Australian Government

Australian Fisheries Management Authority

Climate Risk Framework

Integrating climate impacts in decision-making

Securing Australia's fishing future

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Executive summary

The impacts of climate change on Commonwealth fish and fisheries are becoming increasingly evident. The current effects of climate change on marine ecosystems are being widely reported and Intergovernmental Panel on Climate Change (IPCC) projections indicate that fish production will be further affected within the relatively short term (e.g. 10 years), to the point where management advice that does not consider this change may result in detrimental outcomes for fisheries (Duplisea et al. 2021).

AFMA has developed the Climate Risk Framework (the Framework) to integrate consideration of climate impacts into management decisions for Commonwealth-managed species/stocks (herein referred to as species). The Framework is based on a risk assessment approach to integrate climate-driven ecosystem and environmental considerations and uncertainty into existing management frameworks.

The Framework employs a four-step process:

1. Evaluate the overall risk to the species, integrating climate change impacts with the stock's biological status, using the best available information.
2. Identify current science, management or industry measures that offer sufficiently robust responses to the full spectrum of climate change impacts, both positive and negative.
3. Evaluate the impact of response measures identified at Step 2 and determine the residual risk remaining to the species.
4. Where necessary, recommend to the AFMA Commission any additional measures needed to respond to climate change impacts.

The Framework is structured to ensure climate impacts and appropriate adaptation responses are considered, with a view of providing advice to the AFMA Commission as part of the total allowable catch (TAC) or total allowable effort (TAE) setting process for the coming fishing year.

The Framework is one element of a broader program of climate adaptation work being undertaken by AFMA to ensure current and projected climate impacts are integrated with decision-making processes. For data-rich species or fisheries with climate-aware stock assessments and harvest strategies, the Framework offers an easily accessible summary of existing measures to respond to climate change. For data-poor species and those yet to have climate considerations in assessments, it provides a pragmatic and process-oriented means of assessing climate impacts and identifying adaptation options.

Acknowledgements

The development of this Framework has benefited greatly from the technical and strategic advice provided by the Expert Working Group, comprising Dr Keith Sainsbury, Dr Beth Fulton, Dr David Smith and Dr Alistair Hobday. Their expertise[1] and insights were instrumental in shaping the direction and content of this work. We also acknowledge the contributions of the AFMA authors – Daniel Corrie, Alice Mcdonald, Natalie Couchman and William Jaggers – whose dedication and collaborative efforts were central to the Framework's development. Valuable input was received from Resource Assessment Groups, Management Advisory Committees, and the AFMA Commission. Their engagement and feedback ensured the Framework reflects a broad range of perspectives and priorities across the fisheries sector.

Contents

Version	Updates	Approver
12 Jan 2024	Version for trials, commencing Feb 2024.	Alice McDonald
10 Jul 2024	Revised version for trials, commencing Aug 2024.	Dan Corrie
29 September 2025	Final version.	AFMA Commission

[1] Appendix B

1 Introduction

Climate change is already impacting Australia's marine ecosystems and fisheries in a range of complex ways. Water temperature, salinity, acidification, circulation and nutrients are all changing, and extreme events such as marine heatwaves are becoming more frequent and severe, with flow-on impacts on habitats and species (Trebilco et al. 2021). The effects of climate change on marine ecosystems are widely reported and Intergovernmental Panel on Climate Change (IPCC) projections indicate that fish production will be further affected within the relatively short term (e.g. 10 years), to the point where management advice that does not consider this change may result in detrimental outcomes for fisheries (Duplisea et al. 2021).

Research predicts that climate change will have both positive and negative impacts on reproduction, recruitment, and distribution of biomass of Australia's commercially important marine species (Fulton et al. 2021). The Commonwealth Fisheries Harvest Strategy Policy (HSP) and HSP Implementation Guidelines (the Guidelines) recognise that non-fishing effects can cause species abundance to fluctuate and conclude that timely responses by management to changes in stock productivity and distribution are important in areas where climate is shown to be changing rapidly (DAWR 2018).

In the context of ecologically sustainable and profitable use of Australia's Commonwealth commercial fisheries resources, AFMA's legislative obligations include the need to ensure that the exploitation of fisheries resources is conducted in a manner consistent with the principles of ecologically sustainable development, including the exercise of the 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* (Government of Australia 1992).

To ensure that these objectives continue to be met, AFMA has initiated a dedicated program focused on incorporating climate change information and known and potential impacts into our decision-making processes. By doing so, we aim to make fisheries management adaptable and resilient to short- and long-term changes in the marine environment.

1.1 Impacts of climate change on Commonwealth fisheries

AFMA is committed to proactively adapting fisheries management in response to the growing impacts of climate change on Australia's marine ecosystems. Recognising the increasing availability of research and data detailing the vulnerability of fish stocks, AFMA is actively integrating climate considerations into its decision-making processes. Resource assessment groups (RAGs), management advisory committees (MACs), and managers are all utilising this information to inform management strategies for Commonwealth-managed species.

A key component of this effort is the development and refinement of Climate and Ecosystem Status Reports for key fisheries (available on the AFMA Climate Adaptation Page). These reports provide valuable insights into climatic and environmental trends, drawing on data such as sea surface temperature, El Niño–Southern Oscillation (ENSO) cycles, water chemistry, and fisher observations. As these reports evolve, they will incorporate increasingly sophisticated population and environmental indicators, enhancing our understanding of climate impacts on stock abundance and distribution. AFMA is drawing on international best practices, leveraging insights from recent publications (Duplisea et al. 2021; Bessell-Browne et al. 2025), leading researchers and organisations like National Oceanic and Atmospheric Administration (NOAA) and their Alaska Marine Ecosystem Status Reports, to refine these indicators and adapt them to Australian conditions.

While the long-term goal is to have climate and ecosystem information integrated into stock assessments, harvest strategies and other formal management plans, AFMA recognises that a phased and pragmatic approach is necessary. Complex quantitative models, while ideal, may not be immediately feasible or cost-effective for all species (Bessell-Browne et al. 2025). Therefore, AFMA is prioritising the development of robust, practical tools and methodologies that can effectively inform management decisions in the near-term. This includes integrating climate information into existing decision-making processes, while simultaneously exploring and developing more advanced quantitative approaches for future implementation.

AFMA is dedicated to continuous improvement and adaptation in the face of climate change. By fostering collaboration with researchers, utilising best available science, and embracing a flexible and adaptive management approach, AFMA is ensuring the long-term sustainability of Australia's Commonwealth-managed fisheries.

1.2 A mechanism to integrate climate impacts in decision-making

AFMAs legislative obligations include the need to ensure that the exploitation of fisheries resources is conducted in a manner consistent with the principles of ecologically sustainable development, which includes exercise of the precautionary principle (Government of Australia 1992). The precautionary principle requires AFMA to address uncertainty and account for known risk, and potential risks, in decision-making.

Given the increasingly evident impacts of climate change, and the understanding that climate change is accelerating (Duplisea et al. 2021), a mechanism to integrate climate impacts into management decisions is needed now, while more sophisticated and longer-term solutions are being developed.

AFMA must ensure that climate and ecosystem impacts are explicitly considered and appropriately integrated in the production of management advice for Commonwealth-managed fisheries. While ‘climate-ready’ stock assessments and harvest strategies are unlikely in the near-term for most species, and may never be necessary or possible for others, semi-quantitative or qualitative approaches are already used in some jurisdictions.

Risk assessment approaches are utilised widely in fisheries, including in assessing and responding to ecological risks in Commonwealth fisheries under the Ecological Risk Management Framework. A risk table (Dorn and Zador 2020) is being utilised in Alaskan groundfish fisheries to support total allowable catch (TAC) decision-making in the North Pacific Fishery Management Council (NPFMC). In these fisheries, recommended biological catch (RBC) estimates and final TAC levels are presented alongside relevant information around assessment uncertainty or modifications, population dynamics not explicitly addressed in the model, and ecosystem state. This provides the context for the decision-making, particularly when there are lower catch recommendations than the ‘acceptable biological catch’ due to ecosystem or environment concerns (including climate impacts). The use of the Alaskan risk table is dependent on informative ecosystem indicators that have been identified and refined through time in Alaska (see for example the Alaska Marine Ecosystem Status Reports).

AFMA has developed the Climate Risk Framework (the Framework) to assess the potential impacts of climate change on Commonwealth-managed species. The Framework utilises the most robust information available to understand how climate change may impact a species. It then prompts an exploration of adaptation responses using the tools that are available within the existing scientific, management and industry adaptation pathways.

The Framework represents a step in a longer-term process. For complex, data-rich fisheries, it lays the groundwork for becoming 'climate aware', paving the way for future, more sophisticated approaches that will continue to determine sustainable harvest levels. For data-poor fisheries, the Framework offers a robust and systematic, risk-based process for reviewing climate impacts and identifying potential adaptation responses. Its strength lies in the structured methodology, which remains appropriate and effective over the long term – even when data availability is limited – making it a sound foundation for addressing the impacts of climate change.

The Framework has been developed through an iterative process, incorporating trial applications across several AFMA-managed fisheries. The Framework reflects the outcomes of those completed trials. The initial trial report, which includes a review of the process and implementation recommendations, is accessible on the AFMA Climate Adaptation Page. While the trial period has now concluded, the Framework will continue to be refined and developed as new information emerges, and its application evolves.

Species Covered by the Framework

The HSP generally refers and is applied to ‘key commercial’ and ‘byproduct’ species. These species are typically managed under fishery harvest strategies and are subject to targeted monitoring and assessment regimes, including quantitative stock assessments. On the other hand, general bycatch and species listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) fall under the Commonwealth Fisheries Bycatch Policy and are generally managed through bycatch and ecological risk management strategies. Monitoring is primarily focused on reporting requirements (e.g. Endangered, Threatened and Protected (ETP) species) and ecological risk assessments (ERA).

The Framework will initially be applied to:

- all quota species
- all non-quota key commercial species
- selected non-quota byproduct species.

Given the different size and scale of fisheries, there is no single approach to the categorisation of species (e.g. into key commercial, byproduct, bycatch species). This should be determined on a fishery-by-fishery basis. Guidance is provided in the HSP and will be used to inform the application of the Framework. With regards to non-quota byproduct species, these will be selected on the basis that they are managed under a harvest strategy and/or a TAC/total allowable effort (TAE) or other form of catch limit and their relative importance to the overall economic performance of a fishery.

2 AFMA Climate Risk Framework for Commonwealth Fisheries

The Framework employs a risk-based assessment approach to identify and integrate climate impacts and uncertainty into formal decision-making processes. The process allows for identification of expected climate-driven impacts on species from readily available information and then determines whether additional measures are required to respond to the identified risk. The approach has been designed to integrate with existing management processes and to utilise tools readily available to fisheries scientists, managers, and industry.

Management refers to the decision-making processes and actions taken to achieve fisheries objectives, typically based on data and advice from scientific advisory bodies.

Science represents the data collection, analysis and research used to understand fish stocks, ecosystems, and the impacts of climate change.

Industry encompasses the commercial fishing operators and related businesses involved in harvesting, processing, and selling seafood.

Climate Risk Framework aims to integrate climate impact considerations into the existing interactions and responsibilities of all three groups.

Figure 1 Relationship between the Climate Risk Framework with Management, Science, and Industry.

The Framework employs a four-step process:

1. Evaluate the overall risk to the species, integrating climate change impacts with the stock's biological status, using the best available information.

2. Identify current science, management or industry measures that offer sufficiently robust responses to the full spectrum of climate change impacts, both positive and negative.

3. Evaluate the impact of response measures identified at Step 2 and determine the residual risk remaining to the species.

4. Where necessary, recommend to the AFMA Commission any additional measures needed to respond to climate change impacts.

The following section provides a detailed overview of each of the steps, including implementation guidance.

2.1 Implementation process

Implementation of the Framework will integrate with existing consultation and advisory group meetings, aligning with decision-making processes, including TAC/TAE advice. For each species, relevant RAGs and MACs, supported by AFMA management, will use the Framework to provide advice to the AFMA Commission. The Framework is established as a guidance process to support decision-making, rather than a rigid set of rules or formal policy. This allows for iterative improvements during initial implementation and as our understanding of climate impacts and adaptive strategies evolves.

AFMA established a Working Group to support the trial implementation of the Framework and provide expert advice to the AFMA Commission and AFMA management on the development, coordination and implementation across AFMA-managed fisheries. This Working Group will assist with ongoing application of the Framework to Commonwealth-managed fisheries, providing expert advice and a consistent approach.

Notwithstanding the oversight provided by the Working Group, RAGs are responsible for completing Step 1 through to Step 4, including providing advice to the AFMA Commission from a scientific perspective. MACs can review the risk ranking established at Step 1 but are largely responsible for validating or adding to the measures identified at Step 2, validating the residual risk ranking at Step 3, and providing advice to the AFMA Commission from a management perspective (see **Figure 2**). It will be the responsibility of AFMA management to consolidate this advice and finalise the Species Assessment Report (example at **Appendix A**) through both groups.

The AFMA Commission will consider the advice, including where there is conflicting advice from the RAG and MAC, and make a final decision.

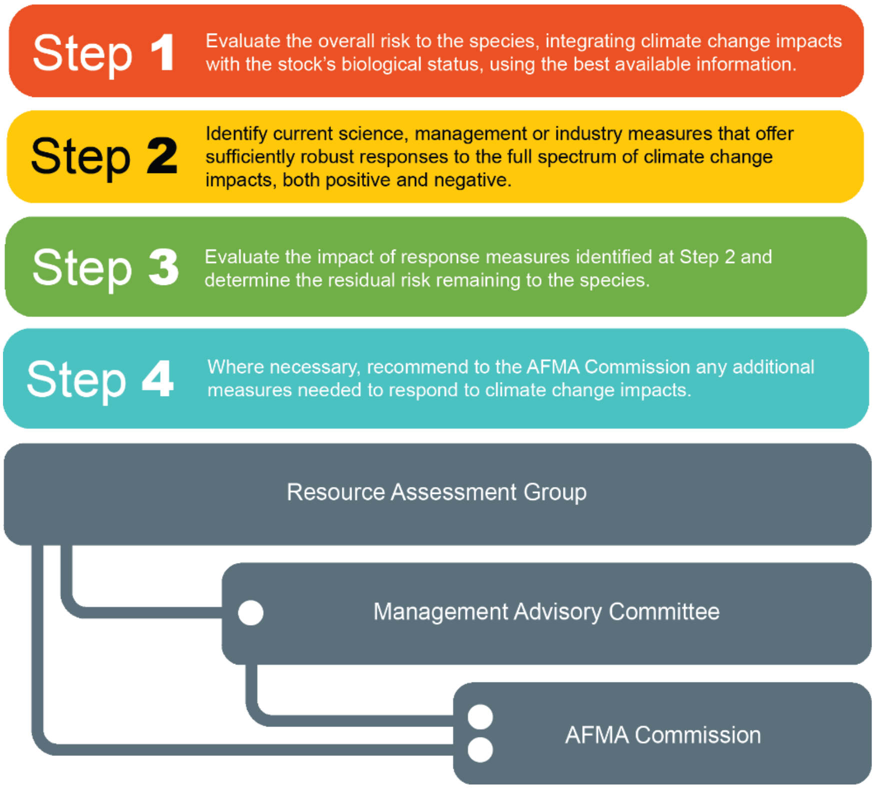

Figure 2 Four-step process, including the role of RAGs, MACs and the AFMA Commission in implementation of the Climate Risk Framework.

Step 1: Assess species risk due to climate impact and stock status

Climate Impact

The RAG, utilising the best available climate information for the species, will undertake an assessment of climate impacts using the criteria set out in **Table 1** below. The RAG should draw upon the most robust information source available for the species, including but not limited to those listed here as categories 1-4.

1. Simulation studies (e.g. attribution or counterfactuals) using single species or complex ecosystem models to explore the effects of climate change. Climate-forced modelling is available for some Commonwealth species. For instance, Fulton et al. (2024) used CSIRO's Atlantis ecosystem simulations to project stock trajectories – with and without climate impacts (counterfactuals) – for key species in the Southern and Eastern Scalefish and Shark Fishery (SESSF). Models of Intermediate Complexity for Ecosystem Assessment (MICE) have been applied in some Commonwealth fisheries (CSIRO n.d.), are also more specifically fit. These robustly fit models have good model skill scores (i.e. have real information content that exceeds what would be gained from a time series alone).

2. Preliminary projections of change in species productivity due to climate change. For example, these are available for most Commonwealth species from the FRDC Project "Guidance on Adaptation of Commonwealth Fisheries management to climate change" (Fulton et al. 2021). These projections come with varying levels of confidence and additional interpretive comments (e.g. likely geographic shifts) for some species. They are based on quantitative models that consider additional factors not

picked up in the sensitivity assessments described below and should be periodically updated to offer the most contemporary understanding of possible climate impacts.

3. Climate sensitivity based on an assessment of life history characteristics is also available for most species in Commonwealth fisheries (Fulton et al. 2021). This information poor assessment provides a climate sensitivity rating of ‘low’, ‘medium’ or ‘high’ for each species following the method of Pecl et al. (2014) applied to all species currently listed in the ERA level 2 productivity-susceptibility analysis for each fishery.

4. Climate and ecosystem indicators are now actively considered as a standing agenda item at most AFMA RAG and MAC meetings when TACs or TAEs are being considered. Climate and Ecosystem Status Reports provide information that is useful in predicting species or stock-specific responses. Although this information cannot be directly used to assign species-specific climate impact scores, it should be considered contextually to support or strengthen the risk assessment. For instance, a species bordering between medium and high risk might be classified in the higher category if it is particularly vulnerable to marine heatwaves and has recently experienced such an event.

Only a few Commonwealth species are likely to have attribution studies or counterfactual simulations available at the stock level, while most species will have preliminary projections and climate sensitivity assessments available to draw upon (though for the most data-poor species this is likely only at an aggregate species group level). AFMA will support the RAG by ensuring the available information for the species of interest is available.

While the short (e.g. heatwaves) and long-term (e.g. sustained warming) climate impacts discussed above primarily relate to changes in biomass over time, climate change can also influence commercial fish stocks through a broader range of mechanisms. These include shifts in species distributions, but also encompass changes in behaviour, ecological interactions, and life-history characteristics such as growth rates, reproductive timing, productivity and migration patterns. Although these factors may not always directly affect stock sustainability, they can have significant implications for fisheries management, particularly when species cross jurisdictional or management boundaries (e.g. State fisheries, marine parks, energy precincts). These broader impacts should be considered when developing adaptation advice and management strategies to ensure responsive and resilient fisheries under changing environmental conditions.

Interpreting Uncertainty in Climate Impact Assessments

Uncertainty in species assessments can arise in various forms, including conflicting evidence from multiple sources despite a large volume of data, high natural variability in species traits or responses to environmental change, or limited or no data, resulting in a lack of understanding of climate impacts.

In the context of Commonwealth fisheries, species climate impact assessments categorised as ‘uncertain’ are generally considered to represent a medium level of climate risk (**Table 1**). This reflects the assumption that some baseline information, such as species distribution and environmental associations, is typically available, even if comprehensive data is lacking. However, in jurisdictions with poorer information bases, the same level of uncertainty may warrant a higher risk classification. Therefore, the interpretation of ‘uncertain’ should be context-specific and informed by the quality and extent of available data.

To ensure transparency, species assessments should explicitly state the nature of the uncertainty and the rationale for assigning a medium (or other) risk level. This clarity supports consistent interpretation and facilitates adaptation planning across different fisheries and jurisdictions.

Stock Status

It is important to understand the most recent estimate of stock status in the context of climate risk. For species that are above their target reference point (TRP), the potential risk of climate change impacting sustainability is assumed to be is lower than that for a species that is near or below their limit reference point (LRP).

Estimates of stock status vary across Commonwealth species and are based on a range of assessment approaches, from robust data-rich methods that provide estimates of spawning biomass and depletion, to data-poor methods that provide estimates of recent fishing mortality but provide no estimate of stock status.

Table 2 provides guidance on how to rank stock status based on a range of assessment methods, grouped here into three categories. The examples provided here (and in **Table 2**) are not considered exhaustive, and RAGs should use their own discretion and expertise when determining how stock status should be characterised at Step 1 where assessment methods or outputs do not reasonably align with the examples provided (examples are derived from NOAA (n.d.), ICES (2012) and Dowling et al. (2016)).

1. Robust assessments (integrated analysis) of fishing mortality (F) and biomass (B) based on fishery-independent and/or fishery-dependent data. The models utilise statistical techniques to match information about age or size classes to assumptions about a stock's birth, growth, and death rates to estimate a stock's current size, harvest rate, and its management status relative to a TRP. These models also provide forecasts of catch and biomass that managers can use to evaluate the risk associated with a range of harvest options.

2. Model or index-based assessment (with trend analysis) providing estimates of F (based on size and/or age data) or trends in relative abundance based on an indicator such as catch-per-unit-effort (CPUE) from fishery-independent (e.g. surveys) or fishery-dependent (e.g. logbooks) data. Trends are analysed over time, including how they respond to various levels of catch, to provide advice on catches that are expected to maintain the index (considered a proxy for biomass) at a preferred level (i.e. TRP).

3. Data-poor or weight of evidence methods are used when there is little to no knowledge of a stock's size or fishery characteristics. Estimates of F might be available, so while they cannot determine the current status of the stock, they can assess whether recent fishing pressure is sustainable. In some instances, the collective outputs of multiple data-poor assessment types can be used in a 'weight of evidence' approach to provide TAC or TAE advice.

Assessment Uncertainty and Trends in Abundance

The precision of stock assessments depends on the quality and quantity of data available, the complexity of the models used, and the inherent variability of the fish population itself. Generally, the risk to a resource increases as fewer data are available due to potential biases in the assessments and slow response times to unexpected declines in resource status (Dichmont et al. 2016).

While species assessed using data-limited methods are inherently at more risk due to uncertainty in the assessment outputs, even those assessed using robust quantitative stock assessments can be uncertain if the assumptions around life-history parameters are erroneous or dated (Evans et al. 2022). Similarly, climate risk assessments will become uncertain (or less reliable) over time unless assumptions about species productivity and climate drivers are reviewed or updated. New climate information will become available (e.g. improved projections of physical environmental change which could modify estimates of future productivity at all levels). This means climate projections for individual species or ecosystem will also age, potentially becoming less reflective of likely future states.

Trends in estimated biomass should also be considered. Two species might have similar estimates of biomass, however, if one has an increasing trend in biomass, and the other a declining trend in biomass, the latter should be considered higher risk. If increased variability is predicted for a species, the risk should be based upon the likely overall trend over time.

The Framework does not propose to incorporate a buffer to account for time-induced uncertainty in stock assessments. However, to ensure a level of risk equivalency at Step 1, the RAGs should use expert judgement (or metrics where available) to determine whether time-induced uncertainty associated with the stock assessment outputs and overall trends in estimated biomass (or proxies) warrant a change to the risk ranking.

Example: Species A is assessed using a quantitative stock assessment that incorporates a long-term time-series of fishery-dependent data and biological information derived from sampling in the early 2000s. The median estimate of stock abundance is 38%B_0 – a decline from 41%B_0 at the time of the last stock assessment[2]. Assuming a target of 48%B_0 this stock would be ranked as 'near target' with regards to stock status (see **Table 2**). However, likelihood profiles suggest a broad range of plausible biomass estimates ranging 28-44%B_0. The declining trend in biomass, dated biological information, and uncertainty around the estimate of current biomass should be taken into consideration when resolving the stock status risk at Step 1. In this instance, the RAG may consider a higher risk ranking more appropriate.

Guidance notes – Step 1

It is the role of the RAG to assess the overall risk to a species from climate impacts (**Table 1**) and stock status (**Table 2**) using the most recent and robust information available. If two equally robust pieces of information indicate different risk rankings, the highest risk ranking should be used.

Using the matrix in **Figure 3**, a preliminary risk score can be determined. These progress from 'Extreme Negative' where a species is below their LRP and highly susceptible to climate change, to 'Extreme Positive' where a species is near virgin biomass levels and expected to benefit from climate change.

[2] Revised in the most recent stock assessment.

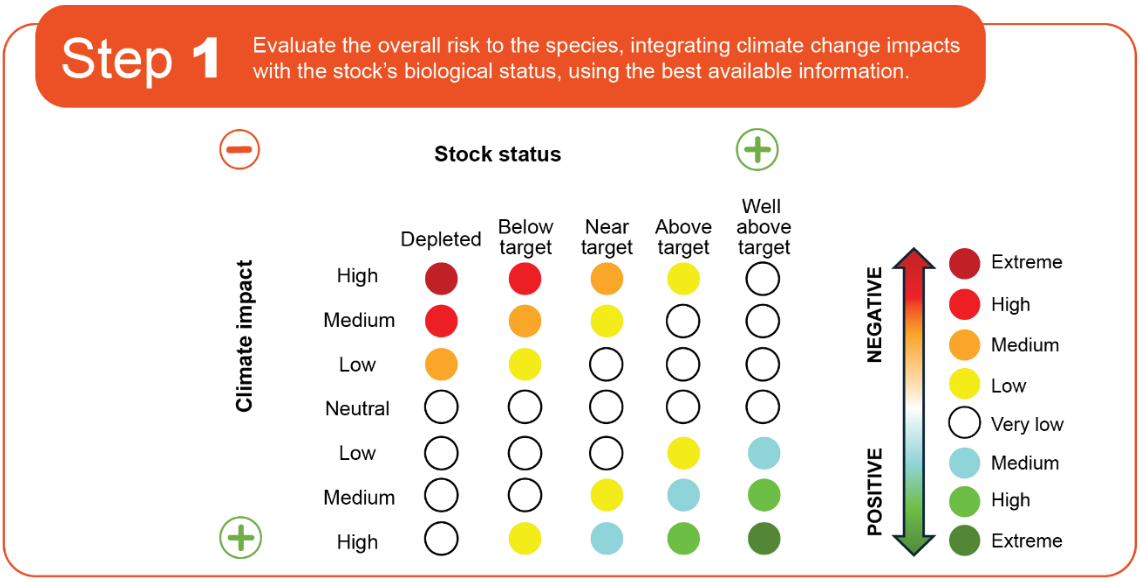

Figure 3 (Step 1) Preliminary risk rankings based on climate risk and stock status risk.

Choosing Reference Points

To ensure the Framework is applied consistently, and drawing on policy guidance under the HSP, where reference points have been determined for a species (e.g. through a formally adopted harvest strategy), these should be used in determining stock status at Step 1. This is because they best reflect the specific objectives of the fishery and in most cases will have been formally tested (e.g. through management strategy evaluation, MSE).

For jointly managed international species, domestic harvest strategies (including reference points) are required where Australia is a major harvester of the stock, and no harvest strategy has been determined internationally. In these cases, the domestic harvest strategy (and associated assessments) should be used to assess stock status. Where Australia is not a major harvester and does not have complementary management for foreign fleets, a domestic harvest strategy would not be effective, and the harvest strategy (and associated assessments) adopted by the relevant regional fisheries body should be used. In cases where reference points have not been adopted internationally, Australia's negotiating position on reference points specific to the species in question should be used.

For data-poor species, species-specific reference points (or assessments) may not be available. In these cases, an expert opinion-based approach weighing up all available lines of evidence regarding a species status should apply – Table 2 provides further guidance.

The reference points and assessments used to assess stock status at Step 1 should be clearly documented in species assessment reports. Where alternative or proxy reference points are used, the justification for doing so should also be documented and supported by expert advice.

Note: Only species with a score of medium or above (positive or negative) need to progress to Step 2. Step 4 must be completed for all species.

Table 1 AFMA Climate Risk Framework - Climate Impact Ranking Criteria. 'Change' can be either positive or negative impacts of climate on a species.

Climate Impact	1. Simulation studies	2. Preliminary projections of change in productivity	3. Climate sensitivity assessment
High	Climate change is the primary driver of stock abundance.	>20% change in productivity by 2040 with medium to high confidence, OR >40% change in productivity with any level confidence.	If projections are not available, where climate sensitivity has been rated high.
Uncertain	Where significant uncertainty exists in available modelling and/or assessments, or both increases and decreases are considered equally possible.		
Medium	Climate change is contributing to changes in stock abundance.	>10-20% change in productivity by 2040 with medium or high confidence, OR >20-40% change in productivity with low confidence.	If projections are not available, where climate sensitivity has been rated medium.
Low	Climate change is only a minor contributor to changes in stock abundance.	>5-10% change in productivity by 2040 with medium or high confidence, OR >5-20% change in productivity with low confidence.	If projections are not available, where climate sensitivity has been rated low.
Neutral	Climate change does not have an influence on the stock.	Change in productivity is up to 5%, regardless of certainty.	

Table 2 AFMA Climate Risk Framework - Stock Status Ranking Criteria.

Stock Status	1. Robust assessments (integrated analyses)	2. Model or index-based assessments (with trend analysis)	3. Data-poor or weight of evidence methods	
Depleted	Stock status is estimated to be at or below the limit reference point (LRP).	Recent relative index of abundance is estimated to be at or below the LRP.	Assessed as high or extreme high risk in the most recent Ecological Risk Assessment (ERA). Available information suggests that the stock is depleted.	**Extreme/ High**
Below Target	Stock status is estimated to be above the LRP, but less than 75% of the Target Reference Point (TRP). E.g. <36%B_0 relative to a B_{48} target.	Recent relative index of abundance is estimated to be above the LRP but less than 75% of the TRP.	Assessed as medium risk in the most recent ERA. Available information suggests the stock is not depleted or biomass is uncertain.	**Medium Risk**
Near Target	Stock status is estimated to be within 25% of the TRP. E.g. Between 36%B_0 and 60%B_0 relative to a B_{48} target.	Recent relative index of abundance is estimated to be within ±25% of the TRP.	Assessed as low risk in the most recent ERA. Available information suggests the stock is sustainable and not subject to overfishing.	**Low Risk**
Above Target	Stock status is estimated to be more than 125% above the TRP. E.g. >60%B_0 relative to a B_{48} target.	Recent relative index of abundance is estimated to be more than 125% but less than 150% of the TRP.	Available information suggests the stock has only been lightly exploited.	
Well Above Target	Biomass is estimated to be within 25% of virgin biomass. E.g. >75%B_0.	Recent relative index of abundance is estimated to be equal to or more than 150% above the TRP.		

Step 2: Identify existing adaptation measures

Once the risk to the stock has been determined, the RAG needs to identify the existing science, management or industry adaptation measures in place. The mechanisms that are available and appropriate will depend on the fishery, species, and the sophistication of the stock assessments, harvest strategy and management arrangements.

The intent of Step 2 is to identify measures that have been taken to respond to the impacts of climate change for a species. Examples are provided here to illustrate how the impact of climate change on a species can be addressed via responses the Framework broadly refers to as 'science', 'management' or 'industry' measures.

There is not always a clear delineation between 'science', 'management' and 'industry' measures, as they are often intrinsically linked. For example, changes to stock assessment parameters (science) will translate to changes in TACs allocated as individual transferable quota (management) which may influence fisher behaviour (industry). The examples are not exhaustive, and in some cases are still being explored as concepts. Others have explored approaches for more directly incorporating climate change impacts, for example in harvest strategies (Bessell-Browne et al. 2025) and in practice, a mix of the three will exist in most fisheries. Responses need not be limited to mechanisms within existing harvest strategies. They may be broad in scope, and if they are clearly articulated and their impacts are well understood, the specific category they fall into becomes less critical.

Importantly, only responses that are expected to offer adaptive capacity should be recorded at Step 2. There is little benefit in listing all management arrangements implemented across the fishery if they are not expected to effectively respond to the impacts of climate change.

While many measures can be expected to effectively respond to climate impacts, it is important to consider the potential risks of 'maladaptive' responses. For example, fishing effort is redistributed due to shifts in stock distribution or the introduction of closures – this may increase the susceptibility of a different life history stage of the species or susceptibility of another species.

In multi-species fisheries with technical interactions (the catch of a mix of species using a single gear type), the adaptation measures implemented for one species, may have effects or implications for other species. For example, closures implemented for one species may also afford protection to other species. In such cases, it may be appropriate to consider adaptation measures and their effect at sub-group, sectoral, or fishery levels. The attribution of effects of adaptation measures to other species should be supported by robust evidence.

Science Measures

Time-varying (or recent estimates of) life history and productivity parameters included in stock assessment models and projections

For example, high or low recruitment scenarios should be used to project future biomass where recruitment deviations show a long-term and consistent trend in recruitment success indicative of a change in productivity. These projections are typically only valid for a short period of time but are a useful way to illustrate the consequence of changes in recruitment and explore options for adjusted TACs.

Linking parameters in stock assessments to environmental variables

For example, using sea surface temperature to adjust assumptions about life history traits like growth can enhance model realism. However, careful consideration must be given to how these changes influence the behaviour of other standard parameter estimates. Importantly, these relationships are not always stable or universally applicable. They should be regularly reviewed, based on current data, and not assumed to hold indefinitely. Environmental influences can shift over time or vary across regions and relying on outdated or overly generalised linkages may introduce bias or reduce model reliability.

Harvest Control Rules (HCRs)

These are pre-determined rules that link the status of the fishery to management actions and typically result in more precautionary management actions if fishery status is low, or opportunistic measures if the fishery status is high. They are expected to account for uncertainties in both the current and prospective future stock status and could include any uncertainties or observed changes that are caused by climate change (e.g. changes in species productivity, spatial distribution, ecosystems or fisheries operations). HCRs are usually selected on the basis of MSE testing.

Management Strategy Evaluation (MSE)

This compares the potential outcomes of alternative management actions across the objectives of management and can include climate scenarios when climate change is agreed to have caused, or is causing, a change. Where climate impacts are unknown, MSE could include evidence from the fishery, or other similar fisheries, to understand the relative chance of the climate effect occurring and the consequences to the fishery if it does occur. These are steps that are common in risk assessments, but they are not often applied to actual or potential climate change effects.

Dynamic reference points and regime shifts

Dynamic reference points and regime shifts can be used to account for changes in stock productivity over time. Shifts in productivity, reflecting non-stationarity in population dynamics, can be addressed by defining stock status (e.g. spawning biomass relative to unfished spawning biomass) using a 'dynamic B_0' approach, where B_0 represents the spawning biomass expected in the absence of fishing under current environmental conditions. This method allows reference points to adapt to changing ecological baselines. However, the implications of adopting a dynamic B_0 approach vary among species, with some experiencing substantial changes in estimated stock status and catch limits, while others show minimal impact. It has been shown that, in many cases, application of dynamic reference points leads to a higher risk because catches can increase even as the estimated unfished biomass declines (Bessell-Browne et al. 2022). Importantly, regime shifts – abrupt, persistent changes in ecosystem structure or function – can fundamentally alter productivity patterns, potentially invalidating historical assumptions. These limitations should be carefully considered when considering a dynamic B_0 approach.

Ecosystem information – providing context for stock assessment processes

This involves providing best available information on ecosystem and environmental properties to set the context for decision-making or for any adjustments to be made to recommendations coming from stock assessments. For example, in years where environmental conditions have been poor (e.g. algal blooms, marine heatwaves or lower levels of primary production) then caution would be advised around any expansion of the fishing footprint or increases in RBCs.

Ecosystem modelling – informing stock assessment processes

This is where outputs from ecosystem modelling are used to modify operational considerations. For example, checking for unintended ecosystem consequences of recommendations coming from stock assessments; or considering driver interactions; or deriving time varying parameter values, reference points or exploitation rates from the ecosystem model (as has been done in a small number of systems in the USA and Scandinavia) and using that to modify what is used by (or comes from) the standard stock assessment process. Or joint climate informed “ecoviability” envelopes that look to find levels of fishing pressure that account for climate influenced productivity, economic and social objectives (as have been calculated for a small number of fisheries in Europe).

Ecosystem model-based indicators

Ecosystem models help incorporate species interactions and environmental dynamics into fisheries management. They can be used to adjust target fishing mortality (F) to reflect food web relationships, ensuring that harvest levels do not destabilize predator-prey balances or broader ecosystem structure.

These models also support cross-checking single-species catch recommendations against ecosystem-level indicators, such as biomass thresholds or the ‘green band’, which represents a range of catch levels considered ecologically sustainable based on modelled ecosystem responses. Comparing proposed catches against the green band helps identify and avoid distortive pressures on ecosystem composition and function. This approach supports more ecologically aligned decision-making, particularly in multi-species fisheries like the SESSF.

Monitoring and research

While these efforts alone will not reduce on-the-water risk to a species, they can provide fisheries scientists (and managers) with further insight to reduce uncertainty and understand risk, which then enables more tangible actions to be taken. For some species, particularly those ranked as very low, low or medium risk, promoting monitoring and research may be a sufficient response to climate risk in the short-term. However, it cannot be used to reduce risk unless other measures are also in place.

For species with less sophisticated stock assessments, or no assessment at all, the RAG may choose to use less technical options to assess climate risk. These are likely to be case-specific but could include ‘borrowing’ biological attributes from species with similar life-history characteristics (e.g. in ERAs) or applying generic discounts (buffers) to assessment outputs.

Management Measures

The management measures available will also depend on the size and complexity of the fishery. In small single-species fisheries, targeted measures like closures or gear restrictions are likely to be effective adaptation options. However, in larger and more complex fisheries, particularly multi-species and multi-gear fisheries, technical interactions may render similar options ineffective or undesirable. Positive climate impacts may not be able to be realised in multi-species fisheries with clear technical interactions.

The management responses listed here are not exhaustive and will be more applicable in some fisheries than others.

Catch limits

These can be adjusted to control total mortality of a species, depending on the risk profile. Catch limits are typically derived from outputs of a stock assessment or surveys followed by application of a harvest strategy and are sometimes subject to discount factors or buffers that account for uncertainty or risk. In some cases, particularly in multi-species fisheries, they can be further adjusted to minimise unintended catch of associated bycatch species.

Spatial/temporal closures

Typically designed to control catches of at-risk species by preventing fishing in an area, either permanently or at certain times of the year. While closures are particularly effective for sessile species like scallops, they can also be targeted temporally and spatially to protect vulnerable age-classes of mobile or migratory species, such as juveniles or older spawning fish. Changes in zoning, or other reductions in fishing footprint as a result of other users of the marine estate (e.g. wind farm exclusion zones) should also be considered as they may indirectly benefit some species. Managers should consider modifying closure boundaries as risk profiles change, or as shifts in distribution become apparent.

Flexible season dates

Allows for key biological processes to occur undisturbed by fishing activity (e.g. spawning prawn migration from estuaries to the ocean) or to align with expected aggregations and promote catching efficiency (e.g. orange roughy on seamounts). Flexible season dates allow industry to adapt to climate-driven changes in the fishery.

Gear modification

Gear modification can include amendments to existing gear to improve selectivity (e.g. increase mesh size) or the addition of exclusion devices to prevent capture of vulnerable species (e.g. turtle exclusion devices). Gear modification may be an effective solution if climate change is known to impact a particular species or age-class.

Buffers

Buffers may be considered an appropriate option to adjust the TAC or TAE for a stock where the risk or uncertainty has not been sufficiently dealt with elsewhere. The RAG and MAC should use their expert judgment to recommend the size of the buffer, with consideration for the following factors:

- the expected climate impacts and stock status of the species
- the role of the species in the ecosystem and fishery
- other discounts already included in the development of the RBC
- other adaptation measure in the management of the fishery (e.g. spatial closures).

There are often a mix of management controls in place for each fishery. Some are species-specific, while others are broader. The RAG and MAC should take note of the various measures in place and determine the cumulative benefits to the species.

Industry Adaptation Measures

While governments and natural resource managers consider climatic changes, many marine-dependent individuals, organisations, and user-groups in fast-changing regions of the world are already adjusting their behaviour to accommodate these (Pecl et al. 2019). The fishing industry is constantly adapting to change – market demands, operational challenges, legislative reform, technology advancements, and certainly, climate change. Some examples are provided here to illustrate how industry could adapt to climate-driven impacts in the fishery and would be considered voluntary (i.e. not enforced by management).

Regional catch limits

Can be agreed across a fleet to allow for vulnerable populations to rebuild. While catch could be taken equally across the species distribution, industry may agree to constrain catches in some areas of the fishery without the need for formal closures or catch limits.

Gear modification

Can be an effective way of excluding non-target species or age-classes that are particularly vulnerable to climate change. These may be adopted across an entire fleet (e.g. increased mesh size) or used only by operators that work in certain parts of the fishery.

Changes to fishing effort

This can take many forms. Redistribution of effort across the area of the fishery is likely to occur as stocks shift in response to changed oceanic conditions. Industry may fish less days, or fish longer/harder on some days, if severe weather conditions mean there are less days when it is safe to fish.

Data collection programs

These are becoming more prevalent in Australia as the fishing industry and management agencies establish co-management agreements. While this typically involves collecting traditional biological data to support stock assessments (e.g. length and age) it could also include routine collection of environmental data to support ecosystem modelling and forecasting (Souza et al. 2023).

Switching target species

This may occur in response to a change in a stock’s size or distribution. This may occur via a change in the species mix rather than complete species shifts.

Guidance notes – Step 2

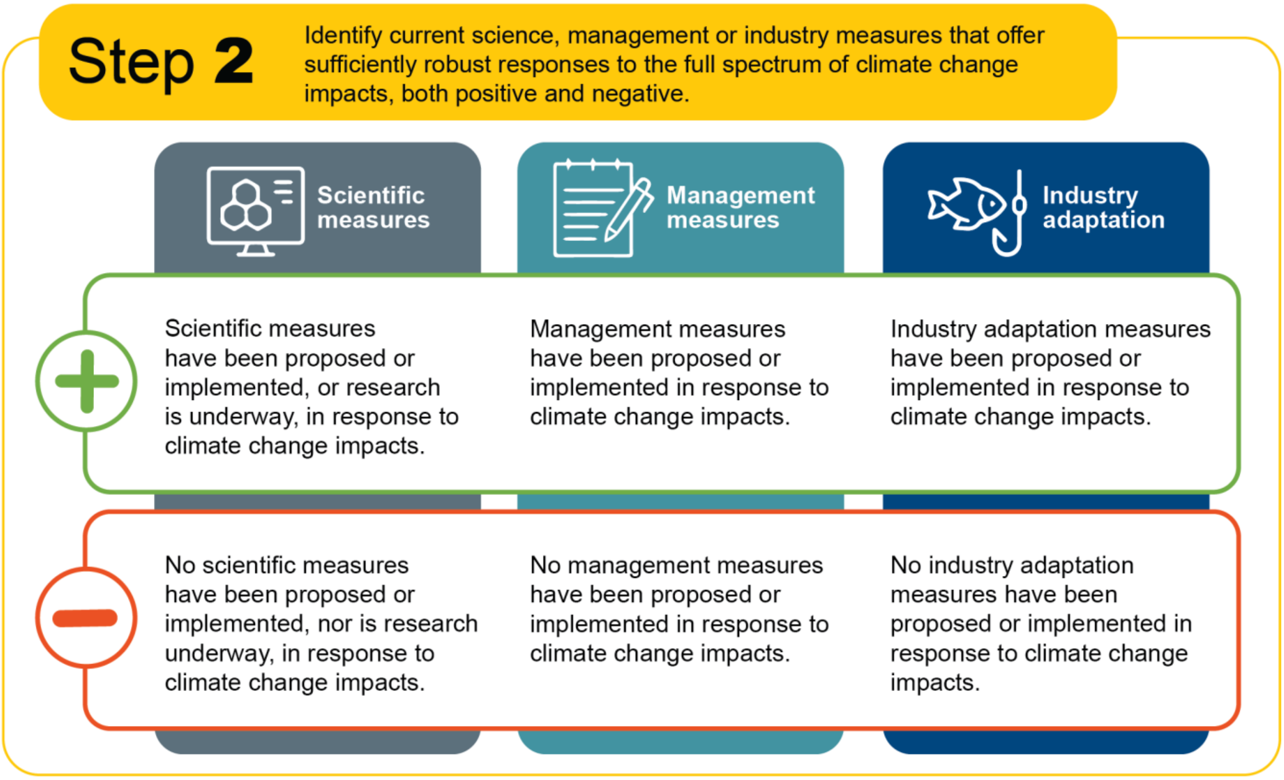

Figure 4 (Step 2) Review of existing science, management and industry adaptation.

The RAG should record the measures identified and how they are expected to translate to a change in risk for each species. Measures identified in Step 2 should be limited to those that: a) directly respond to climate-related impacts, and/or b) enable detection of changes in risk profiles over time, including through planned future work.

It is important to avoid listing all existing management arrangements within a fishery unless they are directly relevant. Only include measures that meaningfully reduce or influence the assessed climate risk.

While the Framework maintains a single-species approach for initial risk assessments, adaptation options and recommendations may be developed at broader levels, such as sub-group, sectoral, or fishery levels, where appropriate. This allows for holistic and practical management responses, especially in cases where species share ecological functions or are managed collectively.

In situations where data for a functional group or basket of species is limited, a representative species may be selected to inform the broader group's adaptation strategy. The selection of a representative species should be based on criteria such as ecological relevance, data availability, and its role within the fishery or ecosystem. Selection of representative species should be consistent with species selected for a multi-species harvest strategy if one exists and should be periodically reviewed as ecosystem structure/composition may shift through time given changing conditions.

It is essential to clearly define how species are grouped and the rationale behind these groupings. For example, if two species are part of a demersal fishery with similar ecological roles and exposure to climate risks, adaptation recommendations may be developed for the group rather than individually. This approach ensures that adaptation planning and implementation remains both scientifically grounded and operationally feasible.

Step 3: Determine the residual risk

Residual risk refers to the level of climate-related risk that remains after adaptation measures have been implemented. These measures, identified in Step 2, are considered the treatment and may include scientific research, management interventions, or industry-led adaptations. Residual risk should be evaluated based on the expected change in stock status or climate vulnerability resulting from the implementation of these measures. It reflects the potential future state of the stock, assuming the treatment is effective.

Only those measures that are likely to directly influence biomass or reduce climate vulnerability should be considered when estimating residual risk. This ensures the assessment remains focused and evidence-based. To guide this evaluation, assessors should ask: "To what extent are the measures identified in Step 2 expected to reduce climate vulnerability and/or change the biomass, thereby lowering the overall risk?"

This question helps ensure that residual risk scores are grounded in realistic expectations of the effectiveness of proposed actions. To see how AFMA applied residual risk processes elsewhere, refer to Fisheries Management Paper 14 - AFMA's Approach to Ecological Risk Assessments and Management.

Where new information becomes available, for example revised estimates of stock status or climate vulnerability, this should be incorporated as changes to the Step 1 risk score, not as part of the residual risk assessment.

Table 3 offers guidance on how residual risk scores should be derived. The types of responses required at each residual risk score are also provided to assist with formulation of next steps and advice to the AFMA Commission (Step 4).

Table 3 Guidance to establish residual risk scores and next steps.

Residual Risk	Negative	Positive
Extreme	**The species is highly vulnerable to climate change and expected to remain or continue to fall further below the limit reference point.**	**The species will likely benefit from climate change and remain, or increase to, well above the target reference point.**
	For depleted species, management actions outlined in the harvest strategy will be implemented before the next fishing season. Over the following 12 months, additional adaptation measures will be developed to support long-term, climate-responsive, and data informed strategies - including for species with positive impacts.	
High	**The stock remains vulnerable to climate change and will either remain below, or rebuild above, the limit reference point.**	**The stock is expected to benefit from climate change and either remain at, or increase to, above the target reference point.**
	For depleted species, management actions outlined in the harvest strategy will be implemented before the next fishing season. Over the following 24 months, additional adaptation measures will be developed to support long-term, climate-responsive, and data informed strategies - including for species with positive impacts.	
Medium	**The species may still be vulnerable to climate change. Current management measures are expected to maintain the stock at, or promote recovery towards, the target reference point.**	**The species may still benefit from climate change. Current management measures are expected to maintain the stock at, or return it towards, the target reference point.**
	Monitoring and data collection programs should be reviewed to ensure they are capable of detecting changes in risk profiles, including climate-driven changes in stock status or distribution.	
Low	**Climate change is not expected to have an immediate impact on this species.** No response is needed beyond periodically reviewing existing monitoring and data collection programs.	
Very low	**Climate change is not expected to have long-term impact on this species.** No response is required.	

Guidance Notes – Step 3

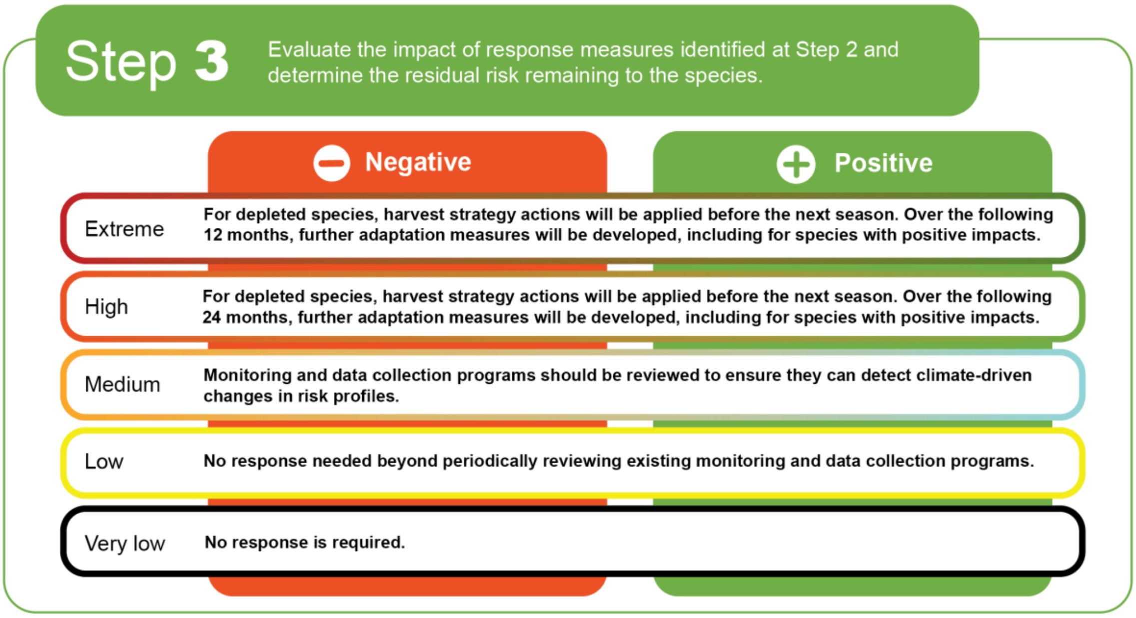

Figure 5 (Step 3) Residual risk analysis rankings and associated guidance for Step 4.

The residual risk score should be supported by data or modelling where it is available. There must be sufficient detail about how the measures identified at Step 2 are expected to respond to the impacts of climate change. A detailed justification for each of the proposed measures will build confidence and facilitate informed decision-making by the AFMA Commission.

In some instances, it might be the case that research is underway, or measures have been proposed but are not yet implemented. In this case, the risk has not actually been treated, so the residual risk should remain the same. If there are no measures identified in Step 2 that reduce the risk for a species, the original risk ranking will remain the same.

Step 4: Provide advice to the AFMA Commission

The RAG and MAC must provide advice to the AFMA Commission for each species to conclude the process. The advice can be simple for species assessed as low or very low risk at Step 1 and conclude that no additional measures are required. For species with higher risk rankings, advice to the AFMA Commission will be more detailed. In providing their advice, RAGs and MACs need to demonstrate and clearly articulate the reasons for that advice.

Guidance notes – Step 4

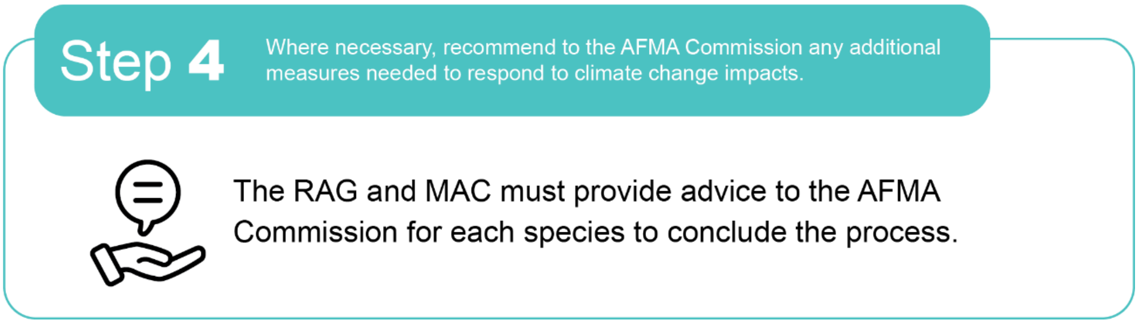

Figure 6 (Step 4) Providing advice to the AFMA Commission

A risk ranking of ‘low’ or ‘very low’ does not preclude the RAG or MAC from providing advice about adaptative responses, particularly where they are designed to reduce uncertainty or future-proof the fishery. This might include additional data collection or more frequent review of fishery indicators.

For any species with a residual risk ranking of ‘medium’ or higher, the RAG and MAC must provide advice to the AFMA Commission regarding additional adaptive responses to respond to climate risks (see **Table 3** for guidance).

For species with an ‘extreme’ or ‘high’ risk ranking, particularly where the risk is associated with climate drivers, these should be tangible measures beyond application of the harvest strategy that are expected to respond to climate impacts.

The intent of the Framework is to identify proportionate adaptation responses in response to climate-driven impacts on species. Some will be short-term measures, such as TAC reductions, while others will be longer-term, such as incorporating environmental variability into stock assessments.

Table 3 provides indicative guidance on the timeliness of management intervention when advising the AFMA Commission. For species assessed as ‘extreme’ or ‘high’ risk, the suggested 12- and 24-month timeframes are not rigid deadlines, but rather reflect the urgency implied by the risk scores. They are intended to guide the development of adaptation strategies that are commensurate with the level of risk, not to prescribe immediate implementation of all measures.

In many cases, the appropriate response may be the development of a longer-term adaptation strategy, rather than the full execution of all actions within the suggested timeframe. This allows for a phased and pragmatic approach, which may include:

- Immediate actions: Adjustments to stock assessments or short-term measures such as changes to TACs or TAEs.
- Medium-term actions: Measures that may be initiated or planned within a reasonable timeframe (e.g. 12–24 months), such as spatial closures, gear modifications, or structural changes to management.

This approach balances the need to respond to elevated risk with the practicalities of implementing effective, science-based interventions. It also ensures space for consultation, data validation, and alignment with broader management strategies.

An example is provided at **Appendix A** to demonstrate how Steps 1-4 should be recorded for each species.

Cross-Jurisdictional Considerations

When a stock is shared across jurisdictions, within or beyond Australia, it is important to consider the relative contributions and responsibilities of each party in managing climate-related risks. If another jurisdiction has a greater share of the catch or fewer adaptation measures in place, the Commonwealth should not be expected to carry a disproportionate burden in responding to the risk. It will seek to provide information to these other jurisdictions on relevant species.

Management responses should reflect the scale of impact and level of intervention across jurisdictions. Collaborative approaches are encouraged, but fairness and proportionality must guide decisions to ensure that all jurisdictions contribute appropriately to adaptation efforts.

2.2 Review periods

Species assessments

The risk score for a species will only change if: a) new information becomes available regarding climate impacts, b) new information becomes available regarding a species stock status, or c) additional adaptation measures are implemented. Notwithstanding inter-annual variability from extreme events, climate impacts are expected to have an impact over the medium term so there is less imperative for annual updates to the risk assessment. Species assessments will be updated subject to the following annual considerations:

Since the last Framework assessment:

- Is there any new information regarding climate impacts or stock status, including extreme events that would undermine previous assessments?
- Have there been any changes to science, management or industry arrangements that would change the risk score?

An annual meeting of the Working Group will be held to consider these questions across all species. A standing agenda item will then be included at RAG meetings to validate the outcomes. If the answer to either of these questions is yes, a reassessment should be undertaken. Otherwise, the reassessment can be postponed for a further 12 months. All decisions regarding reassessment scheduling should be documented, including the rationale. This documentation should be publicly accessible, where appropriate, to ensure transparency and accountability (e.g. RAG meeting minutes). AFMA will maintain a schedule of planned assessments.

The reassessment schedule should allow for flexibility to address region-specific vulnerabilities. For example, regions experiencing rapid warming or increased extreme weather events may require more frequent reassessments.

Framework Review

The legislative, policy and harvest strategy frameworks that underpin the management of a fishery are usually subject to gradual change. Accordingly, the Framework will undergo a performance review every five years. The scope and overall review approach will be constrained to a high-level review of the key components of the Framework, how it has been applied over time, and the extent to which climate adaptation responses have been effectively implemented.

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Appendix A

Species Assessment Report (Example)

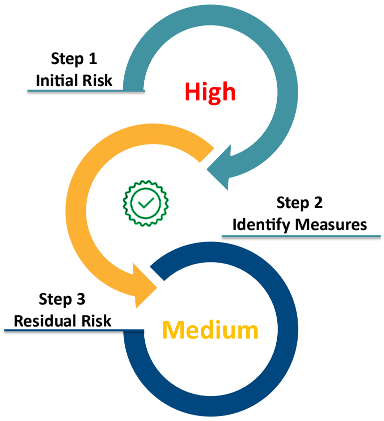
Note: References are not included in the example provided here

Common Name: Southern Jumbo Squid

Species Name: *Dominicus australis*

Fishery: East Australian Squid Jig Fishery

Stock Assessment: Sverre (2022)



Step 1: Evaluate the overall risk to the species, integrating climate change impacts with the stock's biological status, using the best available information.

Climate Risk – High (Category 1 – See **Table 1**)

Atlantis modelling (Category 1) indicates that climate change is a primary driver of stock depletion.

Preliminary projections (Category 2) indicate up to 20% decline in biomass by 2040 with high certainty. Biomass trajectories are based on a combinations of species distribution models and various ecosystem models, coupled with modelled trajectories of climate change (temperature, pH, oxygen, salinity, rainfall) and extreme events.

Climate and ecosystem indicators

Global trends

- Sea surface temperatures (SSTs) in 2024 have been among the warmest on record, with June 2024 marking the 12th consecutive month of global SSTs reaching 1.5°C above pre-industrial levels.
- The El Niño-Southern Oscillation (ENSO) Outlook in September is at La Niña Watch, meaning there are some signs that a La Niña may form in the Pacific Ocean later in 2024. 3 of 7 climate models suggest the possibility of SSTs in the tropical Pacific exceeding the La Niña threshold (below −0.8 °C) from October, with the remaining 4 models suggesting ENSO-neutral values (between -0.8°C to +0.8°C) throughout the forecast period.

Fishery trends

- Accumulated stress is already playing out – there has been some recovery from summer heat, but seasonal stress will still be high. Body conditioning, gonad development etc may be impacted.
- No mortality events, but growth and production likely impacted (and catchability).
- In 2024, the southern region of the fishery had lower than average chlorophyll-a.

Stock Status – Below target (Category 1 – See **Table 2**)

The 2024 stock assessment estimates the 2025 spawning biomass will be 28%B_0. This is a decrease from the 2021 stock assessment estimate of 31%B_0. Sensitivity tests resulted in spawning biomass ranging 19%B_0 to 36%B_0.

Overall risk – High (See **Figure 3**)

The combination of a 'below target' stock status with a 'high' risk score for climate impacts results in an overall risk score of 'high'. The East Australian Resource Assessment Group (EARAG) noted a decline in biomass since the last stock assessment, and that sensitivities provide for a potential biomass below the 20%B_0 limit reference point.

Step 2: Identify current science, management or industry measures that offer sufficiently robust responses to the full spectrum of climate change impacts, both positive and negative.

Science

Stock Assessment

- EARAG (2024) agreed to project low recruitment (from 2023 onwards) in the 2024 base case, on the basis that recruitment has been below average for the last 14 years in which it was estimated (2006-2019). The spawning stock biomass at the start of 2025 was estimated to be 28%B_0, compared to 33%B_0 if average recruitment had been used to project future biomass.
- The 2025 Recommended Biological Catch (RBC) from the low recruitment scenario was 346 t, compared to 521 t from the average recruitment scenario.
- The model estimates, using the low recruitment scenario, that the stock will rebuild to approximately 34%B_0 by 2028.
- A risk-cost-catch analysis, using the RBCs from the long-term average recruitment scenario in a low recruitment model, estimates that the stock will fall below the limit reference point by 2031 if the RBCs continue to be fully caught.

Future Work

The increasing acidification of ocean waters, driven by elevated atmospheric CO_2 levels, is impairing the sensory capabilities of juvenile Southern Jumbo Squid. Juveniles rely heavily on olfactory cues to locate suitable habitats and avoid predators. As pH levels drop, their ability to detect chemical signals becomes compromised, leading to higher mortality rates during early life stages and reduced recruitment success. This sensory disruption is emerging as a critical factor in the species' declining population resilience.

A project has been proposed to understand, predict and respond to the persistent low recruitment of the Southern Jumbo Squid. The project proposes an enhanced monitoring and modelling program focused on early life stages. By expanding larval and juvenile surveys across key spawning and nursery habitats, high-resolution data on abundance, growth, and survival will be collected. These biological observations will be paired with environmental measurements, such as temperature, pH, and current dynamics, to identify the conditions most strongly associated with recruitment success or failure. This integrated approach will improve our ability to detect early warning signs of recruitment collapse and guide timely management responses.

In parallel, the project will develop predictive models that incorporate these environmental drivers to forecast recruitment under various climate and fishing scenarios. Using statistical and machine learning techniques, the models will simulate how changes in ocean chemistry and circulation patterns, particularly those linked to the East Australian Current, affect juvenile survival and stock replenishment. The resulting tools will support adaptive fisheries management by providing scenario-based forecasts and real-time decision support, helping to safeguard the long-term sustainability of the fishery.

Management

The Southern Jumbo Squid is primarily taken as byproduct when targeting Arrow Squid on the east coast of Australia. EARAG (2024) considered a companion species analysis which investigated the link between target species catch and the associated level of unavoidable take of Southern Jumbo Squid, incorporating a range of factors such as area, depth fished and gear type – also known as métiers.

Using logbook data from 2022 and 2023 and expected 2025-26 Total Allowable Catches (TACs) for the main companion species (mostly Arrow Squid; 1,621 t), the estimated unavoidable bycatch of Southern Jumbo Squid for 2025 ranged between 436-482 t, depending on assumed catches of Arrow Squid. This exceeds the level of mortality expected to allow recovery of the stock.

Noting the expected level of unavoidable bycatch, EARAG propose reducing the Arrow Squid TAC from 1,621 t to 1,265 t for the 2025-26 fishing season, a reduction of 356 t from the 2024-25 TAC.

Industry

No industry measures are currently proposed.

Step 3: Evaluate the impact of response measures identified at Step 2 and determine the residual risk remaining to the species.

Residual Risk Score: High

1. **Stock status is likely to remain below the threshold even with reduced catch**

- The projected spawning biomass rebuilds to ~34%B_0 by 2028 does not meet the 36%B_0 threshold required to downgrade the risk from 'high' to 'medium'.
- There is too much uncertainty associated with projections beyond 2028 to establish a robust estimate of stock status relative to the 36%B_0 threshold.
- Sensitivity analyses indicate a realistic risk of spawning biomass falling below the 20%B_0 limit reference point, reinforcing the need for caution.

2. **Climate impact score remains high**

- The current climate risk score is 'high', supported by Atlantis modelling identifying climate change as a primary driver of depletion.
- Projections of 20% biomass decline by 2040 under climate stressors.
- Ongoing ocean acidification is likely to continue impairing juvenile survival and recruitment.
- No outputs yet from the proposed research that would justify a reduction in the climate impact score.

Until such time as either the stock status improves beyond the 36%B_0 threshold, or projections become certain enough to demonstrate a high chance of rebuilding to that level, or the climate risk score is revised downward based on new evidence, the residual risk remains 'high'.

Step 4: Where necessary, recommend to the AFMA Commission any additional measures needed to respond to climate change impacts.

While the Southern Jumbo Squid stock remains vulnerable to climate change, it is currently assessed to be above the limit reference point. Projections indicate that the stock will rebuild towards the target reference point if catch levels are constrained.

Immediate actions (pre-2025-26 fishing season):

- Constrain the TAC for Arrow Squid to 1,265 t for the 2025-26 fishing season. This level is expected to limit unavoidable catch of Southern Jumbo Squid to around 346 t, which is expected to support stock rebuilding.

Medium term strategies (next 24 months):

- Develop and implement additional climate-responsive and data-informed adaptation measures, including:
    - Enhanced monitoring of early life stages and recruitment success.
    - Integration of environmental drivers (e.g. temperature, pH, current dynamics) into predictive models.
    - Scenario-based tools to support adaptive management under evolving climate conditions.

Appendix B – Working Group Expertise

Dr David Smith is a marine systems scientist with extensive experience in fisheries management, interpreting modelling, and policy integration. He served as a Commissioner of the Australian Fisheries Management Authority (AFMA) from 2011 to 2020, contributing to strategic oversight and governance during a period of reform and innovation. He was a Research Director at CSIRO and one of the originators of the Centre for Marine Socioecology at the University of Tasmania. Dr Smith focuses on governance frameworks that support resilient, climate-adaptive marine systems. His work integrates ecological, economic, and social dimensions to inform risk-based decision-making and sustainable harvest strategies. He has contributed to national and international fisheries policy, with a strong emphasis on stakeholder engagement and adaptive management. On the Expert Working Group, Dr Smith brings deep expertise in institutional design and systems thinking, helping ensure climate risks are embedded in fisheries decision-making and aligned with long-term sustainability goals.

Dr Keith Sainsbury is a marine ecologist and modeller with over four decades of experience in ecosystem-based fisheries science. He led major CSIRO programs on sustainable fisheries and served as an AFMA Commissioner from 2004 to 2020, contributing to governance and policy development. He was a member of the Board of the Marine Stewardship Council from 2002 to 2014, was vice-chair of the Board from 2005 to 2014 and has been a member of the MSC Technical advisory body since 2001. His research spans ecological risk assessment, marine protected area design, and the integration of ecosystem principles into fisheries management. Dr Sainsbury has advised national and international bodies on fishery assessment, precautionary and ecosystem-based approaches, and his work has informed reforms in regional fisheries governance. He brings a deep understanding of fishery management, ecological dynamics and risk-based decision-making to the Expert Working Group. His contributions support the integration of climate risk into harvest strategies and management frameworks, ensuring that fisheries remain responsive to environmental change and resilient over time.

Dr Alistair Hobday is a Chief Research Scientist at CSIRO in the Sustainable Marine Futures Program. His research focuses on climate change impacts, marine ecology, and fisheries adaptation. He has developed forecasting tools for marine heatwaves and species distribution shifts and co-developed the Ecological Risk Assessment for the Effects of Fishing (ERAEF), now used internationally. Dr Hobday’s work supports climate-responsive fisheries management through practical, science-based tools that inform harvest strategies and ecological assessments. He has contributed to national and global efforts to align fisheries policy with emerging climate risks, and his research integrates oceanography, conservation planning, and socioecological systems. On the Expert Working Group, Dr Hobday brings expertise in adaptive management and climate risk integration, helping ensure that fisheries decision-making is informed by the best available science and responsive to changing ocean conditions.

Dr Beth Fulton is a Chief Research Scientist and Domain Leader for Integrated Ocean Stewardship at the CSIRO. She specialises in whole-of-system modelling, integrating ecological, economic, and social dimensions to support sustainable marine management, climate adaptation and the blue economy. Her Atlantis ecosystem modelling framework is used globally to inform fisheries and ecosystem policy, and her research has supported decision-making for national and international bodies. Dr Fulton’s work focuses on building resilience in marine systems through scenario testing, stakeholder engagement, and climate adaptation planning. She brings a systems-based approach to understanding marine ecosystems and the pressures they face. On the Expert Working Group, Dr Fulton contributes expertise in socioecological modelling and integrated assessment, helping ensure that climate risk is addressed holistically in fisheries management and that strategies are grounded in a robust understanding of ecosystem complexity.

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