Australian Government

Australian Fisheries Management Authority

Fisheries Management Paper 14

AFMA's Approach to Ecological Risk Assessments and Management

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Contents

Purpose

This paper sets out the Australian Fisheries Management Authority's (AFMA) approach for undertaking Ecological Risk Assessments (ERAs) and administering Ecological Risk Management (ERM) responses in pursuit of its fishery management objectives, particularly Ecologically Sustainable Development (ESD). Details of the Ecological Risk Assessment for the Effects of Fishing (ERAEF) methodology are available at Attachment 1.

The ERM framework is based on the following principles:

- 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, and
- Ecosystem-based approach: This approach recognises that fisheries are part of a larger marine ecosystem, and that the management of fisheries should consider the impacts on all parts of the ecosystem.

The ERM framework is implemented in several steps, including:

1. Data collection: This involves collecting data on the different parts of the marine ecosystem, including commercial species, bycatch species, habitats, and communities
2. Risk assessment: This involves identifying and assessing the risks to the marine ecosystem from fishing activities, Details of the Ecological Risk Assessment for the Effects of Fishing (ERAEF) methodology are available at Attachment 1
3. Management: This involves developing and implementing management measures to mitigate the risks identified in the risk assessment, and
4. Monitoring, evaluation and reporting: This involves monitoring the effectiveness of the management measures and evaluating the risks to the marine ecosystem on an ongoing basis.

The ERM framework is an important tool for managing fisheries in a sustainable way. It helps to ensure that the impacts of fishing on the marine ecosystem are minimised, and that fisheries are managed in a way that is consistent with the principles of ecologically sustainable development (ESD). Figure 1 outlines the linkages between legislation, policy, assessment, and management processes covered by ERM. ERM has multiple components and processes.

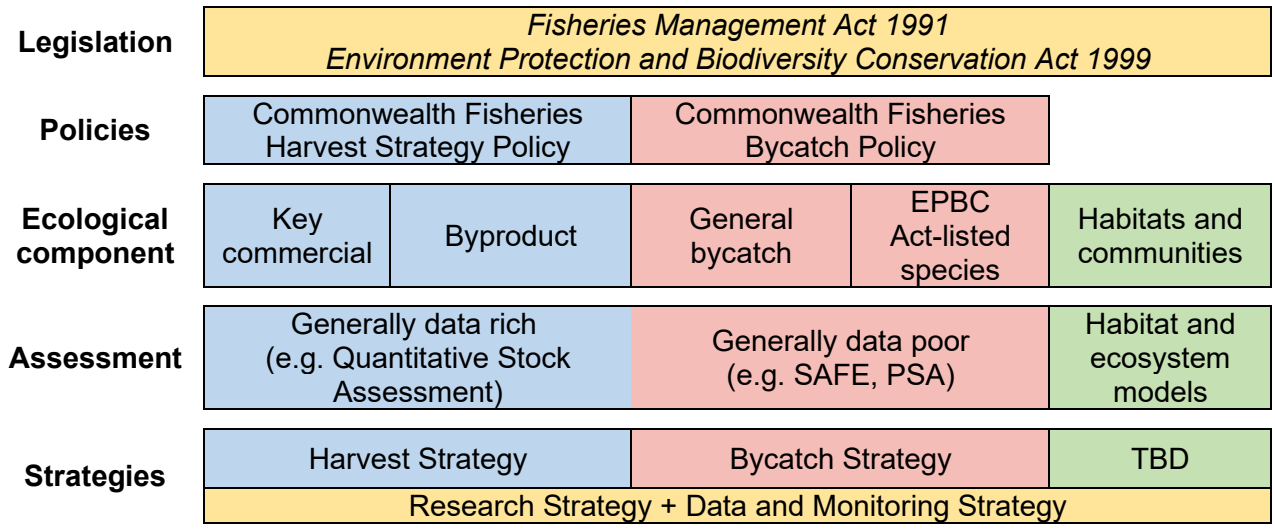

Figure 1: AFMA's ERM and its relationship with fisheries legislation and policies, ecological components and risk assessment tools which address ERM and other fisheries management objectives.

Scope

AFMA's ERM (including ERAEF) assesses and manages the impacts and risks posed by Commonwealth fisheries to the following ecological components:

- Commercial species, including key commercial and byproduct species
- Bycatch species, including general bycatch and EPBC Act-listed species
- Habitats, and
- Communities.

Out of scope

As AFMA only has authority to manage Commonwealth fisheries, the ERM approach only applies to those fisheries and ecological impacts under its jurisdiction. However, with respect to jointly managed fisheries (e.g. Torres Strait fisheries), it does articulate AFMA's preferred approach. Where applicable, AFMA will seek to apply this approach in negotiating and implementing joint management arrangements such as in Regional Fisheries Management Organisations (RFMOs). With respect to other non-Commonwealth fisheries, where possible, AFMA will consider impacts by these other fisheries and develop joint management responses with the relevant agencies.

Objectives

The primary ecological sustainability objectives that AFMA pursues through its ERM framework mirror the sustainability objectives defined in existing fisheries and environmental legislation, policies, guidelines, and international agreements. In summary, they are:

- to ensure that fishing (in Commonwealth commercial fisheries) does not reduce any commercial or bycatch species populations (that is, discrete biological units, commonly referred to as stocks in the BP and HSP) to or below a level at which the risk of recruitment impairment is unacceptably high
- where such fishing impacts have occurred, to put in place management to allow rebuilding of species populations to above that level
- to minimise fishing-related impacts on general bycatch and EPBC Act-listed species by ensuring the exploitation of fisheries resources is consistent with the principles of ESD, and
- to pursue broader habitat security for non-living ecological components.

Consideration of legislative objectives

AFMA's ERM objective aims to pursue the ecological sustainability of all species populations, habitats, and ecological communities that its fisheries interact with. AFMA's management approaches simultaneously pursue a range of other objectives, and in some cases, these result in AFMA seeking to maintain some populations at even higher levels than required by ERM alone.

AFMA's ERM related objectives address only one component of AFMA's requirement to pursue ESD under the FMA which defines ESD as requiring decision processes to *"effectively integrate both long-term and short-term economic, environmental, social and equity considerations"*.

Under the FMA, the ESD objective sits alongside other legislative requirements that AFMA pursues, including:

- efficient and cost-effective fisheries management – for commercial species managed under harvest strategies, risk-cost-catch principles are applied during their development. These principles effectively require the consideration of risk trade-offs between the failure, or success, of a fishery in achieving management objectives. For species which are not managed under harvest strategies (namely most by-product and general bycatch species), the hierarchical ERAEF framework is designed to filter out low and medium risk species and focus management attention on high-risk species in a cost-effective manner

- maximising net economic returns – the HSP gives effect to this objective

- accountability to the fishing industry and Australian community, and

- optimal utilisation of living resources.

Under the EPBC Act, AFMA must also ensure that Commonwealth fisheries are conducted in a manner that:

- requires persons engaged in fishing to take all reasonable steps to ensure that listed threatened species (other than conservation dependent species), listed migratory species, listed marine species and cetaceans are not killed or injured as a result of the fishing

- does not, or is not likely to, adversely affect the survival or recovery in nature of any listed threatened species, and

- does not, or is not likely to, adversely affect the conservation status of listed migratory species, listed marine species or cetaceans or a population of that species.

The BP states EPBC Act-listed species are managed separately to general bycatch species due to their special status under Australia's national environmental legislation (i.e. the EPBC Act).

AFMA's pursuit of the ESD Principles and other objectives can result in species being managed to biomass levels higher than required by the ERM related objectives alone. It is very important to understand the interactions between ERM and other fisheries management objectives when developing management arrangements.

Risk equivalency

With respect to the above ERM objectives, AFMA will pursue risk equivalency as per the requirements of the HSP and Bycatch policy. For general bycatch species, this means that species are not exposed to any greater risk than that accepted for commercial stocks managed under the HSP. Under the BP, general bycatch species are to be subject to an equivalent limit reference point (LRP) as commercial stocks and populations must be maintained above a limit where the risk of recruitment impairment is unacceptably high. Where evidence shows that a general bycatch population has fallen below that limit, the BP requires fishery managers respond in a way that facilitates recovery of that population to above the limit. Where the species is a key trophic species for the ecosystems such as an important prey species for certain predatory species, this species should be managed at a level that is appropriate for its status and the maintenance of the ecosystem.

However, in pursuing risk equivalency across species, it is important to recognise that for many species (particularly byproduct and general bycatch species), the ability to accurately quantify the risk of falling below the limit is highly dependent on data availability, assessment tools that can be used for a given species, and resources available for conducting simulation testing (e.g. management strategy evaluation (MSE)). The BP and BP Guidelines provide further guidance on operationalising risk equivalency.

Cumulative impacts

AFMA will pursue the cooperative assessment and management of species whose populations are impacted by both Commonwealth and non-Commonwealth fisheries, to account for and manage cumulative impacts as detailed in the Commonwealth Harvest Strategy and Bycatch Policies, to ensure ecological sustainability. The BP and BP Guidelines provide further guidance on how to take account of cumulative impacts.

Climate Impacts

AFMA's Climate Adaptation Program aims to ensure information on climate impacts is being incorporated into fisheries management across all AFMA fisheries, and that operational and management adaptation options are being developed and implemented. It is expected that approaches to account for climate impacts will continue to develop but we are already building climate considerations into our decision-making processes, including our Commission meetings and our management advisory committees and resource assessment groups. Other items being progressed through the Climate Adaptation Program include climate and ecosystem status reports and updates and conducting climate research relevant to our fisheries.

Details of the AFMA ERM framework

AFMA's ERM framework is based on the following key elements:

- Ecological risk/stock assessments, and
- ERM responses – these consider results from ecological risk/stock assessments (and other information) and outline the management processes required to mitigate the risk where it is high and address other key fishery management objectives on a per-fishery basis. Responses are documented guided by harvest[1], bycatch, research and, data strategies for each fishery. These strategies are made available on AFMA's website.

The five key phases/processes of the ERM Framework are explained in detail in Attachment 1. In summary they are:

- Stakeholder consultation: Stakeholders are defined as those people who have a direct interest in a fishery, and can include commercial fishers, managers, recreational fishers, Indigenous fishers, conservation focused non-government organisations, fishery scientists, and experts in particular taxa (Hobday et al. 2011)
- Scoping: involves 6 key steps, characterisation of the fishery, listing of units of analysis, identification of objectives, hazard identification, recording of references and agreement of decision rules to move to level 1
- Level 1 SICA (qualitative risk assessment): Scale Intensity Consequence Analysis (SICA) uses an exposure-effects risk assessment approach that is only applied to the "most vulnerable" unit (i.e. species) of an ecological component
- Level 2 (semi-quantitative and quantitative methods): When the risk of an activity at Level 1 (SICA) on a species component is moderate or higher and no planned management interventions that would remove this risk are identified, an assessment is required at Level 2 (to determine if the risk is real and provide further information on the risk), and
- Level 3 (fully quantitative methods): Level 3 is the point in the ERAEF hierarchy where a fully quantitative assessment is first undertaken (Hobday et al. 2011).

1 Including rebuilding strategies where required.

Ecological risk/stock assessments

Ecological risk assessments (ERA) /stock assessments are used to assess ecological risks (posed by Commonwealth Fisheries) to species stocks/populations and to help evaluate potential fishery management response options to mitigate risks where required. A list of Commonwealth Fisheries ERAs, including their status and review dates is available on the AFMA website.

ERM responses

ERM responses to risks identified though ecological risk/stock assessments will be the primary means by which AFMA pursues its legislative and policy-based requirements, including those pertaining to ecological sustainability.

The strategies that make up ERM responses include:

1. **Commercial species strategies** that will include as required:
    a. Harvest strategies for key commercial (and potentially some byproduct) species (that are not subject to rebuilding strategies)
    b. Rebuilding strategies for key commercial species that have been fished (historically) below their biological limit reference point
    c. Risk management approaches for byproduct species (responding to ERA where ecological risk is high)
2. **Bycatch (and discard) strategies** for general bycatch species and protected species that will include as required:
    a. Risk management approaches for bycatch and TEP species (responding to ERA where ecological risk is high)
    b. Additional management approaches as required to meet EPBC objectives/requirements for protected species (e.g. Dolphin mitigation strategies, threat abatement plans etc)
3. **Data strategies** that outline how AFMA will collect the data and information required to support the stock assessments, harvest strategies, rebuilding strategies and bycatch and protected species management approaches, and
4. **Research plans** that identify high priority research needed to ensure AFMA has the information it requires to pursue and achieve ecological sustainability via stock assessments, ERA, harvest strategies, rebuilding strategies and bycatch and protected species management approaches.

Operational implementation, monitoring and performance reporting

Key ERM related activities are incorporated into annual fishery operational planning cycles and include:

- communication of management strategies, arrangements, and directions to the fishing industry usually prior to fishing season in the form of fisheries management arrangements and port meetings
- harvest strategy and rebuilding activities for key commercial species (e.g. TAC/TAE setting, by-product trigger monitoring etc) through RAG and MAC processes and recommendations to AFMA Commission for decision
- Bycatch strategy activities (e.g. EPBC Act-listed species interaction monitoring, ERA trigger monitoring, actions to mitigate risks to bycatch identified as at high risk (by ERA) from the fishery, development of EPBC-Act listed species mitigation strategies and strategic assessments etc, species specific responses if not listed under EPBAC Act)

- data collection activities (e.g. logbooks, observers, electronic monitoring, surveys etc)
- compliance monitoring activities, and
- Research support activities (e.g. development of annual research plan, identification of research priorities and proposal reviews, logistical support, collaboration, RAG review of research, integration of research in management decisions/processes).

Updating of ERAs will be guided by a stepped process whereby Resource Assessment Groups (RAGs) and Management Advisory Committees (MACs) will review reassessment triggers every four years within a five-year cycle and provide advice to the ERMSG as to the need to update their ERA or seek approval to maintain their existing ERA for another 5 years. Noting the possibility of exceptional circumstances an ERA can be updated at any time in consultation with RAGs and MACs. The ERMSG will play an oversight role included accounting for cross fishery implications.

AFMA Management, in consultation with RAGs and MACs will identify priority action and responses to ERA outcomes, consistent with the ecological sustainability objectives and requirements of the HSP and BP, in developing ERM responses. This in turn will be guided by AFMA's annual corporate planning process with progress reported through the annual report. Stock level performance is detailed in the annual ABARES Fishery Status Reports.

ERM governance, roles and responsibilities

Table 1 and 2 details how agencies, groups/committees, stakeholder groups and AFMA will interact to ensure that ERA and ERM processes are successfully implemented.

Table 1: ERA and ERM roles and responsibilities. Red – approval / endorsement; blue – responsible for development; orange – responsible for implementation; yellow – involvement; green – are consulted with.

	Minister for Agriculture	Minister for the Environment /bycatch	Department of Agriculture, Fisheries and Forestry	AFMA CEO / Commission	AFMA Management	ERM Steering Group	Management Advisory Committees	Resource Assessment Groups	Research providers	Industry
Policy Development										
Commonwealth policies e.g. HSP and BP										
FMP 14 ERM Guidance										
Development and review of ERA methodology										
Implementation										
Implementation of Commonwealth policies										
Provide technical advice and guidance on ERA										
Undertake ERAs										
Monitoring and reporting										
ERM performance monitoring / reporting										
AFMA annual report										
Data collection and monitoring										
Re-assessment indicators and triggers										
Evaluation and Improvement										
EPBC Act accreditation										
Periodic internal review										
MSC accreditation										

Table 2: ERM roles and responsibilities of AFMA staff and committees.

Role	Responsibilities
AFMA CEO/Commission	• Overall performance and endorsement of ERM, including reviews of ERA methodology.
ERM Steering Group (ERMSG)	• Oversight of the ERM framework operation and ensure the application of a robust fisheries risk assessment and management framework continues for AFMA's fisheries. • Review the performance of the ERM framework and make recommendations for any appropriate changes and enhancements. • Review outputs of stepped reassessment checklist by RAGs and MACs. • Provide annual reports to the AFMA Commission, noting incremental changes applied in AFMA's fisheries and international developments, and outlining recommendations for improvement. • Apply AFMA's targets and objectives for sustainable environmental management by applying appropriate and up-to-date ERA methods and embed standards to ensure the consistent, robust, and cost appropriate assessment. • Further develop application of this Guide, consistent with objectives of relevant Commonwealth policies. • Identify gaps in research related to ERM and provide advice to the AFMA Research Committee on research required to fill these gaps. • Prioritising ERAEF assessments / re-assessments.
Policy, Environment, Economics and Research (PEER) Section	• Coordinate and support the implementation of ERM across fisheries. • Facilitate continuous improvement of ERM. • Secretariat support for the ERMSG.
Fishery managers and senior managers	Within their fishery: • Identifying ERA as research need in annual Prioritisation processes. • Development of scoping information for ERAEF assessments / re-assessments. • Overall performance of ERM (including planning, implementation, monitoring, review, and improvement).
RAGs	• Provide review and endorsement of the final results of ERAEF assessments / re-assessments. • Provide review of re-assessment indicators and triggers checklist.

Role	Responsibilities
	• Provide scientific/technical advice to assist in development of management options to mitigate risk for species. • Identify data and research gaps and priorities.
MACs	• Participate and contribute to the strategic planning stage, including management arrangements, development of expected outcomes, indicators, and reference points. • Provide management advice to assist in development of management options in response to ERAEF assessments / re-assessments. • Review of ERM performance and providing recommendations for improvement. • Reporting to the AFMA Commission on fishery management outcomes. • Provide review of re-assessment indicators and triggers checklist.

Attachment 1. ERAEF Methodology details

Original design

In its original form, the ERAEF framework involves a hierarchical approach to assessing risk across each of the 5 ecological components (Figure 1). The original methodology is described in detail in two key documents, Hobday et al. (2007) and Hobday et al. (2011). Assessment occurs sequentially through the following phases:

- Scoping – This phase identifies the fishery context, species lists, ecological sustainability objectives, and hazards (fishery activities that may impact the ecosystem)
- Level 1 (SICA) – A comprehensive but qualitative analysis of risk in which the most vulnerable "unit"[2] in each component (e.g. group of species) is assessed. This phase serves to exclude "low risk" components from analysis at Level 2, as if the most vulnerable species is low risk, so will all the less vulnerable species
- Level 2 (PSA) – A species specific (or habitat/community specific) semi-quantitative approach which assesses fishery risks to each unit (e.g. species) carried forward from Level 1. Units assessed to be at high risk at Level 2 can either be managed directly or carried forward to Level 3 for fully quantitative assessment, and
- Level 3 – A unit-specific, quantitative "model-based" approach that accounts for spatial and temporal dynamics of units and fisheries and quantifies uncertainties around stock status.

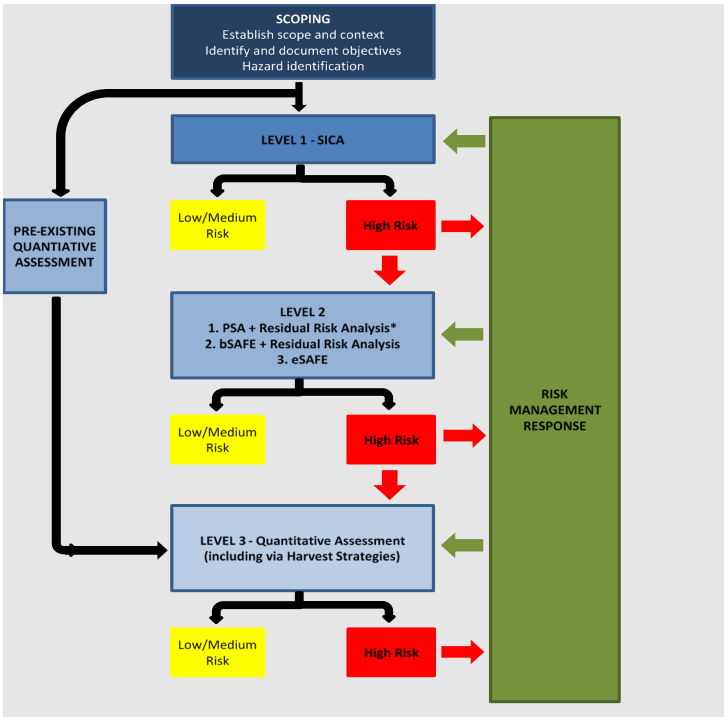

Figure 2: Structure of the hierarchical ERAEF methodology. SICA – Scale Intensity Consequence Analysis; PSA – Productivity Susceptibility Analysis; bSAFE – base Sustainability Assessment for Fishing Effects; eSAFE – enhanced Sustainability Assessment for Fishing Effects; RRA – Residual Risk Analysis. eSAFE may be used for species classified as high risk by bSAFE.

[2] Unit is a generic term, and refers to an individual species, habitat, or community type.

Revised methodology

The overall three-tiered hierarchical structure (i.e. Levels 1, 2, 3) of the ERAEF is maintained under the revised methodology. The revised methodology is expected to be published shortly. A relatively detailed description of each of these levels is provided below. In addition, the five general ecological 'components' that are intended to be evaluated are also maintained (i.e. key commercial species, byproduct/bycatch species, EPBC Act-listed species, habitats, ecological communities). ERAEF will be undertaken at regular intervals, including monitoring reassessment triggers with assessors investigating at least the previous five years of fishery (and other relevant) data to best reflect the current management of each fishery. Some circumstances may permit investigation of fisheries data from greater than five years during ERAEF to also be considered.

Key changes to ERAEF

In relation to species-specific risk assessments (the focus of this chapter), there are several important changes to processes within the tiered structure that should be noted, and which are reflected in Figure 2. These are as follows:

Scoping and Level 1

- Selection of ERA objectives – the primary objectives to be pursued for species assessed under ERA is:
    - to ensure that fishing (in Commonwealth commercial fisheries) does not reduce any commercial or bycatch species populations (that is, discrete biological units, commonly referred to as stocks in the BP and HSP) to or below a level at which the risk of recruitment impairment is unacceptably high
    - where such fishing impacts have occurred to rebuild species populations to above that level to the extent fisheries management is able to do so
    - to understand and inform strategies to minimise fishing-related impacts on general bycatch and EPBC Act-listed species by ensuring the exploitation of fisheries resources is consistent with the principles of ESD, and
    - to ensure broader habitat security for non-living ecological components.
- This is consistent with current legislation and fisheries policies and represents a change from when the ERAEF was first developed and there was less policy or legislation-based guidance on sustainability objectives. A range of secondary objectives remain available to stakeholders for selection where in some instances they may also be appropriate, and particularly provide guidance for assessing habitats and ecological communities (e.g. tables 5A-C in Hobday et al. 2007).

Component	Core Objective
Key commercial species	Maintain key commercial stocks at ecologically sustainable levels Avoid recruitment impairment of key commercial species Avoid negative consequences for species or population sub-components
Byproduct species	Avoid recruitment impairment of the byproduct species Avoid negative consequences for species or population sub-components

Component	Core Objective
General bycatch species	Avoid recruitment impairment of the general bycatch species Avoid negative consequences for bycatch species or population sub-components
EPBC Act-listed species	Avoid recruitment impairment of EPBC Act-listed species Avoid negative consequences for EPBC Act-listed species or population sub-components Avoid negative impacts on EPBC Act-listed species or population sub-components from fishing
Habitats	Avoid negative impacts on the quality of the environment Avoid reduction in the amount and quality of habitat
Communities	Avoid negative impacts on the composition/ function/ distribution/ structure of the community

- Re-assessments will look to cost-effectively review and update the previous scoping information and utilise existing consultation forums and meetings (principally RAG, MAC, ERMSG and the Commission).

- Species list generation – with increased observer and EM coverage and improved ERA methodology, there is now scope to improve methods involved with the generation of species lists to enable improved time and resource efficiency, without sacrificing the precautionary nature of ERA. Within the scoping process, the use of species-accumulation-curves may now be used as a tool for developing the species list. As assessment of these curves will inform assessors and AFMA as to whether the species list is adequate, or if it is likely to be missing species. If it is deemed adequate, species lists will be compiled using only the species included in the curve. Where the curve is not considered to be mature, the species list must be based on all species with a range and depth overlap with the fishery.

- Expansion of generic species listings – traditionally, all generic species groups (e.g. albatross) have been expanded to all species within that group. However, this leads to the ballooning of the number of species that require assessment, many of which likely do not interact with the fishery. To improve this process, only those species that have a range and depth overlap with the fishery will now be included. Interactions recorded in logbooks at the species level will be included within the species list. Final lists are based on observer data (if available) and/or expert advice.

- Assigning of species to ecological components – it is important that species are assigned to the correct component. MACs and RAGs are responsible for providing advice as to how species are categorised.

- Species list for Level 1 (SICA) – once the scoping species list is developed, species which already have re-occurring Level 3 Quantitative assessments (e.g. in association with harvest strategies, rebuilding strategies or other management processes) are not evaluated further as there is another assessment available for them. Species with Level 3 assessments or equivalent (including conservation dependent species with such assessments) should not be included in Level 1 or Level 2 analyses. There may be some cases where a harvest strategy-based assessment is not available, but the RAG considers other available and recent assessments/indicators for a particular species to provide a more robust assessment of risk than Level 2 ERA assessment tools.

- Level 1 bypass mechanism – a mechanism whereby fishery RAGs can request to bypass Level 1 for species components ONLY, and directly undertake Level 2 has been developed by CSIRO. This will reduce costs and improve the efficiency of the ERA process without compromising outcomes for fisheries that are likely to be assessed as 'at-risk' as a result of Level 1. This option has been developed for any fishery that is likely to always require assessment of species at Level 2 given the level of interaction with certain species and the precautionary nature of SICA.

- An automated Level 1 assessment has also been developed by CSIRO, that can assess a particular ecological component of interest and/or applicability. This modular flexible approach enables a Level 1 assessment of one or more ecological component(s) to be undertaken.

Level 2

- This includes both PSA and SAFE methods (noting the latter has been previously described as Level 2.5 or 3), with the preferred assessment tool being bSAFE (base SAFE, rather than eSAFE, enhanced SAFE). SAFE is considered more robust due to its use of explicit reference points and a continuous scale for attributes (greater sensitivity relative to PSA) and greater utility for assessing management responses (Smith et al. 2014).

- PSA should be applied for species with insufficient data (e.g. distributional data) or having biological characteristics (e.g. colonial breeders) that are not suitable for assessment by bSAFE (CSIRO 2015). Typically this has been the case for EPBC Act-listed species (especially mammals, reptiles, and seabirds) and invertebrates.

- It should be noted that PSA and SAFE are only two of a spectrum of tools that might appropriately be used at Level 2 and at this level a merger with the tier structure of harvest strategies or the addition of any equivalent other tool might be possible in future.

- It is recommended that species assessed to be at high risk via bSAFE analyses should then be assessed via eSAFE, providing AFMA does not wish to take management action based on bSAFE alone or the required data is not available.

- SAFE has been further developed to be able to account for cumulative risk across multiple fisheries.

- Residual Risk Guidelines will be applied to species assessed as high risk via PSA and species assessed as high/medium risk via SAFE due to the increased possibility of false negatives via the SAFE method.

Moving between ERAEF Levels

The rationale that needs to be applied when determining whether to progress species between levels of the ERAEF (Hobday et al. 2011) remains essentially the same in the revised process. Such decisions depend on:

- estimated risk at the current level (i.e. low risk species will not be assessed at the next level)

- risk-catch-cost principles – is the cost of assessing at the next level greater than the cost of managing directly (with appropriate precaution) at the current level

- whether the "high risk" estimate may be due to a lack of data

- availability of data to proceed to the next level (e.g. data collection may be required first, or may not be cost justified, and management action might be taken without higher level assessment), and

- management response to risks identified at the current level. For example, if the risk is high but immediate changes to management regulations or fishing practices will reduce the risk (without unacceptable economic impacts on industry), then analysis at the next level may be unnecessary.

Precautionary elements

The ERAEF approach has several features that result in a precautionary or conservative approach to identifying and ranking ecological risk. Principal among these is assuming potential high risk in the absence of data or information to the contrary. This feature provides an incentive to collect data to support future assessments. In general, the precautionary approach will result in more false positives (units identified at higher risk than would occur when assessed at a higher level with more data) than false negatives (units scored at a lower risk than would occur when assessed at a higher level with more data). This bias is important, as false positive results can be screened out at higher levels in the ERAEF hierarchy, while false negatives result in improper elimination of a hazard or unit, with no further opportunity to consider it at later stages in the ERAEF. While no error would be preferable, the uncertainty associated with the qualitative and semi-quantitative risk assessments at Levels 1 and 2 argues in favour of maintaining a bias against false negative results (Hobday et al. 2011). Although this may reduce the efficiency of this process in some instances, it increases the likelihood of ERAEF identifying all components that are at risk which is its most important function.

ERAEF performance criteria

It is intended that the revised ERAEF meet, to the greatest extent possible (recognising there are trade-offs between some factors below), the following criteria (Hobday et al. 2011):

- comprehensive (identify and analyse all potential hazards)
- flexible (applicable to all types of fishery, irrespective of size, fishing method, species)
- understandable (easy for stakeholders to grasp) and clearly articulated/communicated. This includes clarifying its role/interaction with other processes, such as harvest and bycatch strategies
- transparent and repeatable (be clear about the methods, data and assumptions used in the analyses)
- cost effective (make use of existing knowledge, information, and data within realistic limits of time and resources)
- scientifically defensible (be able to withstand independent scientific peer review)
- useful for management (inform appropriate risk management responses)
- take a precautionary approach to uncertainty, and
- where possible ensure risk equivalency across tools and levels.

A key to success of the new framework and methods will be greater acceptance and transparency for stakeholders. This will be facilitated by improved credibility of the methods and assessments themselves, as well as by having a more cost and time-efficient process (Smith et al. 2014).

Key processes in the ERAEF

The following overview is presented here to highlight the key principles, features and most importantly, changes to the processes initially described in Hobday et al. (2007). The following sections provide an overview of the five key phases/processes of the ERAEF:

- Stakeholder consultation.
- Scoping.
- Level 1 SICA (qualitative risk assessment).
- Level 2 (semi-quantitative and quantitative methods).
- Level 3 (fully quantitative methods).

Stakeholder consultation

Participation of stakeholders is an important feature of ERAEF and is particularly important in the more qualitative levels of the hierarchy (Scoping and Level 1). Stakeholders are defined as those people who have a direct interest in a fishery, and can include commercial fishers, managers, recreational fishers, Indigenous fishers, conservation focused non-government organisations, fishery scientists, and experts in particular taxa (Hobday et al. 2011).

Stakeholder participation in the process not only improves the assessments, but also increases the chance of uptake of results and helps in identifying suitable management responses. In many fisheries in Australia, a wide range of stakeholders are already involved in the management process. Without a good representation of stakeholders, issues may not be correctly identified or evaluated, particularly at Level 1 in the ERAEF. Most often, stakeholders are engaged through face-to-face meetings, usually after initial draft documents have been prepared (Hobday et al. 2011). A record of stakeholder involvement is kept as part of the ERAEF process, via a proforma: *Summary Document SD1. Summary of stakeholder involvement for fishery* (Hobday et al. 2007).

Scoping

Scoping involves six key steps. The following is a brief overview of these steps, relevant to a fishery being assessed for the first time. It should be noted that for fisheries being re-assessed, Scoping may comprise a more simplified updating of previously compiled information. These steps are described in more detail in Hobday et al. (2007) and the CSIRO technical summary.

Step 1 – Characterisation of the fishery

This step involves the development of a general fishery characteristics document which provides a reference for discussions and clarification of analysis for Levels 1 and 2 at stakeholder meetings. The information used to complete this step may come from a large range of management and research documents relevant to the fishery being assessed. The information obtained is used to complete a fishery characterisation proforma: *Scoping Document S1 General Fishery Characteristics* (Hobday et al. 2007) and also on the following CSIRO https://research.csiro.au/cor/fisheries-domestic/ecological-risk-assessment/

Step 2 – Listing of units of analysis (e.g. species, habitats or community assemblages)

A revised process for developing species lists for assessment has been developed. With increased observer (and electronic monitoring) coverage and a revised ERAEF methodology, there is scope to improve the efficiency of this process. A step-by-step process will now be applied when developing species lists as follows:

- AFMA to provide initial species list to assessor, including all observer, logbook, electronic monitoring, and any other relevant data from the entire time series for the fishery
- remove any mis-identified species that do not have a spatial or depth overlap with the fishery
- undertake statistical Species Accumulation Curve to inform decision on whether or not existing sampling levels have provided an adequate species list. i.e. it contains all/most species likely interacting with the fishery. Fishery managers should consider issues such as the level of observer coverage, percentage of total species expected and how many species would be expected in the next year to make a judgement on the "maturity" of the curve:
    - If the curve is considered to be "mature", it forms the species list.
    - If the curve is not "mature" the species list includes all species that have a spatial and depth overlap with the fishery.
- all species inclusions and exclusions must be fully justified in the ERA report
- expand generic species listings (e.g. albatross): Where interactions are recorded in logbooks to the species level, these species are to be included in the list. Final lists are based on observer data (if available) and/or expert advice, and
- the final list will be presented to RAG/AFMA/expert groups for review and endorsement. Ideally, this information is provided before the assessment is undertaken, to increase efficiencies in this process.

Species Accumulation Curve plots show the rate of accumulation of new species observed within a fishery over time Figure 3. If this curve plateaus, then the occurrence of new species in the fishery is rare, and therefore, all species that are likely to interact with the fishery have been recorded, assuming no major changes in the fishery (e.g. spatial effort, gear). If this plot has not plateaued, and the number of new species being recorded is still occurring on a common basis, then species recorded in the period chosen for re-assessment may not sufficiently represent all those that are interacting with the fishery. If this is the case, species not recorded should also be considered for assessment.

Although this revised technique may be considered less precautionary, it is also important to note that any new species observed in intervening years will be immediately assessed using the new Level 2 online PSA/SAFE tool during annual reporting and review of fisheries. Therefore, the likelihood of a species that is interacting with the fishery significantly remaining unassessed is very low, maintaining the precautionary nature of ERAEF.

The set of habitats is based on geo-morphology (Williams et al. 2011) and more recently on habitat assemblages (Pitcher et al., 2016, 2018). Substratum and faunistic characters and the community units are either qualitative or model-based food-web descriptions. These are recorded via Scoping Documents S2A, S2B and S2C (Hobday et al. 2007). Development of improved habitat and community data is an ongoing priority.

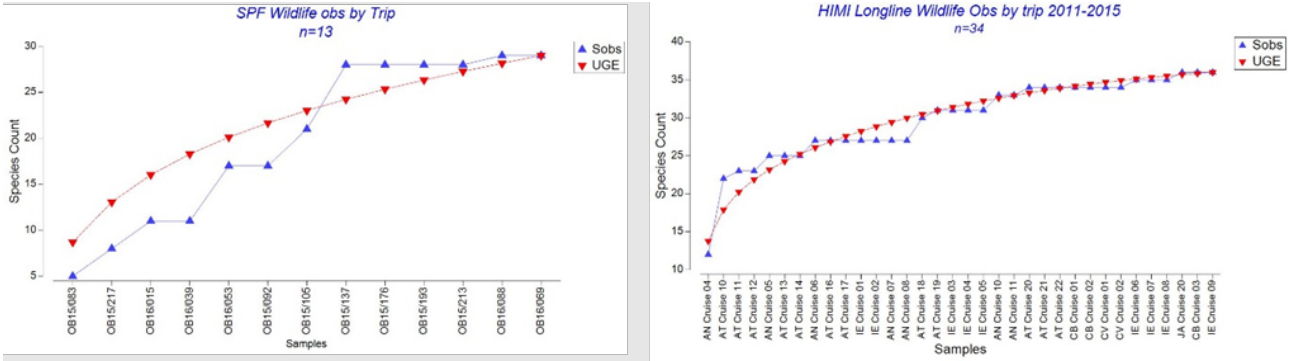

Figure 3: A comparison of Species Accumulation Curves for two AFMA fisheries. A) Small Pelagic Fishery and B) Heard and Macquarie Island Fishery. The rate of species accumulation in the HIMI is much lower due to 100% observer coverage and the longevity of the fishery. In contrast, the SPF, a relatively new fishery, is still interacting with new species commonly despite 100% observer coverage. Therefore, species not observed in the SPF should be considered for assessment, whereas the HIMI seems to have adequate observer coverage with just six new species observed throughout the last two thirds of sampled trips.

Step 3 – Identification of objectives for components and sub-components

Management objectives need to be identified for each component (core objectives) and sub-component (operational objectives), with the latter expressed as limits to acceptable change (what is "acceptable" needs to be defined in each case). Core objectives (also called endpoints) identify what you are trying to achieve. Operational objectives (or measurement endpoints) are objectives stated in ways that can be measured. It is important to identify objectives that managers, the fishing industry, and other stakeholders can agree on, and that scientists can quantify and assess. The identified objectives are used as part of the Level 1 SICA analysis. For species, it is important that the objectives chosen are consistent with those in fisheries policies, guidelines, and this Guide. The key species level risk being managed for under the ERM objective is avoiding recruitment impairment.

Step 4 – Hazard identification

The set of activities is selected from a comprehensive checklist. Formally, these activities are known as hazards (Burgman 2005). In ERAEF, hazards are the activities undertaken in the process of fishing, together with any external activities, which have the potential to adversely impact on ecological components (i.e. species, habitats, communities). The fishery-specific hazards are divided into the following categories based on the major effect of the activity.

- Capture/removal.
- Direct impact without capture.
- Addition/movement of biological material.
- Addition of non-biological material.
- Disturbance of physical processes.
- External hazards.

These categories are then subdivided into fishing activities (of the fishery being evaluated) and external activities (including other fisheries) (Hobday et al., 2007). These fishing and external activities are scored on a presence/absence basis for each fishery. Only those activities that are scored as present in a fishery are then carried forward for analysis in subsequent levels.

Step 5 – Bibliography

All references are to be included in the ERA Results Report bibliography.

Step 6 – Decision rules to move to Level 1

Any hazards that are identified at "Step 4 Hazard Identification" as occurring in the fishery are carried forward for analysis at Level 1 (Hobday et al. 2007).

Level 1 – Scale Intensity Consequence Analysis (qualitative risk assessment)

Scale Intensity Consequence Analysis (SICA) uses an exposure-effects risk assessment approach that is only applied to the "most vulnerable" unit (i.e. species) of an ecological component. This makes SICA an efficient screening process of low-risk components as those deemed to be low risk are rejected at Level 1. It scores each fishing activity (hazard) for impact against a core objective. The scale and intensity of the activity are each scored (≈exposure), and then the consequence score (≈effect) is selected from a component-specific set of scoring Guidelines (Hobday et al. 2007). These scoring tables, adapted from Fletcher et al. (2002), reflect a range of impact levels from negligible (score 1) to extreme (score 6). Scores of 3 or higher within a component result in that component being examined at Level 2.

The scale and intensity scoring reflects potential changes in the catch/removal term of the logistic model (q and E) due to the hazard, while the consequence scoring reflects the effect the hazard will have on the intrinsic rate of increase (R). For example, a high intensity score would indicate that "removal" is highly likely, while a high consequence score indicates that the rate of increase or carrying capacity would be greatly reduced by this activity. The effort term (E) is approximated by the spatial and temporal scale of the activity, which is an important consideration in evaluating the risk for particular activities.

SICA relies on expert judgement and stakeholder input. Stakeholders provide feedback on three key components of SICA initially compiled by the assessor. Stakeholders and experts provide input during selection of the "most vulnerable" unit of an ecological component for subsequent assessment. Once agreed upon, assessors will undertake the analysis. Draft results are then presented to stakeholders to provide input on scale and intensity scores and overall risk rankings. Lastly, stakeholders provide input detailing appropriate rationale of overall risk scores which is important for the broader public uptake of results and to increase transparency.

Uncertainty and precautionary elements

SICA employs a "plausible worst case" approach to evaluation of risk, rather than considering all possible interactions. In assigning a consequence score for each activity/component combination, the highest-scoring (worst case) plausible scenario is selected. For example, in scoring the direct impact of fishing on the bycatch component, the stakeholders would consider the relative vulnerability to the gear among the bycatch species and select the most vulnerable species based on the combination of exposure to the gear and potential rate of recovery of the species to impact. The highest score consistent with a plausible scenario is reported. If the plausible worst-case scenario is not assessed to be at significant risk, then all other hazards will be at even lower risk. This leads to considerable efficiency in screening out low risks. The level of consequence that is deemed "significant" can also be selected with precaution in mind. In Australian applications to date, any consequence level above "minor" (score of 2) either elicits a management response or is analysed further at a higher level in the hierarchy.

Inclusion of current management arrangements can be incorporated into SICA because these are based on expert judgement that can include knowledge of such arrangements (Smith et al. 2014).

Issues to be aware of

- For fisheries that have significant bycatch components and are likely to require assessment at Level 2, a mechanism has now been developed whereby stakeholders/AFMA can decide to bypass Level 1 for species components only (habitats and communities still assessed at Level 1) and be directly assessed at Level 2. This will reduce costs and improve the efficiency of the ERA process without compromising outcomes for fisheries that are likely to be assessed as 'at-risk' because of Level 1. This may also aid fisheries in attaining external sustainability certification (e.g. MSC).

- An automated Level 1 assessment has also been developed by CSIRO, that can assess a particular ecological component of interest and/or applicability. This modular flexible approach enables a Level 1 assessment of one or more ecological component(s) to be undertaken. There is a possibility that results of a Level 2 could lead to false-positive risks, particularly for data-limited fisheries/sub-fisheries, should a Level 1 assessment be bypassed.

- Where an external hazard (e.g. coastal development) is considered to be a high risk activity at Level 1, it must be appropriately handled. Because this is an external hazard and not within the jurisdiction of AFMA, this will not move to Level 2 and a management response will likely be ineffective. Therefore, it is the responsibility of AFMA fishery managers to make the relevant authority is aware of such risks.

Level 2 (semi-quantitative and lower tier quantitative methods)

When the risk of an activity at Level 1 (SICA) on a species component is moderate or higher and no planned management interventions that would remove this risk are identified, an assessment is required at Level 2 (to determine if the risk is real and provide further information on the risk). The tools used to assess risk at Level 2 allow units (e.g. all individual species) within any of the ecological species components (e.g. commercial, bycatch, and EPBC Act-listed species) to be effectively and comprehensively screened for risk. The units of analysis are identified at the scoping stage. To date, Level 2 tools have been designed to measure risk from direct impacts of fishing only (i.e. risk of overfishing, leading to an overfished fishery), which in all assessments to date has been the hazard with the greatest risks identified at Level 1[3].

Changes to Level 2 since the original ERAEF

In the period since ERAEF was initially implemented across Commonwealth fisheries, much of the management focus has been on the assessment results associated with Level 2 and 3 risk assessment methods, which comprise semi-quantitative or rapid simple quantitative methods (e.g. PSA and SAFE). This level has been subject to the greatest level of change and improvement, and these are discussed in the following sections.

Level 2 was originally designed to rely on a single risk assessment methodology, the Productivity Susceptibility Analysis (PSA), however a more quantitative method called the Sustainability Assessment for Fishing Effects (SAFE) was developed early in the implementation of the ERAEF and is now the preferred Level 2 methodology. SAFE has been developed in two forms, base SAFE (bSAFE) and enhanced SAFE (eSAFE). eSAFE has greater data and resourcing (time/money) requirements than bSAFE but can more appropriately model spatial availability aspects when sufficient data are available.

[3] Future iterations of the methodology will include PSAs modified to measure the risk due to other activities, such as gear loss.

Under the revised ERAEF:

- bSAFE has now been re-classified as the preferred Level 2 method (over PSA) where sufficient spatial and biological data (to support bSAFE) are available. Typically, this has been used for teleost and chondrichthyan species
- species estimated to be at high risk under bSAFE may then be assessed under eSAFE which may provide reduced estimates of uncertainty pertaining to the actual risk
- where either the data or species biological characteristics are insufficient to support bSAFE analyses, it is recommended that PSA be applied instead. This will be the case for many EPBC Act-listed species, invertebrate bycatch species and some other species
- at Level 2, either PSA or SAFE methods should be applied to any given species, not both
- for high risk species it is a management choice whether to progress to eSAFE, pursue a Level 3 fully quantitative stock assessment, or to take more immediate management action to reduce the risk.
- RRA will be undertaken for high-risk species for both SAFE and PSA, with some medium risk species also considered under SAFE, where applicable, due to the increased possibility of false negatives
- it is also recognised that several additional tools, including some of the "data poor" assessment tools that are used to inform harvest strategies, could potentially be included within the Level 2 toolkit, and
- they are distinguished from Level 3 quantitative tools (i.e. stock assessment models) that are more data rich and able to more precisely quantify the uncertainty.

Productivity-Susceptibility Analyses (PSA)

The PSA approach used under the ERAEF follows on from an approach developed by Stobutzki et al. (2002) and is based on the assumption that the risk to a unit (e.g. species, habitat or community) will depend on two characteristics of that unit:

- The extent of the impact due to the fishing activity, which will be determined by the susceptibility of the unit to the fishing activities (Susceptibility).
- The productivity of the unit (Productivity), which will determine the rate at which the unit can recover after potential depletion or damage by fishing.

It is important to note that the PSA essentially measures relative potential risk of overfishing (hereafter noted as risk) and does not provide a measure of absolute risk, which requires some direct measure of abundance or mortality rate for the unit (i.e. species) in question. The PSA approach examines attributes of each unit that contribute to or reflect its productivity or susceptibility to provide a relative measure of risk to the unit. Full details of the methods are described in Hobday et al. (2007).

PSA is designed to be precautionary in how it assigns risk (Hobday et al. 2011), because:

- attributes default to high-risk values if there is missing information
- independently verified information can be used to modify scores
- some assumptions are precautionary e.g. assuming that the spatial extent of stocks doesn't extend outside a fishery when estimating spatial overlaps.

Thus, PSA is designed to be more likely to produce "false positive" results (classify species as high risk when they are not) than false negative results (classify species as low risk when they are high risk). The RRA process was put in place largely to reduce the number of false positive results but could be used to assess false negatives in future.

The PSA process involves nine key steps. The following is a brief overview of these steps.

Step 1

Identify the units excluded from analysis and document the reason for exclusion (Hobday et al. 2007)

Step 2 – Score units for productivity

The level of fishing impact a unit (e.g. species population) can sustain will depend on its inherent productivity. Productivity determines how rapidly a species can recover from depletion or impact due to fishing. The productivity of a unit such as a species or population is determined by species attributes such as longevity, growth rate, fecundity, recruitment, and natural mortality. The attributes used to score productivity for the three species components (i.e. commercial, bycatch, EPBC Act-listed species) are described in Table 3. A recent improvement has been, with more data available, some of the previously neglected indicators (e.g. growth) may be used, as may the direct measure of recruitment (R). There has also been a refinement of the cut-off scores (Table 4) to decrease the frequency of false positives and false negatives. While units have inherent productivity, fishing can also affect productivity of the unit depending on the size of reduction in the unit and the life stage of a species taken by a fishery (Hobday et al. 2011).

Table 3: Productivity cut off scores for species attributes for the ERAEF Level 2 PSA method. These cut offs have been determined from analysis of the distribution of attribute values for species in the ERAEF database and are intended to divide the attribute values into low, medium, and high productivity categories.

Attribute	Low productivity (high risk, score = 3)	Medium productivity (medium risk, score = 2)	High productivity (Low risk, score = 1)
Average age at maturity	> 15 years	5–15 years	< 5 years
Average maximum age	> 25 years	10–25 years	< 10 years
Fecundity	< 100 eggs per year	100–20,000 eggs per year	> 20,000 eggs per year
Average maximum size	> 300 cm	100–300 cm	< 100 cm
Average size at maturity	> 200 cm	40–200 cm	< 40 cm
Reproductive strategy	Live bearer (and birds)	Demersal egg layer	Broadcast spawner
Trophic level	> 3.25	2.75–3.25	< 2.75

Step 3 – Score units for susceptibility

The level of fishing impact that a unit can sustain depends on its susceptibility to capture or damage by fishery activities. Following Walker et al. (2005), susceptibility is estimated as the product of the following four independent aspects:

- Availability – considers overlap of the fishing effort with a species distribution. Where a fishery overlaps a large proportion of a species range the risk is high because the species has no refuge, and the potential for impact is high. A recent improvement has been continuous scoring for the availability attribute which will allow more continuous measurement of on-water changes.

- Encounterability – considers the likelihood that a species will encounter fishing gear that is deployed within the geographic range of that species. The main component of encounterability considered for each species is its adult habitat. This habitat is also checked to determine if it lies within a bathymetric zone where fishing is permitted.

- Selectivity – for species that encounter fishing gear, selectivity considers the potential of gear to capture or retain the species.

- Post Capture Mortality – evaluates the case that, if captured, a species would be released in a condition that would permit subsequent survival.

The cut-off scores associated with each of these attributes are presented in Table 4. These have been recently refined to decrease the frequency of false positives and false negatives. A multiplicative approach is considered more appropriate for susceptibility because low risk for any single aspect acts to reduce the overall risk to a low value.

The treatment of these aspects has been tailored to utilize original datasets (e.g. FishBase), and incorporate additional information, such as outputs from the BIOREG Project (Lyne et al., 2005), and additional distributional information compiled specifically for EPBC Act-listed species that represents an improvement over previous datasets.

Table 4: Susceptibility cut off scores for species attributes for the ERAEF Level 2 PSA method. These example cut offs have been determined from analysis of the distribution of attribute values for species in the ERAEF database and are intended to divide the attribute values into low, medium, and high susceptibility categories. A choice of attributes exists for some susceptibility aspects, such as availability; where data are available, Availability 1 is preferred over Availability 2, while for Encounterability, the maximum score of the two attribute choices (Encounterability 1 and Encounterability 2) is used. More specific detail is provided in the PSA spreadsheets.

Attribute	Low susceptibility (low risk, score=1)	Medium susceptibility (medium risk, score=2)	High susceptibility (High risk, score=3)
Availability 1. Overlap of species range with fishery	<10% overlap	10–30% overlap	>30% overlap
Availability 2. Global distribution. Also need to consider stock proxies	Globally distributed	Restricted to same hemisphere/ocean basin as fishery	Restricted to same country as fishery
Encounterability 1 – Habitat (scores vary by fishery)	Low overlap with fishing gear	Medium overlap with fishing gear	High overlap with fishing gear
Encounterability 2 – Depth check (scores vary by fishery)	Low overlap with fishing gear	Medium overlap with fishing gear	High overlap with fishing gear
Selectivity (scores vary by gear type, this example is for set gillnets)	Species < mesh size, or >5 m in length	Species 1–2 times mesh size, 4–5 m in length	Species >2 times mesh size, to say, 4 m in length
Post-capture mortality (scores vary by fishery)	Evidence of post-capture release and survival	Released alive	Retained species, or majority dead when released

Step 4 – Plot individual units of analysis onto a PSA Plot

The productivity and susceptibility attributes in Steps 2 and 3 are scored as 1 (low), 2 (medium) or 3 (high). Missing attributes are scored as a 3. The average productivity and multiplied susceptibility scores for each unit of analysis (e.g. for each species) are then displayed on a PSA plot (Figure 4). The relative position of the units on the plot will determine relative risk at the unit level as per the PSA plot. An overall risk score is the Euclidean distance from the origin, which allows a single risk ranking (Hobday et al. 2007, 2011).

- Units that fall in the upper third of the PSA plots are deemed to be at high risk.
- Units with a PSA score in the middle are at medium risk.
- Units in the lower third are at low risk regarding the productivity and susceptibility attributes.

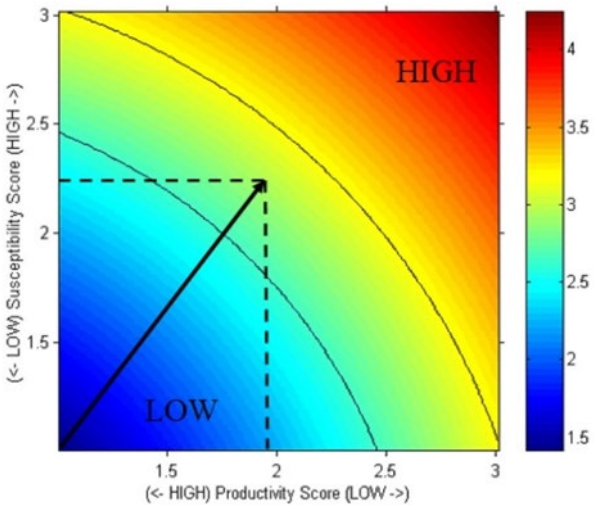

Figure 4: Example PSA plot showing the paired productivity/susceptibility scores for example species, relative to the low, medium and high-risk areas of the plot.

The divisions between these risk categories are based on dividing the area of the PSA plots into equal thirds. If all productivity and susceptibility scores (scale 1–3) are assumed to be equally likely, then 1/3rd of the Euclidean overall risk values will be greater than 3.18 (high risk), 1/3rd will be between 3.18 and 2.64 (medium risk), and 1/3rd will be lower than 2.64 (low risk). It is important to note that these risk values are mostly determined by "intrinsic" properties of the species (productivity), and while the relative fishery interactions are measured through the susceptibility attributes, assessment of the actual impact of the fishery on the species is not made. None of these risk thresholds relate directly to actual population status reference points.

Step 5 – Uncertainty ranking of overall risk to each unit

The uncertainty is due to missing attributes, which is partly handled by the division into data deficient and robust categories.

Step 6 – Residual Risk Assessment (RRA)

Due to the semi-quantitative nature of a Level 2 PSA assessment, there is a number of limitations. In particular, certain management arrangements which mitigate the risks posed by a fishery, as well as additional information concerning levels of direct mortality, may not be easily taken into account in the assessments. Further, the number of interactions recorded for each unit is purposefully not included within PSA due to historical issues of low observer coverage and how to define risk based on interaction numbers given the large variation in population abundance for different species.

RRA is used to consider additional information, particularly the mitigating effects of management arrangements that were not explicitly included in the attributes. RRA also considers factors such as the number of interactions recorded by observers/logbook data and whether new or missing data is available that may influence a species risk status. RRA is undertaken for species assessed as high risk under PSA due to its bias towards false positives. However, in theory RRA could also be used to determine if some species have been incorrectly classified as low/medium risk.

The Residual Risk Assessment is conducted by applying the following guidelines. At the moment, the guidelines are applied to species and are not applicable to habitats and communities. They are:

- Guideline 1. Risk rating due to missing, incorrect or out of date information
- Guideline 2. At risk due to external factors (cumulative risks)
- Guideline 3. At risk in regards to level of interaction/capture with a zero or negligible level of susceptibility

- Guideline 4. Effort and catch management arrangements for key and secondary commercial and byproduct species

- Guideline 5. Management arrangements to mitigate against the level of bycatch, and

- Guideline 6. Management arrangements relating to seasonal, spatial and depth closures.

The residual risk guidelines are not seen as a definitive guide on the determination of residual risk, and it is expected that in a small number of cases, the guidelines may not apply. Care must also be taken when applying the guidelines to ensure residual risk results are appropriate in a practical sense. There are several conditions which underpin the guidelines and should be understood before the Guidelines are applied:

- All assessments and management measures used within the RRA must be implemented prior to the assessment with sufficient data to demonstrate the effect. Any planned or proposed measures can be referred to in the assessment but cannot be used to revise the risk score.

- When applied, the Guidelines generally result in changes to particular "attribute" scores for a particular species. Only after all Guidelines have been applied to a particular species, should the overall risk category be re-calculated. This will ensure consistency, as well as facilitating the application of multiple Guidelines.

- Unless there is clear and substantiated information to support applying an individual guideline, then the attribute and residual risk score should remain unchanged. All supporting information considered in applying these Guidelines must be clearly documented and referenced where applicable. This is consistent with the precautionary approach applied in ERAs, with residual risk remaining high unless there is evidence to the contrary ensuring a transparent process is applied.

- The results (including supporting information and justifications) from RRA must be documented in "Residual Risk Reports" for each fishery (or can be integrated into the Level 2 risk assessment report). These will be publicly available documents.

Step 7 – Evaluation of reasons for "high" risk rankings

Following the Level 2 PSA and RRA, the high and medium risk species can be divided into five categories that highlight potential reasons for the higher risk scores. These categories should also help identify any remaining areas of uncertainty and assist decisions regarding possible management responses for these species. The categories are independent, and species are allocated to each category in the order the categories are presented below:

- Category 1: Missing attributes data.

- Category 2: Spatial overlap (widely distributed or low overlap).

- Category 3: Very low (susceptibility) attribute score outweighed by low productivity.

- Category 4: Spatial uncertainty (unreliable distributional data).

- Category 5 Other: risk score not affected by 1–4 considered above.

Step 8 – Evaluation of the PSA analysis after RRA

This involves the summarisation and reporting of PSA results to stakeholders via a template report format specified in Hobday et al. (2007).

Step 9 – Management response to risk assessments

Following RRA (or in future, the application of a PSA with management axis) those species identified as potentially being at high risk are expected to be the focus of further work, either through:

- Implementing a management response to address the risk to the vulnerable species
- Collection of missing attribute information and re-assessment at Level 2 (for species where high-risk ranking may be due to missing attribute data), and
- Further examination for risk within the particular ecological component at Level 3.

Units at low risk will be deemed not at risk from the sub-fishery and the assessment is concluded for these units. Units at medium risk may not be a focus of initial management attention but may receive attention where resources allow and high-risk units have been addressed to the extent possible.

Issues to be aware of

PSA provides a measure of relative potential risk, rather than absolute risk. It helps fishery managers to understand which species, amongst a group of species caught in a fishery, is at a relatively higher potential risk of overfishing. In situations where the fishery has not been overfished in the past (or currently) it may also provide an indication of the relative potential risk of the population becoming overfished in future (assuming constant values for susceptibility and or productivity attributes).

However, the methodology as it currently stands has several limitations:

- Unlike Level 3 stock assessments, PSA cannot quantify the probability that overfishing is occurring.
- PSA cannot estimate any measure of biomass, nor can it indicate either the relative or absolute risk of a fish stock being overfished.
- Furthermore, where an overfished fishery has occurred and is still current, it may be that the relationship between "susceptibility" and risk (of overfishing) is also modified.
- PSA is designed to be biased towards false positive results (i.e. it's precautionary) and in addition, is unable to take account of some management measures, such as catch or effort restrictions, which might lower the inherent susceptibility of a given species. It is for this reason that an additional process, RRA, was developed.
- It should be noted that PSA is now used on a much smaller subset of species (EPBC Act-listed species and invertebrates mainly) than occurred when the ERAEF was developed.
- PSA is not currently configured to allow for the assessment of cumulative risk across multiple fisheries.

Sustainability Analysis for Fishing Effects (SAFE)

SAFE has been developed in two forms, base SAFE (bSAFE) and an enhanced SAFE (eSAFE). eSAFE has greater data and resourcing (time/$) requirements and is recommended to only be used to assess species estimated to be at high risk via bSAFE.

bSAFE

Relative to the PSA approach, the bSAFE approach (Zhou and Griffiths, 2008; Zhou et al. 2011) is:

- a more quantitative approach (analogous to stock assessment) that is able to provide an absolute measure of risk of overfishing by estimating fishing mortality rates relative to fishing mortality rate reference points (based on life history parameters)
- requires less productivity data than PSA
- is able to account for cumulative risk, and
- potentially outperforms PSA in several areas, including consistency with Tier 1 overfishing assessment classifications (Zhou et al. 2016).

Like PSA, the bSAFE method is a transparent, relatively rapid and cost-effective process for screening large numbers of species for risk and is far less demanding of data and much simpler to apply than a typical quantitative stock assessment.

As such it is recommended that bSAFE be used as the preferred Level 2 assessment tool for all fish species and some invertebrates and reptiles (e.g. some sea snakes) with sufficient data.

In estimating fishing mortality, bSAFE utilises much of the same information as PSA, to estimate:

- spatial overlap between species distribution and fishing effort distribution
- catchability resulting from the probability of encountering the gear and size-dependent selectivity
- post-capture mortality.

Fishing mortality is essentially the fraction of overlap between fished area and the species distribution, adjusted by catchability and post-capture mortality. Uncertainty around the estimated fishing mortality is estimated by including variances in encounterability, selectivity, survival rate and fishing effort between years.

The three biological reference points are based on a simple surplus production model:

- F_{MSM} – instantaneous fishing mortality rate that corresponds to the maximum number of fish in the population that can be killed by fishing in the long term. The latter is the maximum sustainable fishing mortality (MSM) at B_{MSM}, similar to target species MSM. Species assessed to be below this line will be considered to be at low risk.
- F_{LIM} – instantaneous fishing mortality rate that corresponds to the limit biomass B_{LIM} where B_{LIM} is assumed to be half of the biomass that supports a maximum sustainable fishing mortality ($0.5B_{MSM}$). Species assessed to be below this line, but above F_{MSM}, will be considered to be at medium risk.
- F_{CRASH} – minimum unsustainable instantaneous fishing mortality rate that, in theory, will lead to population extinction in the long term. Species assessed to be above this line, but above F_{LIM}, will be considered to be at high risk (Figure 5).

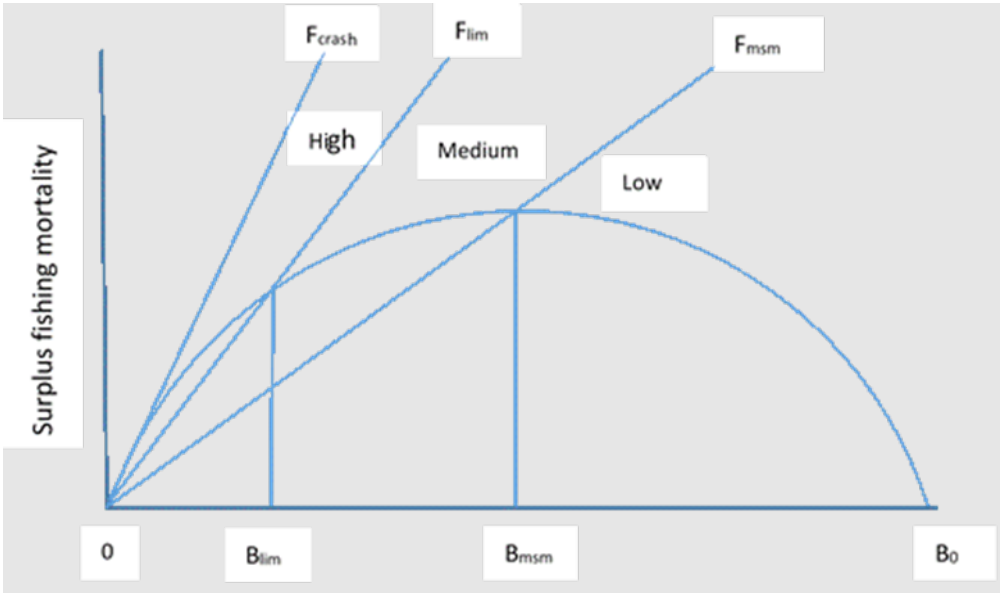

Figure 5: Stock productivity, biological reference points and ecological risk assessment categories for managing bycatch species.

This methodology produces quantified indicators of performance against fishing mortality-based reference points (Figure 6) and as such does allow calibration with other stock assessment and risk assessment tools that measure fishing mortality. It allows the risk of overfishing to be determined, via estimates of fishing mortality relative to reference points. Uncertainty (error bars) are related to the variation in the estimation of the scores for each axis.

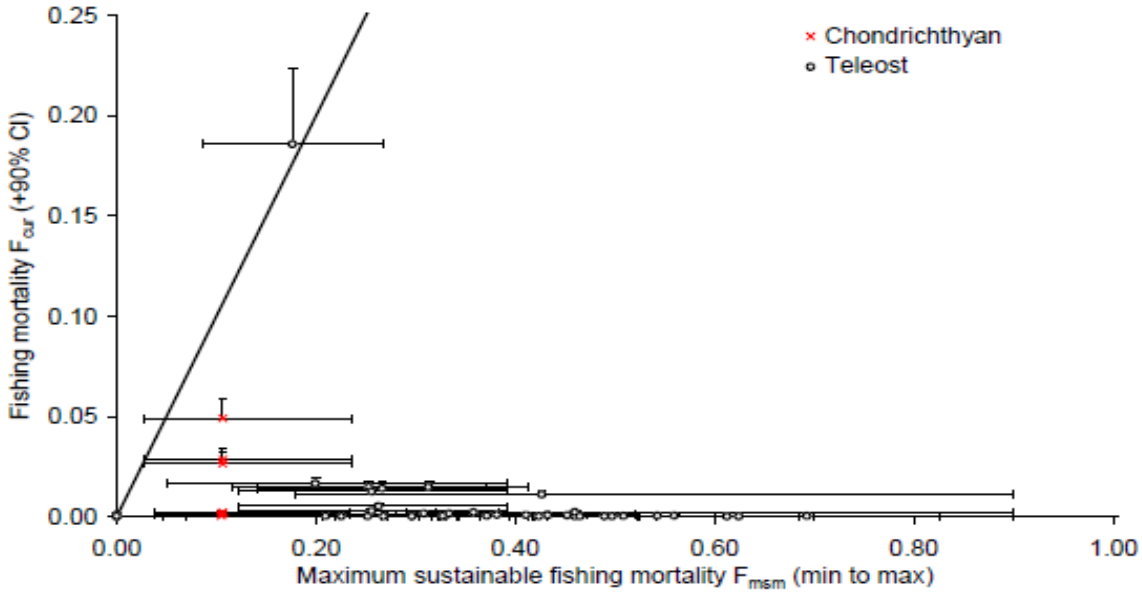

Figure 6: Example comparison of estimated "recent" fishing mortality FCUR and the reference fishing mortality corresponding to the maximum sustainable mortality.

eSAFE

Enhanced SAFE (eSAFE) appears, based on calibration with Level 3 assessments, to provide improved estimates of fishing mortality relative to bSAFE (Zhou et al. 2016). eSAFE requires more spatially explicit data and takes more analysis time than bSAFE, and so might only be used to further assess species that were identified at high risk using bSAFE (and which have not had further direct management action taken). eSAFE enhances the bSAFE method by estimating varying fish density across their distribution range as well as species- and gear-specific catch efficiency for each species.

Issues to be aware of

- Comparisons of PSA and SAFE for the same fisheries and species support the claim that PSA generally avoids false negatives but can result in many false positives. Limited testing of SAFE results against full quantitative stock assessments suggests that there is less "bias" in the method, but that both false negatives and false positives can arise (Zhou et al. 2016).

- SAFE analyses retain some of the key precautionary elements of PSA, including assumptions that fisheries are impacting local stocks (within the jurisdictional area of the fishery).

- Although bSAFE provides direct estimates of uncertainty in both the exploitation rate and associated reference points, they are less explicit about uncertainties arising from key assumptions in the method, including spatial distribution and movement of stocks.

- For bSAFE, the method assumes there would be no local depletion effects from repeat trawls at the same location (i.e. populations rapidly mix between fished and unfished areas). The fishing mortality will likely be overestimated if this assumption is not satisfied.

- The method also assumes that the mean fish density does not vary between fished area and non-fished area within their distributional range. Hence, the level of risk would be overestimated for species found primarily in non-fished habitat, while risk would be underestimated for species that prefer fished habitat (ERA TWG, 2015).

- The SAFE methodology makes greater assumptions than Tier 1 stock assessments in coming to its F estimates (due to a lack of the data relative to that used in a Tier 1 assessment) and it is not capable of measuring risk of a stock being already overfished (so the type of risk it measures relates only to overfishing, which may then lead to future overfished state). The limitations of SAFE with respect to measuring overfished risks are the same essentially as for PSA.

- RRA will be applied to species identified by SAFE as medium or high risk. The assessment of medium risk species is due to the increased likelihood of false negatives occurring relative to PSA.

Level 3 (fully quantitative risk assessments)

Level 3 is the point in the ERAEF hierarchy where a fully quantitative assessment is first undertaken (Hobday et al. 2011). A range of methods and approaches already exists at this level, but there remain challenges in finding methods that can work within the constraints of limited data and time for analysis. Application of Level 3 assessments can occur via two mechanisms:

- There is a pre-existing and re-occurring Level 3 quantitative assessment already run as part of a harvest strategy or other research (e.g. EPBC Act-listed species population assessments) or management processes.

- Management decision to develop a new Level 3 assessment following determination of high-risk status for a given species at Level 2.

Spatial considerations and assessing cumulative risks

In assessing ecological risks of fishing to species, the assessments need, where possible, to take account of:

- Species stock structure and overlaps with the spatial extent of the fishery, and
- Interactions and cumulative impacts with adjacent fisheries. In many Commonwealth fisheries there are species taken which are also caught in other Commonwealth fisheries, State/Territory fisheries and/or international fisheries.

The following text describes four different scenarios relating to these two issues and provides guidance as to how these scenarios may be assessed and managed.

Scenario A

The area of the fishery and the stock are the same (complete overlap) or the stock area lies entirely within the Commonwealth fishery area. Under this scenario, only the Commonwealth fishery impacts the stock and available assessment tools (e.g. stock assessment, SAFE, PSA etc) work relatively well.

Scenario B

The area of the fishery encompasses the area of two separate stocks of the same species. Where there is no information on population structure, the ERA process assumes by default that species comprise a single stock. However, in conducting risk assessments it is important to identify and consider all information pertaining to stock structure and where there is evidence to support the existence of two or more stocks, then each stock should be assessed separately. Failure to assess stocks separately (where separate stocks exist) can potentially lead to fishing pressure on one stock becoming too high, but not being picked up by the combined assessment. Even where the evidence may be weak, it may be more precautionary to assume separate stocks.

Scenario C

The area of the stock overlaps two (or more) adjacent Commonwealth fisheries which all interact with (i.e. catch from) the stock. Under this scenario, a cumulative risk assessment should be conducted which identifies the fishery specific impacts/risk and the total cumulative risk. Such cumulative risk assessment is currently possible using the Level 2 SAFE tool (used to assess most byproduct and bycatch species) but is not possible using PSA (used to assess EPBC Act-listed birds, mammals, reptiles, and some invertebrates). Redevelopment of the PSA to assess cumulative risk, or adaptation of SAFE to assess species currently assessed via PSA, will be required in future to address this issue.

Scenario D

The area of the stock overlaps the area of both the Commonwealth fishery and adjacent (or distant) non-Commonwealth fisheries, which can include state commercial or recreational fisheries or international fisheries, which also interact with (i.e. catch from) the stock. Under this scenario:

- every effort should be made to identify, obtain, and use data that will allow assessment of the impacts of all fisheries upon the stock. This will require cooperation between the agencies monitoring/managing each fishery. Ideally, an assessment would identify the impacts of each fishery (including Commonwealth) upon the stock and of the combined fishery impacts on the stock. It is often the case however that information pertaining to other fishery catches is not available, and
- it should not be assumed that low local (Commonwealth) fishing mortality means that there is a low risk of overfishing or an overfished stock, as other fisheries may be imparting significantly higher impacts, or the cumulative impacts may be high.

In all the scenarios above, it may often be the case that information is not available pertaining to stock structure, stock spatial distribution, of total fishing mortality/catches, creating uncertainty in the risk assessment results. In such cases, the assumptions underpinning the assessments must be clearly documented.

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