Shark Bay where this stock is also known to occur (Kangas *et al.*, 2007). These formal restrictions result in the effective level of annual effort that can be applied by this fishery being very small (<5% of the shore line) if the extent of the distribution of fishing effort is compared with that of whiting across the entire Shark Bay region.

In addition to these formal restrictions, this fishery has been subject to processor restrictions for over a decade. To meet the market requirements of high-quality fish reaching the factory, commercial fishers are subject to a ceiling on the amount of fish they can land per day. Most importantly, the catch composition is dominated by fish well above the age at maturity (Gary Jackson, pers. comm.).

Including these additional lines of evidence in the analysis reduced the uncertainties and therefore the "sphere" of plausible outcomes (Table 6). It is much more certain that the effective level and distribution of annual effort is relatively small compared with the total distribution of whiting across Shark Bay. This reduces the potential level of fishing mortality on this stock. Furthermore, the size composition of the catch that has been maintained during the long history of stable catch and catch rate levels are relatively high, both of these lines of evidence are also consistent with the view that the level of fishing mortality is acceptable. In combination with the life history and catch history outlined above, these additional lines of evidence are all consistent with a stock that is stable and subject to sustainable levels of fishing.

Importantly, none of these additional lines of evidence were consistent with the scenario that the fishery has been operating on a collapsed stock (C4) for decades. For this to have remained plausible, the effective overlap of effort on this stock would have to be high with catch dominated by juveniles, as is true for those stocks known to be in a collapsed state (e.g. eastern gemfish; Flood *et al.*, 2012). The additional data were also inconsistent with this stock being close to being overfished (C3); hence, at most, there is only a remote likelihood of this scenario.

To further reduce uncertainty and discriminate between this stock being lightly fished (C1) or sustainably/"fully" fished (C2) would require a quantitative estimation of fishing mortality. Any decision to collect the additional data needed for this should be based on economic considerations because it should not be needed to meet sustainability objectives.

Stakeholder involvement and risk score selection processes

Issue: Application of this methodology can be undertaken with a high degree of stakeholder involvement with participants able to directly assist when selecting the appropriate C × L score combinations. This approach can increase the acceptance of the outcomes, but it can also lead to large discrepancies in the scores selected among individuals. This can often reflect that some stakeholders (i) are really assessing different objectives, (ii) have different ideas of acceptable impact, (iii) have different knowledge bases on the subject, or (iv) are unwilling to accept alternative risk outcomes to their preconceived positions.

Refinements: It is strongly recommended that workshops that apply this method utilize an experienced facilitator who fully understands both the underlying concepts and terminology of risk management and has direct experience in applying the ISO-based C × L methodology, including its idiosyncrasies. It is also preferable for any participants directly involved in scoring to be given some level of instruction on how these methods operate. This approach is one of the most widely used in the world, which means it is covered within the introductory risk courses available in most countries.

The discussions during these workshops must be undertaken in a language, and within an environment, where the participants feel comfortable and are able to freely and easily express their opinions (de Young *et al.*, 2008; SA, 2010; FAO, 2012). If there are different language or sector groups, it may be necessary to initially run separate sessions and have a separate meeting that synthesizes the outcomes.

Where the number of participants is very large, even with good facilitation, it can be hard to ensure that everyone is willing and able to apply the system in a consistent and objective manner. In such circumstances, it can be more effective to have the final risk score combinations chosen by a smaller "expert" panel which can include non-technical people. The broader audience can provide their input during an open discussion phase and provide subsequent comment on the outcomes. For example, the Western Rock Lobster Fishery in WA has both a Stakeholder Working Group and a Technical Panel that participate in risk assessments (Stoklosa, 2013). The Stakeholder Working Group includes a range of individuals and organizations involved in or interested in the fishery while the Technical Working Group is made up of a range of scientists with specific expertise relevant to the assessment. While both groups discuss all aspects of the risk assessment, only the Technical Panel completes the final risk scores with any discrepancies in scoring noted (Stoklosa, 2013).

Recording and reporting

To ensure that sufficient discipline and intellectual rigor has been applied to the risk analysis, it is essential that there is suitable documentation of the results of the assessment (SA, 2012). The justifications for choosing each of the different combinations of consequence and likelihood must be recorded within a suitably detailed narrative that examines and integrates all the lines of evidence, including their consistency and inconsistency with alternative scenarios.

A defendable case needs to be developed for the choice of each score combination so other parties who were not directly part of the risk assessment process can examine and understand the logic and assumptions used to make the decisions. Such documentation also assists the review of the risk sometime in the future if it is clear why the levels were originally chosen.

Assessing all relevant objectives

Issue: Applying an ecosystem approach involves the examination of a wide spectrum of objectives. If only risks associated with ecological objectives are examined, this will often lead to arguments or dissatisfaction with the outcomes of the risk assessment process because the ecological objective may not always be the highest risk. For example, the most common area where high risks have been identified, especially for developing fisheries, has been in governance, not ecological components as many would expect (Fletcher, 2008). The implications of using different consequence categories to assess the same information are illustrated below.

Example: Albacore Tuna are the primary target species for the tuna longline fishing managed by the Western Central Pacific Fisheries Commission and form the basis for cannery operations in some of the member countries (Williams and Reid, 2006). This species has a relatively robust biology and the stock assessment model at the time suggested it had been relatively resilient to the long history of fishing with the spawning biomass having not been substantially reduced. Under the rates of exploitation at the time, the total stock was likely to fluctuate well above the stock sustainability threshold level of B_{msy} (Figure 4a). Nonetheless, its local density can become reduced through intense fishing within a specific area and its migration routes can be affected by regional oceanographic conditions, both of which can affect the catch rates of member countries (Langley and Hampton, 2006).

Given the estimated biomass trajectories of the stock of Albacore at the time, from a stock sustainability perspective, it was unlikely (L2) the stock would decline to even a moderate level of depletion (C2). This represented only a low risk against this stock sustainability objective. From an economic objective perspective, however, the fishery needed to have the catch rates levels maintained at their historical levels with any material reduction in biomass expected to reduce the catch rate levels generating unacceptable economic outcomes (Figure 4b). Therefore, it was possible (L3) that the stock would decline below its current level (C3) which represents a moderate to high economic risk. This economic risk score explains why there were comprehensive management arrangements in place for this stock within each of these countries when the sustainability risk score was only low. The B_{mey} biomass level was effectively being used as the basis to determine acceptability in the risk/stock analysis.

Refinements: To implement an ecosystem approach, it is essential that the risks associated with all relevant objectives that were identified during the risk context step are assessed. This includes not only the risks associated with objectives for the ecological assets (target species, bycatch species, habitat, ecosystem structure) but also the assessment of objectives associated with: (i) the set of outcomes (economic and social) the community wants generated from the "use" of these assets; (ii) the governance (institutional and legal) systems used to manage the assets to achieve the outcomes; (iii) the set of organizational assets (buildings, people, etc.) and processes that undertake the management, and (iv) the external drivers (outside of direct management control) that may affect the ability to achieve these objectives all need to be assessed.

A starting set of consequence tables has been developed for applying the ecosystem approach (Table 7) which covers the most common fishery and management agency-related objectives. The descriptions for each of these tables has been developed based on experiences gained across many fisheries and situations but should be examined, and where necessary amended, to ensure they suit local circumstances.

Risk evaluation

Overview description: The risk evaluation step uses the risk scores or risk levels calculated from the risk analysis to help make decisions about (i) which risks need treatment, (ii) the degree of treatment required, and (iii) the priority for undertaking these actions. The risk evaluation is completed either by comparing the calculated risk score with those associated with the different levels of risk (e.g. Table 8), alternatively, where the risk scores are not considered sufficiently linear, each specific combination of consequence and likelihood can be directly assigned to a specific risk level (SA, 2012). Importantly, the determination of what risk scores, or what specific C × L combinations correspond to the different levels of risk, must be determined during the risk context step (i.e. before the risk assessment phase). These should be based on what constitutes acceptable performance and the degree of risk aversion of the managers and stakeholders (SA, 2012).

Issue: Following the risk assessment process, there can still be a large number of moderate or higher risk level issues identified that require attention. Determining the appropriate level and type of risk treatment (management actions) that should be applied to each issue will generally involve a number of factors apart from just the level of risk to one objective.

Refinements: A clear separation in the definition between a risk and a priority has now been included. The level of risk is only one of the factors that need to be considered when determining the priority of an issue. Other factors include the relative social, economic, or other benefit for society generated, the level of risk to these benefits, the time frame for failure if actions are delayed, the level of additional political fallout if it "fails", and also the degree to which the risk can be directly controlled. Determining priorities can involve some form of informal or formal multi-criteria analysis or other cost–benefit method which usually involves a high level of political input in the final decision-making process. To assist with these processes, a number of formal methods have been outlined in the EAF toolbox (FAO, 2012).

Discussion

The qualitative risk assessment methodology adapted for fisheries and aquatic management by Fletcher (2005) has been reviewed and updated to ensure full compliance with the revised international standards for risk management. In addition, many refinements have been made to assist with the efficient implementation of more holistic, ecosystem approaches.

The enhancements facilitate a higher level of stakeholder engagement and participation throughout each step of the risk assessment process, which should lead to a greater level of ownership and trust in the outcomes (de Young *et al*., 2008; SA, 2010). The new tools enable stakeholders to outline their expectations and concerns, including relevant external factors, in a manner that can be assessed in a more consistent and objective manner. The highly transparent and logical nature of the C × L risk analysis method encourages full stakeholder engagement in discussions, scoring, and reviews of risks. These attributes were the principal reasons for the NSW

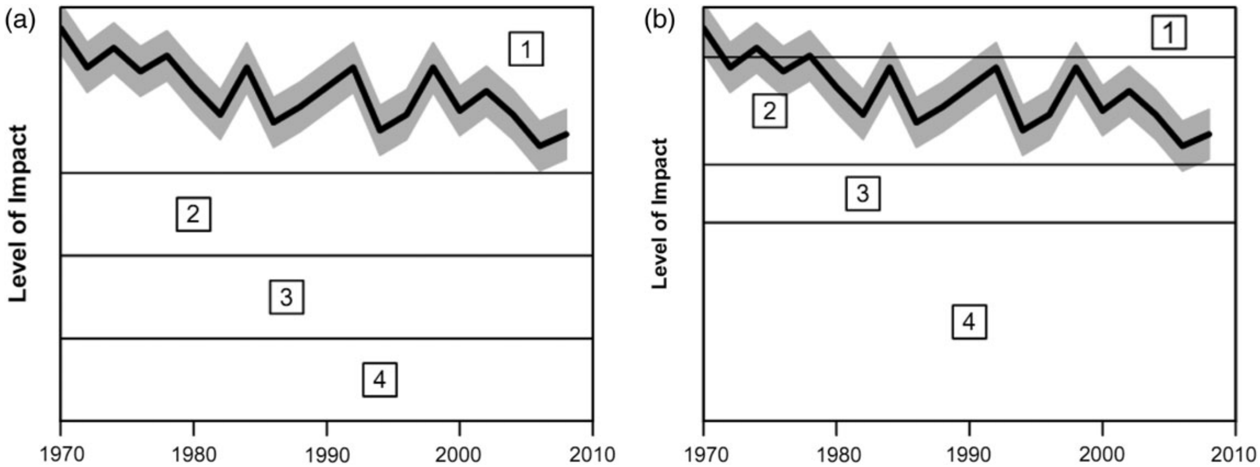

Figure 4. Illustration of how the same levels of impact on Albacore tuna abundance can result in different consequence scores using (a) stock sustainability and (b) economic outcomes as objectives. The horizontal lines in each graph indicate the separation points between the different consequence levels 1–4.

Marine Estate Management Authority deciding to adopt the C × L approach for their threat and risk framework rather than the methods previously applied in NSW (MEMA, 2013).

The method can be applied to the full variety of objectives relevant to the ecosystem approach including ecological, social, economic, political, and occupational safety issues. The different types of consequences and the levels of acceptable impact just need to be defined for each situation. This is often important for assessing objectives related to non-target, iconic species because the acceptable levels of impact can vary greatly among countries and time frames based on social considerations. For example, when the season for the western rock lobster fishery in WA was recently extended, this resulted in increased interactions with whales (i.e. entanglement of whales in ropes attached to lobster pots). A risk assessment completed in 2013 for this fishery as part of its ongoing MSC certification considered both the ecological and the social impacts of these whale entanglements (i.e. public concern for a dead whale on beach, a whale freed of entanglement or an entangled whale). While the impact of entanglements on the stock status of whales was considered C1 L1 (negligible), the social risk was, however, assessed as C2 L3 and therefore required management intervention (Stoklosa, 2013).

The selection of the appropriate risk score combinations for each objective is the most critical element in any risk assessment process and requires an appropriate level of discipline. Some risk analysis methods impose discipline by adopting a highly structured set of data inputs and score calculation procedures (e.g. MSC, 2014). This may result in a high level of consistency in outputs but unless all available information can be included and there are no complex or variable interactions among factors, their accuracy may be affected. Some of these methods have recognized this potential issue and have added an "expert override" step (e.g. Zhou *et al.*, 2011).

The selection of risk scores for the C × L method are made directly by either all or a subset of the participants following input and discussion of all the available information and viewpoints. These selections are all deliberate, "expert opinion" based decisions, with no predefined formulae used to calculate the final risk scores, so outputs from other analysis methods may be included within the deliberations. Most importantly, there are no restrictions on what information can be used or how it must be used to make the final decisions (although the basis for those decisions must be recorded). This high level of flexibility can potentially enable more accurate outcomes to be generated, but it also requires a higher comprehension of the underlying principles of risk assessment and strong discipline to apply the method appropriately and consistently (SA, 2012). The suite of refinements outlined above has been designed to achieve these improved outcomes.

It has been recognized for some time that the implementation of risk management could be assisted by improved consistency in the use of terminology (Francis and Shotton, 1997). The increasing level of adoption of risk-based approaches within aquatic management and its associated scientific literature suggests that it may be timely to better enforce compliance of use with the ISO standard irrespective of which risk analysis method is applied. The word risk, and all other risk-related terms, should, therefore, be restricted to the ISO definitions, similar to how the word "significant" is now largely restricted in scientific publications to a statistical definition.

Improvements to stakeholder understanding of the risk assessment process have also been obtained through the development of the various pictorial representations of how impacts, consequence levels, uncertainties, and likelihoods combine to determine the risk scores. The portrayal of qualitative assessments using two-dimensional graphs with the same conceptual units as would be applied in quantitative assessments effectively bridges the gap between these methodologies. It is consistent with the notion that the same principles should be applied for both qualitative and quantitative assessments except words rather than numbers are used to describe the magnitude of both the potential consequences and the probability (likelihood) that those consequences will occur (SA, 2012). For example, all stock assessments are essentially just specific forms of risk assessment that are completed to assess the risk status of fish stocks (see also Francis and Shotton, 1997).

The improved written and visual descriptions illustrate how the different risk analysis methods can be linked such that, with increasing levels of quantitative information, the precision for the levels of risk increases from (i) a qualitative "sphere" of plausibility; to (ii) a

Table 7. Qualitative levels of consequence for each of the main objectives relevant to the ecosystem approach.

Objective	Minor (1)	Moderate (2)	Major (3)	Severe (4)
Target species	Measureable but minor levels of depletion but no impact on dynamics Abundance range 100–70% unfished levels (B_0)	Stock has been reduced to levels approaching that associated with B_{msy} Abundance range <70% B_0 to >B_{msy}	Stock has been reduced to levels below B_{msy} and close to where future recruitment may be affected Abundance range <B_{msy} to >B_{rec}	Significant stock size or range contraction has occurred with average recruitment levels clearly reduced (i.e. recruitment limited) Abundance range <B_{rec}
Bycatch species	Species assessed elsewhere and/or take is very small and area of capture small compared with known distribution (<20%).	Relative level of susceptibility to capture is <50% and not a vulnerable life history	N/A. Once a consequence reaches this point, it should be examined using target species table	N/A
Protected species	Few individuals directly impacted in most years, no general level of public concern	Catch or impact at the maximum level that is accepted by public	Recovery may be affected and/or some clear public concern	Further declines generated and major ongoing public concerns
Ecosystem structure	Measurable but minor changes to ecosystem structure, but no measurable change to function	Maximum acceptable level of change in the ecosystem structure with no material change in function	Ecosystem function now altered with some function or major components now missing and/or new species are prevalent	Extreme change to structure and function. Complete species shifts in capture or prevalence in system
Habitat	Measurable impacts very localized. Area directly affected well below maximum accepted	Maximum acceptable level of impact to habitat with no long-term impacts on region-wide habitat dynamics	Above acceptable level of loss/impact with region-wide dynamics or related systems may begin to be impacted	Level of habitat loss clearly generating region-wide effects on dynamics and related systems
Economic	Detectable but no real impact on the economic pathways for the industry or the community	Some level of reduction for a major fishery or a large reduction in a small fishery that the community is not dependent upon	Major sector decline and economic generation with clear flow on effects to the community	Permanent and widespread collapse of economic activity for industry and the community including possible debts
Social structures	Impacts may be measurable but minimal concerns	Clear impacts but no local communities threatened or social dislocations	Severe impacts on social structures, at least at a local level	Complete alteration to social structures present within a region
Food security	Food security important but no impacts observed	Direct impacts on food resources but not to the point where these are threatened	Significant and long-term (>weeks) impacts on food for a community. Likely to lead to health problems	Severe ongoing reductions in food resources leading to starvation, abandonment of region, or requiring aid
Social amenity	Temporary or minor additional stakeholder restrictions or loss of expectations	Ongoing restrictions or decrease in expectations	Long-term suspension or restriction of expectations in some key activities	Permanent loss of all key expectations for recreational activities
Reputation and image	Low negative impact, low news profile	Some public embarrassment, moderate news profile, minor ministerial involvement	High public embarrassment, high impact, and news profile, Third party actions, public and significant ministerial involvement	Extreme public embarrassment, prolonged news coverage. Third party actions/enquiry, government censure
OHS	First aid only	Minor medical treatment required, visit to doctor's surgery. Less than a week off work	Hospitalization and/or intensive and extended treatment period required for recovery	Serious or extensive injuries/disease/permanent disability or death
Operational effectiveness	Non-achievement of an entire strategic directive	Minor element of one key deliverable unable to be achieved on time	Significant delay but achievement of key deliverables	Non-achievement of more than one key deliverable or major delay to entire strategic directive

Note the 0 level has not been included as this is generally described in all circumstances as not detectable impact.

range of different likelihoods for each of the plausible consequence levels; (iii) a single consequence level; (iv) a fully quantitative point estimate with error; and (v) a historical and future quantitative trajectory with error. The two-dimensional format has been successfully applied to illustrate other risks where the level of impact can theoretically be measured (see Albacore economic example, above). Where it is not possible to conceptually display the level of impact to the objective in such a manner suggests either that the objective has not been clearly defined or that another risk analysis method may need to be applied.

Table 8. Levels of risk and their associated likely management responses and reporting requirements (modified from Fletcher *et al.*, 2002; Fletcher, 2005).

Risk level	Risk scores (C × L)	Probable management response	Expected reporting requirements
Negligible (0)	0–2	Acceptable with no management actions or regular monitoring	Brief justification
Low (1)	3–4	Acceptable with no direct management actions and monitoring at specified intervals	Full justification and periodic reports
Moderate (2)	6–8	Acceptable with specific, direct management and regular monitoring	Full regular performance report
High (3)	9–16	Unacceptable unless additional management actions are undertaken. This may involve a recovery strategy with increased monitoring or even complete cessation of the activity	Frequent and detailed performance reporting

These concepts have also been incorporated into the risk analysis process through the explicit examination of the degree to which each line of evidence is consistent with each of the consequence level scenarios. Each information source is explicitly considered on its merit within an overall narrative that transparently discusses how these factors are thought to interact to determine which consequence scenarios are considered plausible and, where relevant, their specific likelihoods. The analyses of these various lines of evidence must include explicit consideration of how the current (or proposed) management system interacts with the underlying properties (e.g. productivity/susceptibility/vulnerability) of the asset being managed. The whiting example illustrated that with a more comprehensive examination of the effectiveness of the management restrictions, the calculated level of susceptibility assessed for this stock was substantially reduced compared with that which resulted from a simplistic assessment of susceptibility using fishing boundaries and biological productivity. Moreover, when used in combination with additional information on outcomes generated by management such as the patterns of catch, catch rate, and catch composition, a more precise risk profile was generated for this fishery.

Another advantage of the C × L methodology is that it can often be completed within a very short time frame using whatever data are available. For management agencies, this can be important because risk-based decisions are often required to be made in a matter of hours or days, not months or years. This attribute was recently used to provide timely advice to the Western Australian Government concerning their proposal to station drum lines off selected WA beaches to mitigate the risk of shark attacks (Government of Western Australia, 2013). A number of risk assessments associated with this proposal were completed to assess the potential environmental risks of this proposal and to examine the potential risks to the staff directly involved or indirectly affected by its implementation. Despite the short time lines available, the submitted environmental risk assessment (DoF, 2014) subsequently withstood independent review by the Environmental Protection Authority (EPA, 2014). Furthermore, the OHS-based operational procedures that were developed using this risk approach enabled the timely implementation of this controversial strategy by the Department in a safe and controlled manner.

While there are a number of clear benefits of this methodology, even with the added refinements, a number of inherent difficulties remain. Principally, if the facilitator has minimal experience with these concepts, and/or where the language skills and formal education of participants are not high, the use of this risk analysis method can be difficult to complete efficiently. In these situations, undertaking a simpler "risk category" based analysis method (see FAO, 2012) or other preliminary hazard analysis (IEC, 2009; SA, 2012) could be better options. A simple procedure well done may often provide better results than a more sophisticated procedure poorly done (SA, 2012).

Conclusion

The adoption of risk-based methodologies is now clearly seen as an essential component for the successful implementation of ecosystem management approaches (FAO, 2005, 2012), with qualitative assessments often the most appropriate for this purpose (Cochrane, 2013). The suite of refinements that have been developed for the C × L qualitative method over the past decade has greatly improved both its rigor and accessibility for stakeholders.

The focus of these refinements, which are relevant to all methods, emphasizes that risk assessment should not be viewed as just a technical scoring procedure but as an intellectual process that involves developing a conceptual model for each issue and an illustrated narrative that examines the consistency of all the lines of evidence against this model in a disciplined and auditable manner. These narratives should explicitly consider how the management system and uncertainties have affected the selection of the most appropriate risk score. From a manager's perspective, it is these narratives and the depictions of risk status that provide the basis to determine the most appropriate future "risk treatments" for an objective, not the risk score.

Incorporation of the conceptual elements from a number of qualitative and quantitative approaches in the updated methods have not only increased the reliability of those methods but also have enabled more seamless transition across these methods as more lines of evidence are collected and used to update the assessment. This will also assist agencies in the wider adoption of risk management principles to cover all their activities.

Given the variety of issues and situations that often arise when completing risk assessments, additional nuances are frequently identified that better explain or complete the process. It is expected that further refinements to the various risk assessment guidelines will continue to emerge over time.

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