Australian Government
Department of Agriculture
and Water Resources

Guidelines for the Implementation of the Commonwealth Fisheries Bycatch Policy

Cataloguing data
This publication (and any material sourced from it) should be attributed as: Department of Agriculture and Water Resources 2018, *Guidelines for the Implementation of the Commonwealth Fisheries Bycatch Policy*, Canberra, June. CC BY 4.0.

ISBN: 978-1-76003-160-2

Internet
This publication is available at agriculture.gov.au/publications.

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Chapter 1

Introduction

The 2018 *Commonwealth Fisheries Bycatch Policy* (Bycatch Policy) establishes the requirement for bycatch management in Commonwealth-managed fisheries. The *Guidelines for the Implementation of the Commonwealth Fisheries Bycatch Policy* aim to provide assistance to Australian Government entities (principally the Australian Fisheries Management Authority (AFMA) but also bodies (industry or otherwise) that AFMA outsources to, including industry-based co-management arrangements) in interpreting and implementing the requirements of the Bycatch Policy.

Bycatch is defined as a species that is either incidentally taken in a fishery and returned to the sea, or incidentally killed or injured as a result of interacting with fishing equipment in the fishery, but not taken. The Bycatch Policy distinguishes between two classes of bycatch—general bycatch and *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) listed species. General bycatch are species that are not listed under the EPBC Act. EPBC Act–listed species are managed in parallel and, where feasible, jointly with general bycatch. However, these species are principally managed under Australia's national environment legislation—the EPBC Act. Specific guidance for managing EPBC Act–listed species is provided separately by the Department of the Environment and Energy. These guidelines do not aim to alter or influence that management. These guidelines are for general bycatch species only and not EPBC Act–listed species.

1.1 Relationship with the Harvest Strategy Policy

These guidelines operate in parallel with the *Commonwealth Fisheries Harvest Strategy Policy* (Harvest Strategy Policy) and the *Guidelines for Implementation of the Commonwealth Fisheries Harvest Strategy Policy* (Harvest Strategy Policy Guidelines) and support AFMA's approach to fisheries planning and documentation. AFMA has recently revised its approach to planning and documenting the management of Commonwealth fisheries. AFMA has commenced the development of a Fisheries Management Strategy (FMS) for each of its Commonwealth fisheries to combine management of commercial species (under a harvest strategy), non-commercial species (under a bycatch strategy), habitats and communities, research, and data and monitoring into a single integrated document for each of its fisheries. This single strategy approach aims to provide greater consistency, clarity, transparency and cost efficiency in how AFMA develops, documents and implements its management processes. It also aims to ensure better linkages between these components.

These guidelines are designed to assist AFMA deliver against the requirements of the Bycatch Policy and assist in developing the bycatch chapter of the FMS for each Commonwealth fishery. Where appropriate, examples are provided to illustrate key points that address specific fisheries management challenges.

1.2 Intent of the Bycatch Policy Guidelines

The Bycatch Policy advocates a risk-based approach to assessing and managing general bycatch. These guidelines provide information to assist AFMA in operationalising this approach. They encourage innovation and adoption of global best practice where appropriate. They also promote a balance between the risks to bycatch and the consequences of additional management on the fishery. Where the risks of negative impacts from fishing on bycatch are low, management responses are expected to prioritise innovation to minimise interactions without unnecessary restriction on commercial operations. Conversely, where the risks are high, greater prescription may be required to reduce the risks to bycatch (that is, to medium or low risk through appropriate management responses) in addition to promoting innovative solutions. This approach is consistent with the principles of risk–cost–catch applied to the development of harvest strategies for commercial stocks. The guidelines assist AFMA with recognising information uncertainty and incorporate it into its assessment of risk and application of the precautionary principle.

AFMA inspection of the turtle excluder device

Chapter 2

Operationalising the Bycatch Policy objectives

2.1 Objectives for general bycatch

Specific objectives for general bycatch in a Commonwealth fishery's fishery management strategy (FMS) should replicate or be equivalent to the objectives of the Bycatch Policy. As articulated in the Bycatch Policy, the primary objective for bycatch management is to minimise fishing-related impacts on bycatch species in a manner consistent with the principles of ecologically sustainable development (ESD) and with regard to the structure, productivity, function and biological diversity of the ecosystem.

In delivering on this objective for Commonwealth fisheries, the Bycatch Policy requires AFMA to:

- draw on best-practice approaches to avoid or minimise all bycatch, and minimise the mortality of bycatch that cannot be avoided
- manage fishing-related impacts on general bycatch species to ensure that populations (that is, discrete biological units, commonly referred to as stocks in the Harvest Strategy Policy) are not depleted below a level where the risk of recruitment impairment is regarded as unacceptably high
- in instances where fishing-related impacts have caused a bycatch population to fall below the level described, implement management arrangements to support those populations rebuilding to biomass levels above that level.

Operationalising these objectives will need to consider fishery-specific objectives for ecological sustainability, management accountability, compliance by industry, responsibilities to international agreements to which Australia is a signatory, and cost-effectiveness. When considering fishery-specific ecological sustainability objectives, consideration should also be given to two directives in the Bycatch Policy:

1. No general bycatch species should be exposed to any greater risk than that faced by a commercial species managed under the Harvest Strategy Policy.
2. Where fishing interactions with a bycatch species precipitates an unacceptable risk to the functioning of the marine ecosystem, that risk should be mitigated.

When considering international obligations, the Bycatch Policy requires that Australian fishers apply domestic fisheries management arrangements for bycatch regardless of where they fish. These requirements may exceed those adopted by international organisations or arrangements.

Guidance on operationalising objectives

Operational objectives should be consistent with relevant policies. Listing the relevant policies and legislative requirements in the introductory section of the bycatch chapter of each FMS would assist with ensuring that all obligations are included. The objectives section of the bycatch chapter of each FMS should separately specify ecological sustainability, accountability and compliance, international agreements and cost-effective management objectives. Further guidance on operationalising objectives is provided in Appendix 1.

Although FMS objectives do not need to be identical to those of international and regional fisheries management organisations (RFMO), they should be consistent with the requirements of these entities for which Australia is a member.

Where the Australian Government's domestic settings for bycatch management are superior, more advanced or more conservative than those of the RFMO, Australian fishers are required to apply the more advanced or more conservative management requirements when operating in jointly managed fisheries.

A consistent treatment of shared bycatch stocks across jurisdictions within Australia and internationally should be a desired outcome and will assist with achieving regulatory efficiencies. The Australian Government should advocate for those organisations to adopt management that is equivalent to the Australian Government's domestic settings.

Prawn trawler at sea
© Australian Fisheries Management Authority

Chapter 3

Application of indicators, performance measures and reference points to bycatch

Indicators and performance measures are key components of the Bycatch Policy. They are designed to trigger a management response and allow an evaluation of management effectiveness. The types of indicators, performance measures and reference points used in a particular fishery may differ depending on the level of knowledge. Although applying a similar approach to that used in the Harvest Strategy Policy is intended, indicators for bycatch may be similar but evaluated with different data (for example, data deficient or risk-based techniques).

Indicators are used to provide information on the state of the species or system. Performance measures are used to provide information on management performance against pre-determined reference points. Reference points can be either a target (a desirable outcome such as a level of biomass that allows for a catch that maximises economic returns) or a limit (an outcome to be avoided such as a level of biomass that puts successful future recruitment of the population at an unacceptable risk). Indicators for bycatch are usually an assessment or observation of the state of the species, or a measure of the level of risk to the species from fishing, or state of the fishery (for example, quantity of discarding). Performance measures are used to measure progress against management objectives. They are usually a measure of where an indicator is in relation to a reference point. A management response (often referred to as a control rule for target stocks) is usually implemented to respond to the performance measure (for example, if the performance measure is less than the limit reference point then implementation of a management measure is prescribed to rebuild the population to a level at or above the limit reference point).

The Australian Government's Bycatch Policy defines a limit reference point for general bycatch. That limit is the level below which the risk of recruitment impairment is regarded as unacceptably high. The Bycatch Policy does not define target reference points for general bycatch because these species contribute little or no economic value to the fisheries (that is, no optimal level of catch for general bycatch would maximise the economic return from these species). Where practicable, the Bycatch Policy advocates modification of fishing practices (including fishing gears) and fisher behaviour to avoid and minimise interactions with general bycatch.

Although bycatch mitigation is often approached on a species by species basis, measures that reduce interactions for a suite of species can also be implemented (for example, changing mesh size for gillnet or trawl fisheries). Negative impacts on other species as a result of focus on one species can also occur and should be avoided when considering options. For example, changing hook shape to reduce shark capture may result in more ingestion of hooks by another species.

3.1 Equivalency between Bycatch Policy and Harvest Strategy Policy

The Bycatch Policy and the Harvest Strategy Policy have differing high-level objectives, one to minimise mortality (Bycatch Policy) and the other to maximise economic yield (Harvest Strategy Policy). However, both policies direct management to control levels of fishing mortality. Both policies impose an equivalent biomass limit reference point but each policy operationalises this directive differently. The Harvest Strategy Policy requires strategies be implemented that pursue targets for commercial stocks (which when combined maximise economic returns from the fishery as a whole) and avoid limits. The limit reference point is defined in the Harvest Strategy Policy as the biomass level where the risk to the stock (in terms of recruitment impairment) is regarded as unacceptably high. The Harvest Strategy Policy also requires the testing of harvest strategies to ensure that all commercial stocks remain above the limit reference point at least 90% of the time. See the *Guidelines for the Implementation of the Commonwealth Fisheries Harvest Strategy Policy* for more information on these requirements.

Although the Bycatch Policy invokes a biomass limit reference point (the level below which the risk of recruitment impairment is regarded as unacceptably high), due to reasons of data availability and key knowledge gaps in species biology and ecology, estimation of levels of depletion are unlikely to be reliable. The Australian Government currently advocates the use of fishing mortality and ecological risk-based reference points to pursue policy objectives. Bycatch species are not managed through harvest strategies and current assessment methods do not allow for equivalent testing to be undertaken for bycatch species. As such, the '90% of the time' criterion cannot be applied in the same way to bycatch.

Guidance on operationalising biomass limit reference points for bycatch species

Due to current data and knowledge gaps for general bycatch, estimating performance using a biomass limit reference point for general bycatch is likely to only be an option for a few species. Equivalent fishing mortality and ecological risk-based reference points are recommended when biomass limit reference points cannot be estimated. The Australian Government does not advocate a target reference point for general bycatch.

The 90% risk criterion is a performance measure for evaluating the design of harvest strategies for commercial species and does not currently apply for general bycatch.

Although bycatch mitigation may be approached on a species-by-species basis, measures that reduce interactions for a suite of species can also be implemented (for example, changing mesh size for gillnet or trawl fisheries).

AFMA should be mindful of unintended consequences on other species as a result of focusing on one species.

Chapter 4

Avoid and minimise

4.1 How fisheries avoid and minimise

A fundamental principle of the Bycatch Policy is that bycatch should be minimised, but it does acknowledge that in many cases some bycatch is unavoidable. The policy requires that fisheries avoid bycatch and minimise the mortality of bycatch that cannot be avoided.

Bycatch can be reduced in several ways, including technical measures (changes to gear and bycatch reduction devices), education (changes in survival due to improved handling or gear setting), temporal measures (for example, seasonal closures and day/night setting restrictions) and spatial measures (for example, depth restrictions or spatial closures—fixed or dynamic).

Commonwealth fisheries are already operationalising the avoid and minimise objective in many ways. Bycatch reduction devices have been widely adopted across Commonwealth fisheries. These devices take many forms across fisheries (and gears deployed) and each fishery has undergone an evolution of technologies and approaches with the explicit aim of avoiding or minimising bycatch in line with fishery-specific objectives.

In longline fisheries, fishing gear (hook type, leader type and gear configuration) has been modified to reduce the catches of, or interactions with, different types of bycatch including sharks and non-marketable fish. Various devices are used in trawl fisheries to reduce general bycatch. Trawl nets have been modified in various ways to provide for escapement of unwanted fish. These include square mesh panels, T90 mesh and gear modifications that aim to provide pockets or areas of relatively lower pressure to facilitate exit of bycatch (for example, fisheye and pop-eye fish-boxes). Gillnet fishers have adapted and refined their gear to select for the size class of sharks and species of fish they desire. Animals that are larger than the mesh size cannot be enmeshed and animals smaller than the mesh size can swim through the net. Area closures (permanent, temporary or dynamic) that restrict or prevent fishing from particular spatial areas and depths also reduce the risk of fishing to general bycatch by reducing the spatial overlap of the fishery with bycatch.

Education is important as an accompaniment to bycatch mitigation measures and also in its own right. Improved handing practices can reduce the mortality of captured animals, such as minimising time on deck, or treatment of hooked animals (for example, cutting the line rather than attempting to pull or cut out a hook).

The history of bycatch management in Commonwealth fisheries demonstrates that actions that avoid and minimise mortalities will continue to improve. Monitoring of performance has been conducted through specific trials and ongoing observation. Evidence of performance and broad application are required before wider adoption. In circumstances where alternatives or multiple measures are to be adopted, management should ensure that such options are at least complementary (that is, alternatives have a similar level of performance in reducing bycatch) and where multiple measures are used together, their effects are at least additive. Similarly, management need to ensure that measures designed to minimise bycatch for one particular species (or group) does not increase the risk for other bycatch species.

When established as effective, these activities have been typically implemented through bycatch plans, codes of practice, industry liaison and education programs. AFMA has developed a guide for implementing ecological risk management (ERM) in Commonwealth fisheries (AFMA 2017). Application of the ERM guide will provide an additional tool to identify areas for further work with regard to bycatch mitigation and assist with coordination of management responses that further pursue these objectives (particularly application of sensitivity analyses to identify susceptibility attributes that have most influence on risk scores).

Maximising the potential for live release and post-release survival, where capture of bycatch species is unavoidable, should be included in future investments in avoid and minimise innovation. Education of fishers is a critical part of this, by sharing best practice used by experienced operators or based on new evidence from animal welfare specialists. Adoption is likely to be greater for innovation that includes the cost-effectiveness of mitigation measures. Where trials are anticipated, experimental designs should be statistically robust and differences between research trials and commercial fishing operations should be anticipated when evaluating the benefits of adoption (the measure may not be as effective in all fisheries and all circumstances).

The implementation of measures in pursuit of the avoid and minimise objective will be a key indicator of performance in Commonwealth fisheries. Implementation of actions through bycatch plans, codes of practice, industry liaison and education programs demonstrates operationalisation of the avoid and minimise requirements of the policy. Consequently, encouraging adoption of best-practice mitigation measures for general bycatch should be a priority for the bycatch chapter of an FMS. The degree to which these chapters prescribe measures to avoid and minimise general bycatch should be proportionate to the risk (from the fishery and cumulative) that fishing imposes on the species impacted. Opportunities to use bycatch for human consumption or alternative seafood products should also be explored, increasing the profitability of fisheries (FRDC 2018; Knuckey et al. 2017).

There is an unresolved scientific debate about precision fishing (remove only the target species) and balanced harvesting. The approach to fisheries termed ‘balanced harvesting’ calls for fishing across the widest possible range of species, stocks and sizes in an ecosystem, in proportion to their natural productivity, so that the relative size and species composition is maintained. Such fishing is proposed to result in higher catches with less negative impact on exploited populations and ecosystems. Empirical and model-based evidence exists both for and against positive effects of balanced harvesting. The Bycatch Policy (and these guidelines) currently advocate an avoid and minimise objective for bycatch. However, monitoring of the strength of the scientific evidence for alternative approaches should be undertaken.

Guidance on operationalising avoid and minimise requirements

Avoiding and minimising interactions will be a key indicator of performance for general bycatch in Commonwealth fisheries. Encouraging adoption of best practice for general bycatch should be a priority for the bycatch chapter of the FMS.

Adoption of specific avoid and minimise measures should be based on: (1) sound logic and evidence for the performance of the mitigation measures; (2) maximising the potential for live release and post-release survival where capture of bycatch species that will not be retained is unavoidable; (3) designing mitigation measures to minimise bycatch of a high-risk species or species group that do not, where practicable, increase fishery impacts on other high-risk species (or increase low or medium risk species to high risk); (4) bycatch mitigation measures that are mandated as alternatives to each other have a similar level of performance in reducing bycatch; and (5) where multiple mitigation measures are required to be used together, ensuring their effects are at least additive.

The Australian Government should provide a regulatory framework that encourages innovation by industry to avoid interactions with bycatch species.

When considering the adoption of new avoid and minimise measures or encouraging further development of measures, the Australian Government needs to ensure that: (1) statistically robust experimental designs for research trials of bycatch mitigation measures have been or will be applied; (2) the cost-effectiveness of mitigation measures was or will be assessed at an appropriate level of detail; (3) differences between research trials and commercial fishing operations are anticipated; and (4) the trials resulted in statistically significant reductions in bycatch mortality.

In addition to reporting the quantity and fate of interactions between fishery operations and general bycatch species, AFMA should consider reporting the degree of compliance with implementing best practice mitigation measures as part of its annual reporting. This would assist with demonstrating the achievement against the avoid and minimise objective.

When undertaking residual risk analyses as part of AFMA's ERM, AFMA should consider additional sensitivity analyses to identify whether modifications to availability, encounterability, selectivity or post-capture mortality attributes would lower risk rankings for general bycatch. AFMA should evaluate whether such changes could be achieved by adopting alternative or additional mitigation options. Where appropriate, AFMA should further evaluate the practicality of such mitigation using a risk–cost–catch trade-off on its impact on commercial operations. Where inappropriate, AFMA should consider incentives to encourage development and implementation of further innovation.

The Australian Government should use tools such as the Bycatch Management Information System and the Bycatch Reduction Techniques Database as sources of up-to-date information and consider collaborating with developers of these tools to provide AFMA and the industry with ready access to the latest technology, protocols and methods.

Chapter 5

Management of risk

5.1 Current approaches for applying ecological risk assessment and management to bycatch in Commonwealth fisheries

The ecological risk assessment for the effects of fishing (ERAEF) is the primary methodology underpinning the Australian Government's approach to ecological risk management (ERM). The ERAEF was developed to assess and monitor the risk posed by Commonwealth fisheries to the ongoing sustainability of ecosystem components that interact with Commonwealth fisheries. AFMA can use the results from the ERAEF to inform their risk management responses, which are designed to be aligned with legislative and policy responsibilities. The ERAEF framework has been increasingly adopted internationally for use in fisheries risk assessments (for example, MRAG 2009; MSC 2016). AFMA has developed guidelines (AFMA 2017) for implementing ERM in Commonwealth fisheries, which include enhancement of methods for assessing and quantifying risks from fishing to ensure they remain best practice.

The ERAEF involves a hierarchical process of risk assessment, with a qualitative analysis at Level 1, an indicator-based analysis at Level 2, and a model-based analysis at Level 3. The hierarchical approach allows AFMA to balance the need to quantify risks with the financial costs of doing so, and the costs of managing the risk. The components of the current ERAEF framework are discussed in detail in this chapter.

5.1.1 Pre-assessment

Pre-assessment should include 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). Their participation improves the assessments by ensuring issues are correctly identified and evaluated, and increases the chance of uptake of results and identification of appropriate management responses. AFMA's resource assessment groups and management advisory committees provide opportunities for this consultation. Stakeholder consultation is an important first step and has been undertaken for all Commonwealth fisheries where the ERAEF framework has been applied.

Pre-assessment should also include scoping. Scoping characterises the fishery, finalises species list, and confirms the ecological sustainability objectives and hazards (fishery activities that may impact the ecosystem). A thorough examination of available information should remove any mis-identified species that do not have a spatial or depth overlap with the fishery and should identify whether the existing information is adequate for generating the species list.

5.1.2 Level 1

Scale, intensity, consequence analysis (SICA) is the current method typically applied at Level 1 and is conceptually the same as the Likelihood Consequence approach in the ESD reporting framework. It is only applied to the most vulnerable unit (species) of an ecological component. This makes SICA an efficient screening process of low risk components because those deemed to be low risk are ejected at Level 1. If the most vulnerable unit is assessed as low risk, then a decision can be made whether any more quantification of risk is required; if the assessed risk is medium or high risk then a management action can be implemented to reduce the risk, or the risk assessment process can proceed to Level 2.

5.1.3 Level 2 (semi-quantitative and quantitative methods)

Two methodologies are most commonly applied for Level 2 assessment—productivity susceptibility analysis (PSA) and sustainability assessment for fishing effects (SAFE).

PSA is a semi-quantitative method that assigns to each species in each fishery a score on two axes, the first representing its susceptibility to being caught and the second its biological productivity. A number of different attributes are used to derive each of the indicator scores. Adopting a precautionary approach to uncertainty, high risk scores are assigned to attributes in the absence of information. This means the bias is towards false positives—species will not be found to be at low risk in the absence of information. The PSA only provides a snapshot of the risk at the time of the assessment and within the fishery being assessed (relative risk). The assessments do not provide an assessment of absolute risk, such as risk relative to a known reference point.

SAFE is also a multispecies analysis that estimates fishing mortality based on the overlap between a species' range and fishing effort, using the same biological attributes as are used to derive indicators in PSA. These estimates of fishing mortality can then be compared with estimates of species productivity using estimated natural mortality (M), from which limit reference points can be expressed in terms of acceptable fishing mortality as some proportion of M for each species. These include:

- F_{MSM}—fishing mortality rate corresponding to maximum sustainable fishing mortality (MSM) at B_{MSM} (biomass that supports MSM, equivalent to maximum sustainable yield)
- F_{LIM}—fishing mortality rate corresponding to limit biomass B_{LIM}, where B_{LIM} is defined as 50% biomass that supports MSM
- F_{CRASH}—minimum unsustainable fishing mortality rate that theoretically may lead to population extinction in the long term.

Residual risk analysis is used to consider additional information, particularly the mitigating effects of management arrangements that were not explicitly included in the PSA and SAFE attributes. Residual risk analysis also considers factors such as the number of interactions recorded by observers and logbook data, and whether new or missing data is available that may influence a species risk ranking. Residual risk analysis is undertaken for species assessed as high risk because of the bias towards false positives when applying these semi-quantitative methods. AFMA has developed residual risk guidelines to assist AFMA when applying residual risk analysis. Where practicable, an independent body should apply residual risk analysis to ensure transparency and accountability.

Once satisfied with the Level 2 analyses, species ranked as extreme or high risk should be evaluated to understand the potential reasons for the higher risk scores. This will identify remaining areas of uncertainty and assist decisions about possible management responses for these species. Potential management responses include implementing mitigation measure to address the risk to the species, collecting missing attribute information and re-assessment at Level 2 (for species where a high risk ranking may be due to missing attribute data), or further examining for risk within the particular ecological component at Level 3.

Species at low risk are typically deemed not at risk from the fishery and the assessment is concluded for these species. AFMA may choose to undertake a sensitivity analysis on susceptibility attributes to assist with developing triggers for monitoring (that is, what attributes might change the risk ranking) or whether simple and low cost modifications to susceptibility attributes may further reduce the risk. Species scored at medium risk may not be a focus of initial management attention, but should receive attention where resources allow and high risk units have already been addressed to the extent possible.

5.1.4 Level 3 (fully quantitative methods)

A range of methods and approaches already exists at Level 3, typically quantitative population dynamics models. Challenges remain in finding methods that can work within the constraints of limited data that is a typical scenario for general bycatch in some Commonwealth fisheries. Improving existing methods and developing new methods suited to the analyses of data limited scenarios should remain a priority area of research to assist with developing responses to high risk species.

5.1.5 Applying the hierarchy

This hierarchy is intended to be cost-effective, with low risk species being screened out at Levels 1 or 2, reducing the number of species and costs for higher level assessments. An implicit management objective embedded in the PSA and SAFE methodologies, which is consistent with national and international policy frameworks, is ‘to ensure that fisheries do not contribute to sustained and significant reduction in recruits below average levels’. Both the PSA and SAFE methods provide information about which species are likely to be impacted by fisheries and whether such impacts may be unsustainable in the long term. The PSA scores are ranked indicators of this risk and the SAFE scores provide a proxy measure for fishing mortalities.

The ERAEF acknowledges uncertainty in the results from both the PSA and SAFE methods, with lower levels of assessment having higher uncertainty, concomitant with the reduced data requirements. Reducing this uncertainty requires additional monitoring or research to provide the additional data needed to move to a better or higher level assessment. Therefore, a direct monitoring or data collection cost is associated with reducing the uncertainty in risk assessments. However, uncertainty is a key contributor to risk, and so reducing uncertainty also reduces the risk, resulting in a risk–cost trade-off. Under a precautionary approach, higher uncertainty requires more conservative management decisions, typically resulting in management measures to reduce fishing effort or catch to reduce risk to acceptable levels, despite the uncertainty. This results in a risk–cost–catch trade-off (Dichmont et al. 2017; Dowling et al. 2013; Sainsbury 2005).

Lower level (Levels 1 and 2) risk assessments are, by design, more precautionary, so that application of low-level approaches generally does not result in underestimation of risk. The initial application of lower information, cheaper, Level 1 and Level 2 ERAEF approaches allows highest risks to be identified so that management decisions can be made regarding further costs, to reduce uncertainty, increase information and enable a Level 3 approach. Alternatively, AFMA may choose to accept the lower level assessment results and implement measures that have a high probability of reducing risk, such as closing areas to fishing or restricting use of certain gear types. Depending on management and stakeholder preferences about how to respond to this risk–cost–catch trade-off, the additional costs associated with obtaining the additional information required for more certain assessments may be justified in order to reduce uncertainty and allow fishing effort to continue at higher levels than would otherwise be recommended under a precautionary principle to an uncertain assessment.

The PSA and SAFE approaches enable a prioritisation of species for further research or risk management because they are methods that can consider multiple species in the same assessment. All levels incorporate a precautionary approach to uncertainty by assigning precautionary high risk scores to attributes when data for that species (or from closely related species) are not available—that is, false positives (perceived high risks) are considered preferable to false negatives (perceived low risks). For bycatch species that overlap with, and are impacted by, several different fisheries the cumulative impact across all fisheries should be considered. Where these fisheries occur across different jurisdictions (for example, state and territory, Commonwealth and international fisheries), evaluation of cumulative impacts requires assessments to be conducted across these jurisdictions.

Separate PSA assessments for individual fisheries cannot be easily combined after the fact to try to assess cumulative impacts. For Level 1 (SICA) and 2 (PSA) approaches, cumulative impacts can only be assessed by conducting a risk assessment that covers the spatial extent of all relevant fisheries. This requires that the data needed to identify and rank impacts and risks are available in consistent and comparable format across fisheries and across jurisdictions. In contrast, fishing mortality estimates derived from individual SAFE analyses can be added for a number of different fisheries to generate cumulative estimate of fishing mortality across all of the assessed fisheries.

The Level 2 PSA and SAFE analyses rely on the spatial overlap of the distribution of fishing effort with the distribution of the species. These analyses may need to be redone periodically, in order to take into account any changes in spatial overlap between fishing effort and the distribution of bycatch species. Updated Level 2 assessments and management responses may also need to account for the levels of protection already afforded to bycatch species through closures (that is, application of residual risk analysis to finalised risk scores).

5.2 Risk equivalency

The concept of risk equivalency is fundamental to the management of Commonwealth fisheries. The Bycatch Policy requires that the ecological risk from fishing to bycatch species should be no greater than that for commercial species managed under the Harvest Strategy Policy. Comparisons of methods for teleost species has demonstrated sufficient equivalency between PSA, SAFE and stock status assessments for the Australian Government to adopt these methods for ecological risk assessment. Species ranked as high risk under PSA and extreme and high risk under SAFE corresponded with teleost that were near or below their limit reference points. Species ranked as low risk under PSA and SAFE corresponded with stock status assessments that were above their biomass limit reference points and below their fishing mortality reference points. Species ranked as high risk under PSA and SAFE corresponded with stock status assessments that were above their fishing mortality limit reference points. Details of these analyses can be found in Zhou et al. (2016). A comparison of methods demonstrated that PSA methods are biased towards overestimating the risk of fishing. Verifying risk equivalency is an ongoing task to ensure its ERAEF methods are continuously improved.

Applying these observations allows for the inference that species ranked as high risk to the effects of fishing have a high probability that fishing mortality levels are sufficient to deplete populations to levels close to or exceeding the bycatch limit reference point for biomass. Whereas species ranked as low risk can be considered to have a negligible probability of having exceeded either biomass or fishing mortality limit reference point.

Guidance on operationalising cumulative impacts requirements

Cumulative impacts can only be assessed using Level 1 (SICA) and 2 (PSA) approaches by conducting a risk assessment that covers the spatial extent of all relevant fisheries. The data needed to identify and rank impacts and risks will need to be available in a consistent and comparable format across fisheries and across jurisdictions for these methods to be used.

Fishing mortality estimates derived from individual SAFE analyses can be added for a number of different fisheries to generate cumulative estimate of fishing mortality across all of the assessed fisheries.

Guidance on operationalising risk equivalency requirements

A ranking of high risk under PSA and SAFE for finfish species (after completion of residual risk analyses) corresponds to a fishing mortality rate above the limit reference point.

Species ranked as low risk can be considered to have a negligible probability of having exceeded their limit reference point for fishing mortality rate.

PSA methods are biased towards overestimating the risk of fishing.

Verifying risk equivalency (that is, demonstrating that proxies are reliable) is an ongoing task and responsibility for the Commonwealth to ensure its ERAEF methods are continuously improved.

5.3 How the *Guide to AFMA's Ecological Risk Management* is used for general bycatch species in Commonwealth fisheries

ERM is implemented in Commonwealth fisheries through the FMS. The *Guide to AFMA's Ecological Risk Management* (AFMA 2017) provides detailed information for the preparation of the bycatch chapter within the FMS. The key steps include:

1. Assess (or re-assess) ecological risk.
2. Develop management responses and amend the FMS and annual work plan based on identified ecological risks.

   ERM for low and medium ranked byproduct and bycatch species will in general be restricted to monitoring of fishery catch and effort levels and gear usage to monitor changes in fishery operations that might result in a change of risk to species (or general incentives to reduce interactions). High risk bycatch species are the main focus of specific ERM responses, including additional data collection, higher level assessment, and development of measures to mitigate risk.
   Risk assessments should identify the key attributes that result in a species being classified as high risk. AFMA should identify whether risks are due to spatial overlaps between species and fishery distribution, gear selectivity, catchability factors, fishing effort levels, lack of data on key attributes, and life-history characteristics.

   If existing management measures are in place to mitigate risk to the fishery for a particular species, then AFMA will need to consider and investigate whether they have had any effect on risk, whether they are appropriately targeted at the key drivers of risk, why have they not mitigated the risk to the required level, what additional or alternative management actions will be required to mitigate the risk or whether other factors are at play (for example, regime shifts, historically overfishing, interacting fisheries and cumulative impacts).

3. Develop management performance indicators that will be used to determine if management responses are successful. Performance is tracked at a number of levels—management processes (auditing to ensure that implementation activities are being completed); industry compliance (monitoring and reporting on compliance by industry with management arrangements designed to mitigate ecological risk); and ecological risk reductions (mitigation measures should be regularly reviewed to check that they are reducing ecological risks as expected, and that species at lower risk categories are being maintained in those categories).
4. Determine the monitoring and data collection requirements to support implementation and review of the FMS bycatch strategy.
5. Develop re-assessment indicators and triggers for bycatch species to detect any changes (increase or decrease) in the level of risk posed by the fishery to any species. Key indicators on which such triggers could be based include changes in gear type/use, mitigation measures (use or type), area fished, catch or interaction rate, and fishing effort. Where possible, the triggers should take into account additional sources of risk from interacting non-Commonwealth fisheries.
6. Undertake performance monitoring and reporting, including monitoring of management processes (initial outcomes), compliance (intermediate outcomes), re-assessment indicators and triggers (intermediate outcomes); and ecological risk (long-term outcomes).
7. Assess timeline and guidance for review, evaluation and improvement of the FMS bycatch strategy (currently five years).

Guidance on operationalising ERA and ERM methods and frameworks

ERA and ERM methods and frameworks are continuously evolving and AFMA is encouraged to maintain its ERM Steering Group to ensure its approaches keep pace with these improvements. AFMA should endeavour to ensure the membership of the ERM Steering Group has sufficiently skilled experts to advise it on the limitations of current approaches, opportunities for improvement and inclusion of global developments.

Chapter 6
Recovering overfished bycatch

For a general bycatch species (or stock) considered to be below its limit reference point, a strategy will be developed and implemented to rebuild the species (or stock) to above the limit reference point. The strategy should describe all management arrangements prescribed to support population rebuilding and measures (or proxies for) to demonstrate that rebuilding has occurred. Consistent with the approach to risk equivalency between the Harvest Strategy Policy and the Bycatch Policy, the timeframe for recovery should be consistent with that articulated in the Harvest Strategy Policy Guidelines. By definition, little or no economic benefit is derived from bycatch. As such, recovery objectives are more closely aligned with ensuring the species is returned to a level where management is confident that the species no longer experiences an unacceptable risk of recruitment impairment. This equates to demonstrating that fishing mortalities and risk has been reduced to, and in each year is maintained at, a level that allows for recovery within the prescribed recovery timeframe. Management responses to recover bycatch species may, by necessity, impact activities targeting other stocks.

Chapter 7

Categorising bycatch

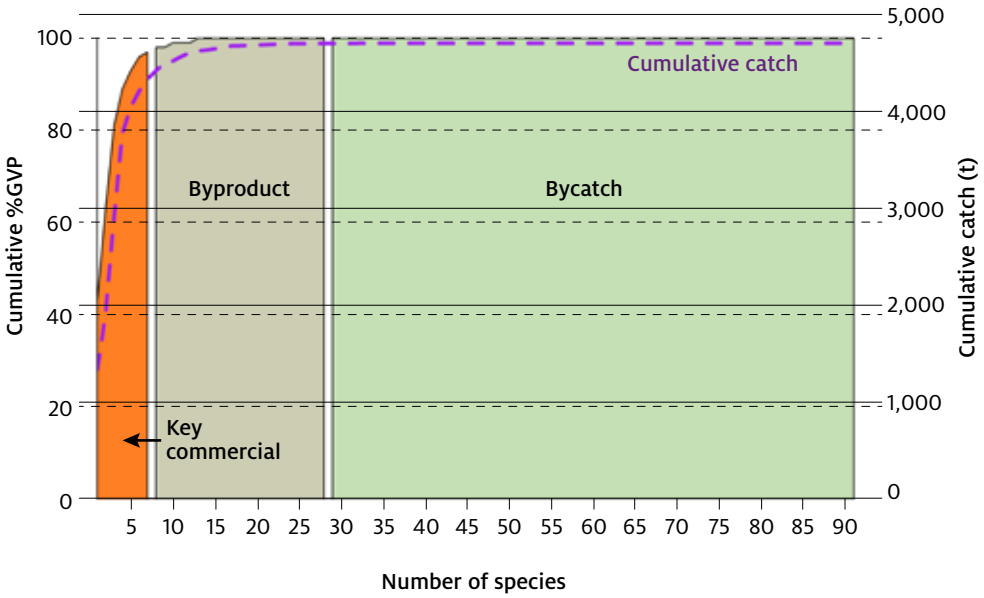
According to the Bycatch Policy, categorisation relates to identifying those species or stocks impacted by fishing that are not key commercial or byproduct (noting that in most cases the assessment and management approaches for byproduct are the same as that for bycatch).

AFMA will need to characterise a fishery in terms of its interactions with species or stocks. Although the Harvest Strategy Policy Guidelines advocate a characterisation process centred around identifying key commercial species, in the context of bycatch categorisation simply requires the documentation (listing) of species that meet the policy definition of bycatch. When such a list is developed, EPBC Act–listed species are easily identified through consultation with information collected and reported by the Department of the Environment and Energy. The balance of species on the list will be general bycatch.

Cumulative contribution to catch and gross value of production (GVP) can be used initially to separate key commercial stocks from byproduct and further distinguish commercial stocks from bycatch (Figure 1). Determining the thresholds of catch or GVP that differentiate species between key commercial, byproduct and bycatch can be undertaken using a variety of methods. These include qualitative descriptive analyses supported by expert consultation (Knuckey et al. 2017) or model-based approaches (FRDC 2018). Although bycatch does not generally contribute much to GVP, AFMA should be aware that, in multispecies fisheries employing non-selective gears, a large number of species can fall into this category (Figure 1).

Developing fisheries may not have sufficient records (from either logbooks or observers) to be confident that all species that interact with the fishery have been reported. In such circumstances, the species list should be developed with the addition of information from other sources to include all species that could have spatial and depth overlap with the fishery.

FIGURE 1 Species accumulation curve for 91 species, following categorisation into key commercial, byproduct and bycatch species



Guidance on operationalising categorisation requirements

Initial species list

Logbooks, observer databases, electronic monitoring and scientific literature and surveys are the most reliable sources of information to generate a bycatch species list for a fishery. Where only generic species names are reported (for example, deepwater shark), the full list of plausible species that are known to occur within the spatial area of the fishery under that generic name should be included. Where interactions are recorded in logbooks to the species level, these species should be included in the list. Where data are reported at the family level, the family should not be expanded to all component species because this can result in the inclusion of too many species, some of which may not be encountered in the fishery. Expansions from family level should be based on observational data (that is, human observers and electronic monitoring). After generating an initial list, any species that do not have a spatial or depth overlap with the fishery should be removed.

Finalising species list

Generating statistical species accumulation curves will inform decisions on whether existing sampling levels have provided an adequate species list (that is, does the list contain all or most species likely to be interacting with the fishery). Species accumulation curve plots show the rate of accumulation of new species observed within a fishery over time. If this curve plateaus, then the occurrence of new species in the fishery is rare. Therefore, most species that are likely to interact with the fishery have been recorded, assuming no major changes in the fishery (for example, spatial effort or gear). In this circumstance, the curve would be considered complete (Figure 2). If the curve has not plateaued, and the number of new species being

recorded is still increasing, then the species list may not sufficiently represent all those that are interacting with the fishery. In this circumstance, the curve would be considered incomplete (Figure 3). AFMA should also 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 completeness of the curve. If the curve is considered to be complete, it forms the species list. If the curve is incomplete, the species list should include all species that have a spatial and depth overlap with the fishery (including those with no confirmed records of capture or interaction with the fishery).

FIGURE 2 Complete species accumulation curve

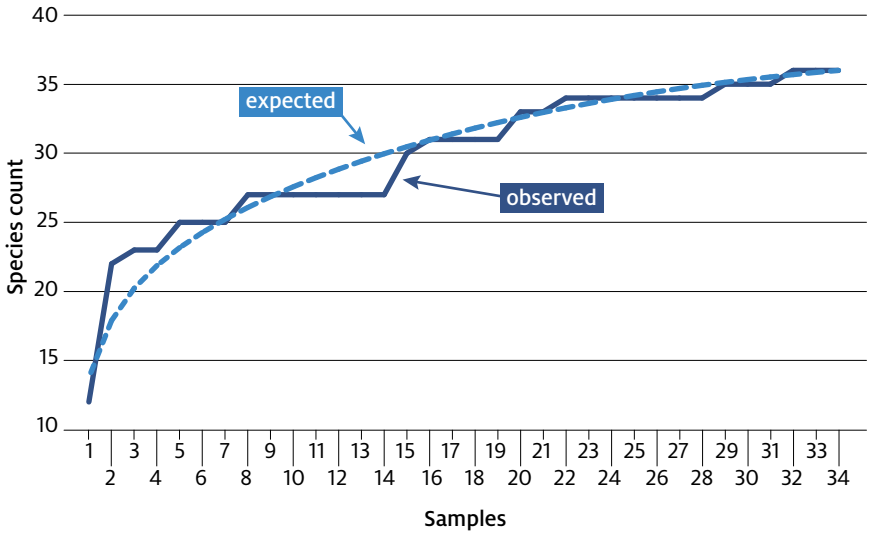
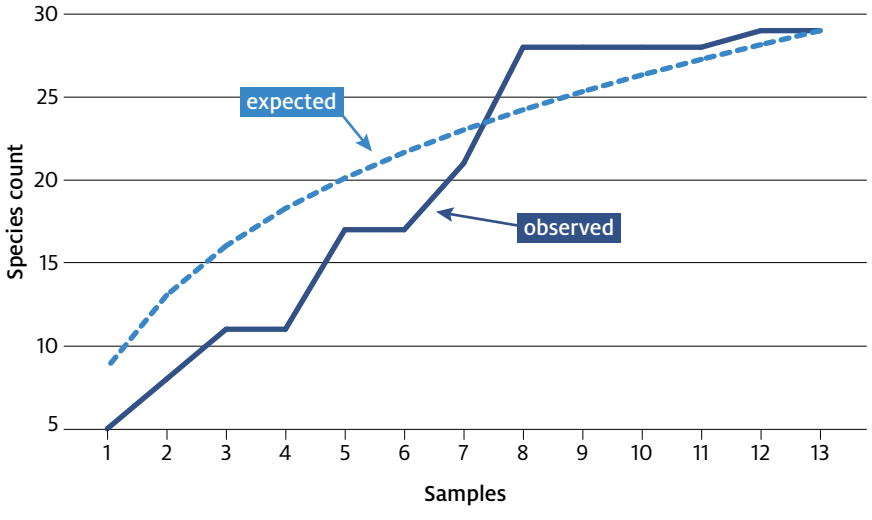


FIGURE 3 Incomplete species accumulation curve



7.1 Transitioning between categories

As fisheries change and evolve, the relative importance of species may change. Key commercial stocks are unlikely to become bycatch in the immediate future but some transitioning between bycatch and byproduct may occur. Reviewing categorisations within five years or whenever significant changes in the fishery occur would be best practice. Significant changes in gear, spatial distribution of catch or effort, or changes in targeting behaviour should trigger a review of the categorisation within a fishery.

Guidance on review period of species categorisation

Categorisation should be reviewed after five years of implementation or where significant changes in gear, spatial distribution of catch or effort or changes in targeting behaviour occur.

Prawn trawler at sea
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Chapter 8

The risk–catch–cost trade-off

The risk–catch–cost trade-off seeks to balance the amount of resources invested in data collection, analysis and management of a fishery, the level of catch (or fishing mortality) taken from that fishery and the risk level. The higher the level of uncertainty about the state of a species, stock or fishery and how that species, stock or fishery is performing against its objectives, the more the fishery should mitigate or offset the risk of getting things wrong (for example, overfishing or overcapitalising) through being more precautionary (for example, reducing catch/fishing mortality and investing in additional monitoring).

The Bycatch Policy requires that general bycatch species are not exposed to an unacceptable risk of recruitment impairment. As such, fishing mortality should always be controlled to ensure that a species is not exposed to an unacceptable risk. In the context of bycatch species, ERA frameworks provide a structured and integrated way of assessing risks to species in a fishery. The current ERA framework does not consider ecological roles and the impact that fishing may have on structure and function of ecosystems.

8.1 Risk and cost

In cases where a risk assessment is the only option available for estimating the state of a species or stock, a high risk rating (once residual risk analyses are completed) will be interpreted as a breach of the F_{LIM}. For such species or stocks, fishing mortality should be constrained to reduce the risk to an acceptable level. The requirement for addressing unacceptable risk will always remain, but the costs and benefits of undertaking higher levels of assessment should be considered.

Uncertainties and gaps in risk assessments can be addressed by collecting additional information, either to fill the gaps or to enable a higher level of assessment (with a lower level of uncertainty). However, collecting additional information or undertaking additional or higher level of assessments comes at a cost. The mitigation of risk (actions taken to reduce fishing mortality rate) also comes at some cost.

The net economic returns to a fishery will influence what the fishery can afford to spend to obtain data to inform management decisions. In some cases, it may be more cost-effective to address an issue through immediate management action based on current information, rather than invest in an improved understanding of risk. A small and low-valued fishery may need a low-cost approach, because the potential for additional benefits (catch or profit) is low. A fishery with larger potential for increased net benefits may justify higher levels of investment in information or analyses. AFMA needs to weigh the relative costs and benefits in the methods they apply to tackle incidents of unacceptable risk. In some cases, a lack of resources may rule out further data collection or analyses, leaving AFMA with the option to reduce risk by intervening in the fishery to control catch.

Some less obvious costs should also be factored into the ERA and ERM processes. These include the cost of getting the management wrong and potentially having to recover a species from an overfished state. Such actions can have broader implications for the fishery in terms of restricting commercial catches. There may also be a reputational risk or cost resulting from a public perception of poor fisheries management. This may manifest in increased pressure for demonstrating sustainability from non-government entities (incurring cost) or restricted trade opportunities resulting from the perception of compromised sustainability credentials (a lack of desire to sell and consume fish from unsustainable or poorly managed fisheries), which may also incur costs.

Monitoring effectiveness and measuring progress in risk management are important elements of the trade-off. These require ongoing monitoring and periodic updates to ERA in order to confidently and consistently manage the risks.

Chapter 9

Determining reference points for bycatch

9.1 Appropriate reference points for bycatch

There can be substantial differences in data quality and quantity among species impacted by fishing. The data available to assess the interactions between fisheries and bycatch species are often sparse when compared with data for commercial stocks, and are often different. Consequently, the quality and type of assessments that can be undertaken for bycatch can vary substantially to those undertaken for species managed under the Harvest Strategy Policy. Further, the estimable parameters from those assessments may not include biomass. In such circumstances, consideration needs to be given to the use of proxy measures that can be used to infer the impacts on biomass from fishing. The underlying assumption of applying these proxies is that they are equivalent to the species true biomass limit reference point. The limit reference point is defined in the Bycatch Policy and the Harvest Strategy Policy as the biomass level where the risk to the stock (in terms of recruitment impairment) is unacceptably high.

The ERM Guide assumes that a low risk ranking is equivalent to not exceeding a limit reference point when using PSA methods. A medium risk ranking when using PSA methods is also interpreted as not exceeding the limit reference point. However, analyses to verify PSA risk scores report an increasing error in risk categorisation in the medium class (that is, some medium risk classified species had breach their limit reference point) and additional precaution or analyses may be warranted for species categorised into medium risk.

When applying the SAFE method (Zhou, Smith & Fuller 2007), a fishing mortality that is lower than the maximum sustainable fishing mortality rate reference point (F_{MSM}) is not considered an unacceptable risk to the stock breaching the limit reference point. Higher estimates of fishing mortality may result in the limit reference point being breached contingent on the number of consecutive years that fishing mortality has exceeded the SAFE reference points. The stock may be exposed to an unacceptable risk if the fishing mortality is estimated to be between F_{MSM} and F_{LIM} for seven or more consecutive years; fishing mortality is between F_{LIM} and F_{CRASH} for five consecutive years; and fishing mortality exceeds F_{CRASH} for three consecutive years.

Given the sparse data and costs associated with collecting more comprehensive data on many bycatch species, model-based analyses to estimate biomass limit reference points is unlikely to be common place. The use of either SAFE or PSA risk-based proxies for the limit reference point are more likely for general bycatch. However, for some species of bycatch sufficient data may be available for applying more direct measures of biomass or fishing mortality or application of the risk-catch-cost trade-offs may warrant more precise data collection. Determining what data are available and what data can be collected in the future will provide a guide to the metric that can be used to evaluate performance in relation to the limit reference point. This will be assisted by determining what indicators (for example, catch per unit effort (CPUE), biomass, fishing mortality) can be generated from monitoring data and what performance measures can be used to measure progress against (management) objectives (that is, where the indicator is in relation to the limit reference point).

Guidance on operationalising reference points through the use of proxies

The use of SAFE and PSA risk-based proxies for the bycatch limit reference point are likely to be selected given available data for general bycatch. Applications of ecological risk management in Commonwealth fisheries have assumed the following limit reference point breaches:

- PSA—risk is greater than medium (Zhou et al. 2016)
- SAFE—if F is between F_{LIM} and F_{MSM} for seven consecutive years (Zhou, Smith & Fuller 2007)
- SAFE—if F is between F_{CRASH} and F_{LIM} for five consecutive years (Zhou, Smith & Fuller 2007)
- SAFE—F is greater than F_{CRASH} for three consecutive years (Zhou, Smith & Fuller 2007).

Alternative SAFE and PSA limit reference points to these could be applied but should be more rather than less precautionary unless there use can be justified with scientifically accepted evidence.

Other limit reference points may be developed for bycatch where there are sufficient data for applying more direct measures of biomass or fishing mortality or the application of the risk–catch–cost trade-offs warrant more precise data collection and estimation. This would be determined on a case-by-case basis and once the available data and what is practical to collect has been evaluated.

9.1.1 Potential indicators

Assessments of risk (or other possible assessments for bycatch) in relation to their respective limit reference points is unlikely to be warranted on an annual basis for every fishery, particularly for low risk species. It is more realistic for reassessment to occur on multi-year time frame (for example, every 5 or more years) unless the fishery undergoes major structural change. However, to remain responsive to changes in the status of bycatch, indicators should be monitored annually.

AFMA should select indicators appropriate to the circumstances of each of their fisheries. The magnitude of change in a potential indicator will be fishery specific and dependent on the available information. When choosing potential indicators, AFMA should provide the rationale for the indicator and the magnitude of change that would trigger a management response. These should be documented in the bycatch chapter of the respective FMS. Example indicators listed (for illustrative purposes only) are based on relatively easily obtained fishery-dependent data such as catch, effort and size composition of the catch:

- catch—greater than 20% change in any one year
- catch—increase or change in spatial distribution of catch by area
- effort—greater than 20% increase, or greater than some upper limit
- CPUE—greater than 2 standard deviation change in any one year
- CPUE—statistically significant trend over 5 years
- fishing mortality (F)—greater than 20% increase
- mean size—statistically significant trend over 5 years
- size/age composition—statistically significant change in composition
- recruitment indices—statistically significant trend over 10 years
- proportion immature—falls below some target proportion.

Provided adequate monitoring is in place to measure the chosen indicators (with acceptable levels of uncertainty), many of these are easily applied. However, collecting information can be costly, particularly for bycatch species that are not retained (for example, information needs to be monitored by on-board observers). The benefits of collecting this information includes reducing the probability of making a poor decision, but this benefit needs to be considered against the cost of collection (see risk–catch–cost section). Table 1 provides a summary of potential indicators, performance benchmarks and management responses for low, medium and high risk bycatch species.

TABLE 1 Potential indicators, performance benchmarks and management responses for low, medium and high risk bycatch species

Risk	Indicator	Management response	Benchmark
Low	SICA: scale, intensity, consequence score PSA score Size, maturity, fecundity, overlap, selectivity, catch rate.	Verify risk classification; Monitor for substantial increases in drivers of risk. Mitigation measures implemented	$A_{Y+1} < 2.A_Y$, $E_{Y+1} < 2.E_Y$ $CPUE_{Y+1} < 2.CPUE_Y$ % Vessels implementing
Medium	PSA score; SAFE score; Total catch, fishing mortality rate, natural mortality.	Verify risk classification; Monitor for changes in key drivers of risk; Reduce risk, mortality rate or uncertainty of these.	$Risk_{High} \rightarrow Risk_{Low}$ $IR_{Y+1} < IR_Y$ $C_{Y+1} < C_Y$ $N_{Y+1} < N_Y$ $F_{Y+1} < F_Y$ $CV_{Y+1} < CV_Y$
High	Fishing mortality rate; Total catch or mortality; PBR; Population census; tagging studies; Demographic models.	Verify risk classification; Minimise mortality and uncertainty; Ensure total mortality is below sustainable level; Ensure biomass is above minimum viable level.	$C_{Y+1} < C_Y$ $N_{Y+1} < N_Y$ $F_{Y+1} < F_Y$ $N < PBR$, $N/PBR < 1$ $B_{Y+1} > B_Y$, $B > 1/n\ B_0$

A = fishing area; B = biomass; B_o = biomass in the absence of fishing; C = total catch; CPUE = catch rate; CV = coefficient of variation; E = fishing effort; F = fishing mortality rate; IR = Interaction Rate; N = total number of captures or interactions; PBR = potential biological removals; Y = year.

Chapter 10

Cumulative risk

Risk-based assessment approaches are typically designed to assess the risk to a species or species group, in a fishery, at a particular time. While this approach is useful to allow AFMA to focus on discrete management issues, it creates challenges for managing risk across fisheries.

Bycatch populations may be impacted by multiple fisheries operating across a broad geographical range and under the management of multiple jurisdictions. Qualitative (level 1 - SICA) and semi-quantitative (level 2 - PSA) risk assessments generally do not provide quantitative estimates of risk that can easily be added to evaluate risk across fisheries and jurisdictions. Quantitative approaches, such as the SAFE assessment can generate metrics which can be partitioned or added to evaluate risk within or across fisheries (Zhou et al 2013). Michelli et al (2014) and Battista et al (2017) provide alternate approaches for estimating cumulative risk. These assessments can be designed to output metrics that can be accumulated across fisheries and compared with reference points to understand cumulative risk.

There are space and time dimensions across which fisheries-related cumulative impacts can occur:

1. **Impacts occur across different fisheries:** Where the distribution of a bycatch population overlaps with the operating areas of a number of different fisheries, these fisheries may have a cumulative impact on that species. This holds true both within and between management jurisdictions (international, Commonwealth, state or territory).
2. **Impacts accumulate over time:** Fishing related assessments need to be designed to determine mortality rates to allow for the evaluation of cumulative effects over time (as well as space). If risks or mortalities are not expressed as a rate, they cannot be compared against a reference point, now or through time.

Mortality in any one year might seem quite low, but this needs to be assessed in relation to the bycatch population's current status. There may have been historical impacts, sometimes unrelated to fishing, that need to be accounted for when evaluating current bycatch rates.

10.1 Fishing and non-fishing related risks

There can be various non-fisheries related impacts on bycatch species, as well as indirect fisheries-related impacts on bycatch species. Fishing activities may also indirectly affect bycatch populations through disturbance of habitats (for example, demersal trawling), reduction in water quality (for example, dredging), the release of organic matter (for example, discarded fish catch or offal) and resulting alterations to the composition of animal communities and ecosystems. The assessment and management of bycatch species should account for all sources of mortality, including indirect impacts such as regime shift, climate variability factors, mortalities from fishing and any other factors that a species may face across its range. The Bycatch Policy recognises that AFMA is only responsible for managing the risk of fishing-related mortalities in Commonwealth-managed fisheries.

10.2 Qualitative assessment of cumulative risk

For bycatch species, where only qualitative assessments have been undertaken (ERA level 1 and 2) and for which there is no urgency to invest greater resources in a higher level assessment, an assessment of cumulative risk essentially requires that the scope of the risk assessment be broadened to consider the range of fisheries across which the species is interacting. This means that the fishery boundary can be scaled up to include the multiple fisheries that are impacting that species.

Under qualitative approaches, it is difficult to differentiate between the impacts of different fisheries and, it is assumed that, if risk to a species has been assessed as high in any one fishery, then risk to that species is high across all fisheries. Management measures must be designed to respond to the likelihood that risks are high for that species in all fisheries or jurisdictions, and comparable measures put in place to reduce risks to acceptable levels in all fisheries. Qualitative assessments techniques are typically used as a prioritisation tool to identify relatively high risk species for more quantitative assessments.

10.3 Quantitative assessment of cumulative risk

The preferable way to evaluate cumulative impacts across fisheries or jurisdictions is to generate quantitative mortality rate estimates that can then be summed to generate estimates of cumulative mortality rate (Zhou et al. 2013). These can then be directly compared with reference points.

There are additional information requirements and additional costs associated with moving to higher level quantitative approaches. A substantial investment in monitoring and data is required to conduct quantitative assessments or single species population assessments.

Guidance on accounting for cumulative risk

Accounting for cumulative risk from fishing will be fundamental for demonstrating that the Australian Government is appropriately addressing its bycatch responsibilities.

AFMA and the Department of Agriculture and Water Resources will need to work collaboratively to address cumulative risk. Such analyses would need to potentially account for impacts from fisheries that are not solely managed by the Australian Government.

Chapter 11

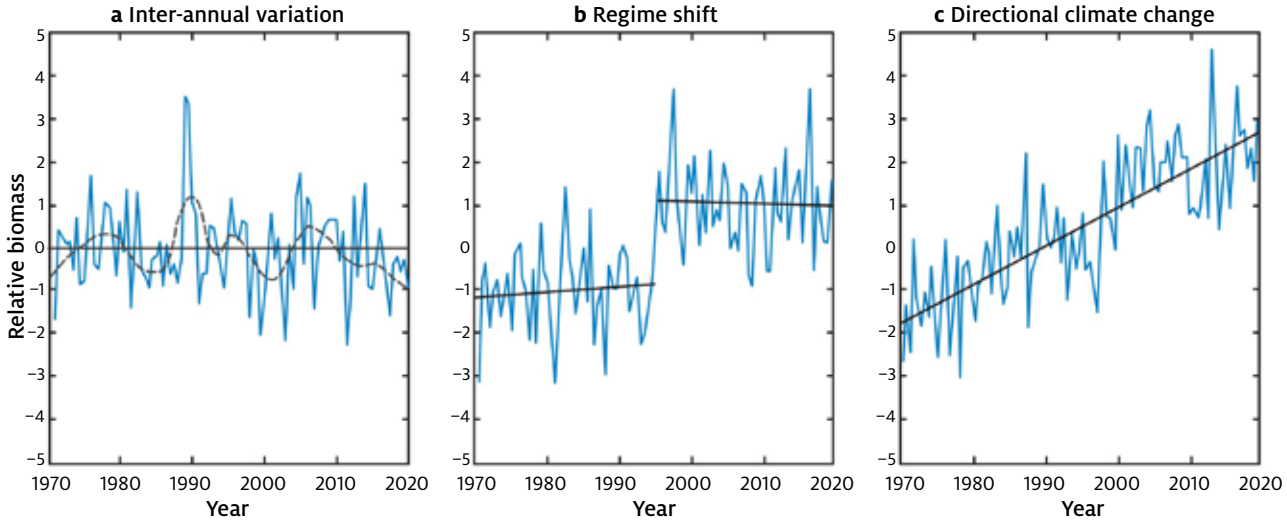
Variability, regime shift and climate change

11.1 Background

Productivity and biomass of marine resources is intrinsically linked to oceanographic conditions. In favourable conditions, recruitment, growth and survival are high, biomass will tend to increase, and sustainable fishing mortality rates may be higher. The converse is true in periods of unfavourable conditions and the total biomass supported by the environment in the absence of fishing (for example, dynamic B_0 or $B_{(F=0)}$) may be lower. Understanding the state of the environment with respect to biomass and productivity of a species or ecosystem is critical for fisheries management, and likely environmental effects should be formally recognised in any bycatch strategy. Attention must be given to existing or new monitoring required to detect environmental change. Even if a change in the productivity of a species is not due to fishing, fishery management agencies might still need to respond.

Environmental variation between favourable and unfavourable conditions can occur on a range of time scales, which will influence the particular harvest arrangements. Inter-annual variation shows no long-term trend but with evidence of cycles, regime shift showing a persistent increase in average biomass between two periods, and directional climate change showing a continual increase in biomass over time (Figure 4).

FIGURE 4 Illustration of the effect of various types of environmental variability on biomass



Inter-annual variability: Inter-annual environmental variability operates typically at time scales of 1-5 years. Inter-annual variability can manifest itself either as unpredictable noise, or relatively predictable episodic or periodic cycles, even where there is no long-term trend (Figure 4a).

Regime shifts: Marine ecosystems are occasionally subject to sudden, dramatic, long-lasting changes in ecosystem structure and function (Figure 4b). Regime shifts operate at large spatial scales (for example, regional to basin scales) and are characterised by temporal variability that is coherent across multiple taxa and trophic levels within a community. Regime shifts can occur as responses to natural (such as low-frequency climate variability) or anthropogenic causes (such as overfishing, eutrophication, habitat loss). Regime shifts are best known from the north-east and south-east Pacific Ocean, where spatially extensive, multi-decadal observational time series allow changes in ecological structure to be documented. Long-term biological observations are scarce in most marine ecosystems globally, which may make the formal detection of regime shifts difficult or impossible on a time scale that is useful for management.

Directional climate change: Long-term sustained environmental change is occurring in a particular direction or is projected to occur over many decades (Figure 4c). This may be due to anthropogenic climate change, resulting in long-term warming and acidification of the ocean. Long time series are needed to detect these changes.

Changes in the environment on these time scales can influence a range of factors relevant to design of a bycatch strategy, including:

- Reference points—limit reference points may need to be changed to reflect changes in system productivity.
- Estimating an appropriate B_0—estimates of B_0 may be larger when conditions are good, and smaller when conditions are poor. Setting a dynamic B_0 or $B_{(F=0)}$ allows for response to changing environmental conditions.
- Rebuilding targets—rebuilding targets and timeframes may not be achieved if the environmental conditions have shifted to a new state (for example, a less productive regime). Alternately, rebuilding may be quicker than expected if conditions have improved.
- Spatial and temporal closures—a particular species may not occur at the time and space previously inhabited due to geographic shifts in suitable environmental conditions. As a consequence, a portion of a population previously protected in a closed area may now be exposed to human activities, rendering the closure ineffective.
- Companion species—changing species compositions (including the entry of new species not previously recorded for the area), resulting in increased or decreased susceptibility of species to a fishery, need to be considered when evaluating any aspect of the bycatch strategy that may be influenced by changing natural mortality rates or gear interactions.

11.2 Monitoring to detect environmental change

Monitoring programs to detect change can include data collection from the commercial fishery (catch, size, species composition and effort) and fishery-independent estimates of recruitment and biomass. Monitoring of key parameters characterising the environment and ecosystem that support the fishery can also be informative, including remote sensing or oceanographic data logging.

A range of existing monitoring programs can provide data useful for detecting changes relevant to fisheries. These may include large-scale or regional parameters (for example, climate and ocean circulation) and local coastal monitoring (for example, runoff, water quality and inshore habitat). Fishery agencies and/or the fishing industry alone cannot support the cost of an adequate monitoring program, and a coordinated program serving a number of stakeholders in the coastal zone is much more likely to succeed (Hobday & Cvitanovic 2017).

For example, the Integrated Marine Observation System (IMOS) was established in 2005 and has been very important in providing physical information about the ocean conditions (Lynch et al. 2014). This program has supported development of cost-effective monitoring tools and integration and exchange of many datasets. These have been widely used to help understand oceanographic and fisheries trends and have informed climate models used to project changes in fish distribution.

The ability to detect change depends on:

- the rate of change in relation to the frequency of monitoring
- the variation over time in the particular environmental variable
- the length of the time series.

Simulation testing can be used to determine the ability to detect significant change in a monitored variable (Hobday & Evans 2013) and used to design effective monitoring programs.

11.3 Application to bycatch strategy design

Management strategies are usually designed to account for inter-annual environmental variability—for example, by expecting the biomass to vary around the target biomass. Regime shifts and longer term changes that affect species or stocks by shifting productivity which then has consequences for management. Updating of proxy reference points (such as B_0) has been suggested as the best approach for adapting current management strategies for change (Brown et al. 2012). The implication of this for bycatch strategy design will be most evident in the estimation of performance measures. The distance between the chosen indicators and associated reference points are currently difficult to estimate reliably, given variation and short-term, non-stationary information contained in monitoring data. This difficulty is likely to be exacerbated with a changing B_0.

Modifying bycatch strategies on the basis of assumed but untested environmental explanations, rather than fishing-related causes for decline, should be avoided. Accepting an explanation of environmental change should be subject to considerable scrutiny and supported by monitoring data. A weight-of-evidence approach should be applied to use available scientific evidence to test a causal hypothesis. Hypotheses should be articulated prior to evaluation, and the evidence for and against each hypothesis should be evaluated according to pre-determined criteria.

Criteria that could be used to evaluate a claim of regime shift (Klaer et al. 2015) and appropriate for long-term change, include:

- an observed change in a stock productivity indicator, such as growth rate
- confidence in observational data
- confidence in species life history knowledge
- theoretical explanation of how change is linked to the environment.

The nature of the perceived environmental impact on the population must be considered when considering changes in the bycatch strategy. Changes in spatial availability, increased natural mortality and/or decreased reproductive potential due to stress or lower growth rates and body size all have different implications in the context of bycatch strategy design and the setting of reference points.

There may be implications for setting rebuilding targets and time-frames, if system productivity has changed. The challenge is to predict current and future climate change impacts on life history (for example reproductive success and changes in natural mortality) that directly affect the population and its productivity. In the absence of direct estimates of such impacts (based on data and scientific evidence), they will either have to be indirectly estimated from other projected environmental indicator changes, or catered for by introducing a wider range of parameter estimates and/or building in higher levels of uncertainty.

Chapter 12

Monitoring and performance evaluation

12.1 Monitoring to support ecological risk assessment and management

ERA and ERM are currently the primary mechanisms for assessment and management of general bycatch. There are many aspects to the effective implementation of ERA and ERM, but two key aspects that relate to monitoring and performance evaluation are the data collection to support assessment, and the evaluation of the performance of the management response.

Review of monitoring processes should identify data deficiencies in the assessment of species or stocks using ERA process. Given that the qualitative ERA methods (SICA and PSA) default to high risk scores for attributes where data are deficient, AFMA will need to evaluate the relative costs and benefits of rectifying any data deficiencies in the assessment and management of bycatch.

Evaluation of the performance of the management response is an important aspect of the ERA and ERM approach. Where a management response has been implemented to address an unacceptable risk score, appropriate data collection and analyses processes should be put in place to establish that the management response is doing what it was designed to do.

12.2 Other monitoring of performance

The types of data that should be collected across species to demonstrate performance against the Bycatch Policy include:

1. Species level data on bycatch, including quantity, location, effort and gear used. Processes should be put in place such that these data can be verified and established as robust.
2. Metrics of fishery performance (reference points) developed, implemented, documented and monitored as a way of measuring the performance of a fishery with regard to the Bycatch Policy and its objectives. Reference points should be cognisant of the risk equivalency requirements of the Bycatch Policy.

See section 13 for further details.

Guidance operationalising monitoring and performance requirements

Monitoring and performance evaluation will require that general bycatch is identified, quantified and verified. The data and monitoring strategy chapter of each AFMA FMS should be checked to ensure that general bycatch will be identified, quantified and verified through one or more of these fisheries monitoring systems:

- reporting of operational-level catch and effort data in logbooks
- scientific or independent observer programs
- electronic monitoring
- scientific survey.

The bycatch chapter of each FMS should ensure that the design of the adopted fisheries monitoring systems are statistically robust, so as to permit the identification, quantification and verification of general bycatch (when required) with a reasonable degree of confidence and that fishery-wide general bycatch management can be prioritised through analyses of the data collected by these monitoring systems.

Effective performance evaluation will require:

- that robust and practical indicators of fishery effects on general bycatch are identified
- preferably that indicators of fishery effects on bycatch are measured against accepted limit reference points
- when a bycatch management or a mitigation measure is implemented, subsequent monitoring is adequate to assess its effectiveness
- metrics to measure the effectiveness of management actions in meeting their objectives are specified and monitored.

Chapter 13

Reporting

The Bycatch Policy outlines the requirement to report on the performance of bycatch management and the timeframes for doing so. These guidelines do not attempt to alter that reporting requirement. There are resourcing implications for monitoring, performance assessment and reporting on bycatch. The bycatch chapter of each AFMA FMS (as they are developed) will outline how AFMA plan to manage general bycatch, pursue the requirements of the Bycatch Policy and encourage continual improvement.

The Bycatch Policy advocates the merits of independent reporting on bycatch management. Given the resources required, there may be benefits in establishing regular and standardised independent bycatch reporting protocols that are resourced and undertaken outside of normal funding arrangements for AFMA.

Boat at dock
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Chapter 14

Communication and stakeholders engagement

Effective implementation of the Bycatch Policy will need to be supported by communication and stakeholder participation. Strategies developed for communication and stakeholder engagement should consider:

- information on bycatch management and the effectiveness of the Bycatch Policy is communicated through appropriate media—where the same issue is being addressed by different government agencies ensure that bycatch management actions are clearly and consistently communicated
- where feasible, stakeholders are engaged through participation in management advisory committees, issue-specific working groups, stakeholder meetings and direct communications
- stakeholders are consulted before cross jurisdictional meetings that may take decisions that have potential implications for bycatch management in their fisheries.

Appendix A

Operationalising the bycatch objectives

Draw on best-practice approaches to avoid or minimise all bycatch, and minimising the mortality of bycatch that cannot be avoided

- For low risk species, management action are unlikely to be an immediate priority however operational objectives should encourage actions that are consistent with the principal of "avoid and minimise" and be consistent with global best practice and other National and International Commitments (e.g. United Nations Food and Agriculture Organization Code of Conduct for Responsible Fisheries which includes the International Guidelines on Bycatch Management and Reduction of Discards).
- For high risk species, operational objectives should take all reasonable steps to "avoid or minimise" general bycatch as far as possible.
- Any proposed management actions specified in operational objectives need to be designed to respond effectively to specific threats or impacts, be relevant for the fishery and species concerned, and be shown to be effective. It may be more cost-effective to target impact reduction measures that reduce impact on a range of species rather than applying a single species approach.

Directives in the operational objectives for low risk bycatch species in the fishery should include:

- Cost-effective operational mitigation measures that could be implemented to reduce waste as part of a process of continual improvement.

Directives in the operational objectives for medium risk bycatch species in the fishery should include:

- Cost-effective measures to ensure that risk does not increase to high, with evaluation of the risk-cost-catch trade-off or alternative options.

Directives in the operational objectives for high risk bycatch species in the fishery should include:

- Appropriate measures to reduce high risks to acceptable levels. These measures should be designed to reduce one or more of the key contributory factors to high susceptibility, such as encounter rates, catchability, post-capture survival or fishery extent. Measures must be measurable and their effectiveness demonstrated and reported.

Manage fishing-related impacts on general bycatch species to ensure that populations (i.e. discrete biological stocks) are not depleted below a level where the risk of recruitment impairment is regarded as unacceptably high

- Operationalising this sub-objective should encourage actions that evaluate the level of risk and level of impact of each fishery on bycatch species. When evaluating risk, the level of risk that constitutes a bycatch populations being above the limit reference level (i.e. the biomass level that prevents recruitment impairment) should be substantiated.
- Operationalised objectives should encompass directives that ensure that fisheries do not cause general bycatch species to decline:
  - to levels where the risk of recruitment impairment is regarded as unacceptably high.
  - to levels that result in them being listed for protection under the EPBC Act.
  - below levels required for the effective trophic functioning of the ecosystem (e.g. populations of key prey species, or groups of prey species, remain at levels adequate for dependent predator species).
- The inclusion of any benchmarks in operational objectives to measure performance should be appropriate for each situation and species, depending on risk, information availability and consideration of the risk-cost-catch trade-off.
- A test of the likely effectiveness of the operational objectives is an evaluation of their responsiveness and whether an adaptive management system is in place to trigger a management response when risks are (or approach) high.

Directives in the operational objectives for low risk bycatch species in the fishery should include:

- verification/validation that low risk determinations are accurate.
- monitoring to detect substantial changes or trends in key drivers of the risk ranking that may indicate increasing risk, to trigger a re-assessment if such changes occur.

Directives in the operational objectives for medium risk bycatch species in the fishery should include:

- verification/validation that medium risk determinations are accurate, particularly if these result from assumptions e.g. regarding susceptibility.
- Adequate monitoring and reporting should be conducted to detect changes or trends in key drivers of the risk ranking that may indicate increasing risk, to trigger a re-assessment if such changes occur.

Directives in the operational objectives for high risk bycatch species in the fishery should include:

- Checking and validation of high risk determinations to ensure that susceptibility rankings appropriately reflect actual captures or interactions.
- Where high risk rankings result largely from uncertainty in inputs to the assessment, initial efforts could be made to reduce these uncertainties through data collection to improve confidence in the assessment, rather than applying measures to reduce fishery impacts. The approach taken would be a management choice after considering the risk-cost-catch trade-off between these options.
- Benchmarks that are able to clearly detect change from high to lower risk levels.

In instances where fishing-related impacts have caused a bycatch population to fall below the level described above, implement management arrangements to support those populations rebuilding to biomass levels above that level.

- In operationalising this sub-objective management should verify and validate the high risk ranking that indicates the stocks biomass is below a level where the risk of recruitment impairment is regarded as unacceptably high.
- Prioritise management arrangement to rebuild the population to above a level where the risk of recruitment impairment is regarded as unacceptably high (i.e. shift the species from high to a lower risk ranking). These measures should be designed to reduce one or more of the key contributory factors to high susceptibility, such as encounter rates, catchability, post-capture survival or fishery extent. Measures must be measurable and their effectiveness demonstrated and reported.
- Develop and implement time bounded rebuilding plans, consistent with the Harvest Strategy Policy, to allow performance evaluation. Evaluate the plans responsiveness and whether an adaptive management system is in place to trigger further management responses if risk deteriorates or the species fails to respond to implemented management.

An illustrative example of operationalised objectives in the bycatch chapter of a fishery management strategy.

Objective type	Objective
Economic returns	Not applicable as bycatch by definition do not contribute to the economic value of the fishery.
Ecological sustainability	Interactions between the fishing activities and general bycatch species, to the extent practicable, are avoided and minimised to ensure species biomasses are maintained at levels: • where the risk of recruitment impairment is not considered as unacceptably high • that do not result in listing for protection under the EPBC Act • required for the effective trophic functioning of the ecosystem. Apply the outcomes from the application of the AFMA ERA/ERM Guide for prioritising management to high, then medium, then low risk species once risk categorisation is verified and validated. Implement monitoring and measure performance against benchmarks that will detect substantial changes or trends in key drivers that may indicate increasing risk and trigger re-assessment (if such changes occur). For high risk species ensure performance monitoring is able to clearly detect change from high to lower risk levels. Where prescription of measures is required, ensure implementation does not have negative impacts on other species and prioritise those that minimise interactions for multiple species. Encourage industry-led solutions to minimise interactions with general bycatch utilising an individual accountability approach.
Accountability	Management decisions, arrangements and strategies are clearly explained, transparent, documented and communicated to industry and the broader community. Reporting obligations under fisheries policies and guidelines, and international agreements are met.
International Agreements	Management of the fishery complies with all relevant International conservation and management measures for general bycatch.
Cost-effective management	Management responses are proportionate to the conservation status of affected species and Ecological Risk Assessment results and commensurate with the cumulative risks of fishing on the species. Management approaches are consistent with the principle of the risk-cost-catch trade-off.

Glossary

Term	Definition
Balanced harvest	Fishing across the widest possible range of species, stocks and sizes in an ecosystem, in proportion to their natural productivity, so that the activity of fishing does not alter the relative size and species composition that would occur in the absence of fishing.
Biomass limit reference point (B_{LIM})	The point beyond which the risk to the stock is regarded as unacceptably high.
Biomass at maximum economic yield (B_{MEY})	The average biomass which corresponds to maximum economic yield. See also 'maximum economic yield'.
Bycatch	A species that is incidentally either: • taken in a fishery and returned to the sea • killed or injured as a result of interacting with fishing equipment in the fishery, but not taken. Bycatch can include EPBC Act–listed species
Bycatch policy	The *Commonwealth Fisheries Bycatch Policy* provides a framework for managing the risk of fishing related impacts on bycatch species in Commonwealth fisheries.
Byproduct	Byproduct stocks make some contribution to the value of the catch in a fishery but less than that of key commercial species. These stocks may be rarely encountered and usually retained, or frequently encountered and occasionally retained.
Catch	In relation to fishing, means capture, take or harvest.
Categorisation	The act of identifying and partitioning components of a fishery's catch into categories. Typically categories include key commercial, byproduct and bycatch.
Catch-per-unit-effort (CPUE)	The number or weight of fish caught by a unit of fishing effort. Can be used as an index of relative abundance or indicator of change in the fishery.
Cumulative impact	The accumulation of all known impacts.
Cumulative risk	The accumulation of all known risks.

Term	Definition
Discard	Any part of the catch which is returned to the sea, whether dead or alive. In Commonwealth fisheries, the term is predominantly used to refer to commercial species that are not retained.
Discarding	The practice of returning any part of the catch to the sea.
Ecological risk assessment (ERA)	An assessment process that evaluates the relative risk posed by fishing on species, habitats and communities within a fishery.
Ecological risk assessment for the effects of fishing (ERAEF)	Assessment process developed to estimate and monitor the risk posed by Commonwealth fisheries to the ongoing sustainability of ecosystem components that interact with Commonwealth fisheries.
Ecological risk management (ERM)	The management framework for undertaking and responding to outcomes of ecological risk assessment.
Ecologically sustainable development (ESD)	Using, conserving and enhancing the community's resources so that ecological processes are maintained, and the total quality of life, now and in the future, can be increased. Principles of ecologically sustainable development (as per the *Fisheries Management Act 1991*): • decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equity considerations • if 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 • the principle of inter-generational equity—that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations • the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making • improved valuation, pricing and incentive mechanisms should be promoted.
Effort	Also, called fishing effort. A measure of the resources (such as fishing hours or hook sets) used to harvest a fishery's stocks.
Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	The central piece of Commonwealth environmental legislation. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places—defined in the EPBC Act as matters of national environmental significance. Parts 10, 13 and 13A relate specifically to aspects of fisheries.
EPBC Act–listed species (also known as TEP)	EPBC Act–listed species comprises all those protected under Part 13 of the EPBC Act including whales and other cetaceans and listed threatened, marine and migratory species (except for conservation-dependent species which are managed through rebuilding strategies under the Harvest Strategy Policy).

Term	Definition
False positive	A test result which wrongly indicates that a particular condition or attribute is present.
Fecundity	Number of eggs an animal produces each reproductive cycle; the potential reproductive capacity of an organism or population.
Fisheries Administration Act 1991 (FA Act)	Commonwealth Act that establishes the Australian Fisheries Management Authority (AFMA) and its Commission.
Fisheries Management Act 1991 (FM Act)	Commonwealth Act that provides the legal framework for fisheries managed by the Australian Government. The Act sets out, among other things: fisheries management objectives and arrangements for regulating; permitting; and taking enforcement action with respect to fishing operations.
Fishery management strategy (FMS)	An all-encompassing document containing key fishery-level management measures including the harvest strategy and ERA/ERM objectives and requirements.
Fishing	Fishing includes: • searching for, or taking, fish • attempting to search for, or take, fish • engaging in any other activities that can reasonably be expected to result in the locating, or taking, of fish • placing, searching for or recovering fish aggregating devices or associated electronic equipment such as radio beacons • any operations at sea directly in support of, or in preparation for, any activity described in this definition • aircraft use relating to any activity described in this definition except flights in emergencies involving the health or safety of crew members or the safety of a boat • the processing, carrying or transhipping of fish that have been taken.
Fishing mortality rate (F)	The rate of fish deaths due to fishing a stock or a designated component of a stock.
Fishing mortality limit reference point (F_{LIM})	The fishing mortality above which the removal rate from the stock is regarded as too high.
General bycatch	All bycatch that is not listed under the EPBC Act (see 'EPBC Act–listed species').
Guidelines for the Ecologically Sustainable Management of Fisheries (2nd Edition)	Developed to support the assessment of fisheries in pursuing sustainability objectives under the EPBC Act. The guidelines outline the principles and objectives for evaluating the environmental performance of management arrangements for export fisheries and fisheries which operate in Commonwealth waters.
Gross value of production (GVP)	A value obtained by multiplying the volume of catch (whole-weight equivalent) by the average per-unit beach price. In the case of a multispecies fishery, the fishery's GVP is the sum of the GVPs of each species.

Term	Definition
Harvest strategy	A decision framework designed to pursue defined biological and economic objectives for commercial fish stocks in a given fishery (also known as a management procedure). Key elements include: operational objectives, performance indicators, reference points, acceptable levels of risk, a monitoring strategy, an assessment and harvest control rules.
Harvest Strategy Policy	The policy that establishes the requirement for the development of harvest strategies in Commonwealth-managed fisheries.
Indicator	Provides information on the state of the stock.
Interaction	Includes any physical contact between a species and a fishing operation and includes all catch, and any discards or releases. Collisions (that is, an animal that makes contact with the fishing operation but is not caught) are also considered to be interactions.
Key commercial stock	Stocks that are most relevant to the objective of maximising net economic returns to the Australian community from the management of the fishery.
Limit reference point	The level of an indicator (such as biomass or fishing mortality) beyond which the risk to the stock is regarded as unacceptably high.
Management advisory committee	Fishery-specific committees that (inter alia) provide advice to AFMA on stocks and/or species and on the impacts of fishing on the marine environment.
Management procedure	See 'Harvest strategy'.
Maturity	Size (age or length) at which 100% of the fish in a stock or population are mature—where mature refers to an animal that is able to contribute to the gene pool through reproduction.
Maximum economic yield (MEY)	The sustainable catch or effort level for a commercial fishery that allows net economic returns to be maximised. In this context, maximised equates to the largest positive difference between total revenue and total cost of fishing.
Maximum sustainable yield (MSY)	The maximum average annual catch that can be removed from a stock over an indefinite period under prevailing environmental conditions.
Natural mortality rate (M)	Deaths of fish from all natural causes except fishing. Usually expressed as an instantaneous rate or as a percentage of fish dying in a year.
Net economic return (NER)	A fishery's NER over a particular period is equal to fishing revenue less fishing costs. Fishing costs include the usual accounting costs of fuel, labour, and repairs and maintenance, as well as various economic costs such as the opportunity cost of owner labour and capital (see 'Opportunity cost'). The concept of NER is very closely related to economic efficiency, a necessary condition for NER to be maximised.

Term	Definition
Opportunity cost	The compensation a resource forgoes by being employed in its present use and not in the next best alternative. For example, the opportunity cost incurred by the skipper of a fishing vessel is the amount they would have received by applying their skill and knowledge in the next best alternative occupation. The opportunity cost of owning a fishing vessel might be the interest that could be earned if the vessel were sold and the capital invested elsewhere. Although these costs are not usually reflected in a firm's financial accounts, they are very important.
Overfished	A fish stock with a biomass below its biomass limit reference point or below its specified indicator limit reference point.
Overfishing	A stock that is experiencing too much fishing. The rate of removals from a stock is likely to result in the stock becoming overfished. For a stock that is overfished, overfishing is a rate of removals that will prevent stock recovery in accordance with its rebuilding strategy.
Performance measure	Provides information on management performance. They are a measure of where an indicator is in relation to a reference point.
Precautionary principle	Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by: • careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and • an assessment of the risk-weighted consequences of various options.
Productivity susceptibility analysis (PSA)	PSA is a method that assigns to each species in each fishery a score on two axes, the first representing its susceptibility to being caught and the second, its biological productivity.
Population	All the organisms of the same species, which live in a particular geographical area, and have the capability of interbreeding.
Productivity (of a fish)	The rate of generation of biomass in an ecosystem.
Proxy	In the context of the Harvest Strategy Policy, a more easily estimated figure used to represent the value of a reference point. For example a target biomass of $0.48B_0$ is a proxy for B_{MEY} where the actual value of B_{MEY} may be unknown.
Rebuilding strategy	A strategy designed to rebuild an overfished stock to above its limit reference point and towards its target reference point.
Recruit	Usually, a fish that has just become susceptible to the fishery. Sometimes used in relation to population components (for example, a recruit to the spawning stock).
Recruitment	The amount of fish added to the exploitable stock each year due to growth and/or migration into the fishing area. For example, the number of fish that grow to become vulnerable to the fishing gear in one year would be the recruitment to the fishable population that year. This term is also used in referring to the number of fish from a year class reaching a certain age.
Recruitment impairment	A sustained and significant reduction in recruits to below average levels. Typically associated with recruitment overfishing.

Term	Definition
Recruitment overfishing	Recruitment impairment that results from fishing.
Reference point	Specified level of an indicator used as a benchmark within a harvest strategy.
Residual risk analysis	Used to consider additional information, particularly the mitigating effects of management arrangements that were not explicitly included in the original assessment (related to risk assessment process).
Risk-based approach	An approach to fisheries management that recognises that decisions are made in the absence of perfect information. The approach requires that risks of action and inaction are known and appropriately managed.
Risk–catch–cost	The risk-catch-cost trade-off is a concept that seeks to balance the amount of resources invested in data collection, analysis and management of a fishery, with the level of catch (or fishing mortality) taken from that fishery.
Risk equivalency	An equivalent level of risk between two comparable stocks or species.
Sustainability assessment for fishing effects (SAFE)	An analysis that estimates fishing mortality based on the overlap between a species' range and fishing effort, and similar biological and fishing attributes as are used to derive indicators in PSA.
Scale Intensity Consequence Analyses (SICA)	Identifies activities that lead to a significant impact on any species, habitat or community. Involves an assessment of the risk posed by each identified fishing activity on whole ecosystem components including target; bycatch and byproduct; TEP species; habitats and communities. Used as a rapid screening tool, used to ensure only genuine low risk elements are screened out.
Selectivity	Selection of fish by a fishing gear is the process which causes the catch to have a different composition to that of the fish populations in the fished area. Fishing gear can select for particular species, or certain sizes within or across species.
Spawning biomass (SB)	The total weight of all adult (reproductively mature) fish in a population (also referred to as spawning stock biomass).
Spawning stock biomass (SSB)	See 'spawning biomass'.
Species	A group of animals in which members can breed with one another and produce fertile offspring
Species accumulation curve	Statistical approach of plotting the number of new species that accumulate with additional sampling. A species accumulation curve may be used to estimate the likely total number of species under very high (or infinite) sampling rates. May be used to assess adequacy of fisheries sampling, such as observer coverage levels, for detecting interactions.

Term	Definition
Stock (stock structure)	A unit of management (subpopulation) of a particular fish species with common intrinsic population parameters (growth, recruitment, mortality and fishing mortality) and for which extrinsic factors (immigration and emigration) may be ignored. A stock may encompass the whole distribution of a species, in which case the stock and species are in effect the same thing. Or it may be some subset of the distribution of a species, in which case a species would have stock structure and comprise multiple stocks.
SMARP	The acronym for the Strategic Monitoring and Review Project, which was implemented for the Southern and Eastern Scalefish and Shark Fishery
Take (taken)	See 'catch'.
Targeting (also known as targeted fishing)	The tailoring of fishing practices (including fishing gear) to pursue a particular stock, species or size of fish.
Teleost	A fish of a large group that comprises all ray-finned fishes apart from the primitive bichirs, sturgeons, paddlefishes, freshwater garfishes, and bowfins.
Harvest Strategy Policy 90% risk criterion	A one-in-ten-year risk that stocks will fall below B_{LIM}. Forms part of the testing of harvest strategies for stocks managed under the Harvest Strategy Policy.
Threatened, endangered or protected species (TEP)	Species or stocks listed as either threatened, endangered or protected under the EPBC Act.

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DA3416_0518