Australian Government
Australian Fisheries Management Authority

# Climate Risk Framework

## Integrating climate risk in decision-making

**Securing Australia's fishing future**

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# Executive summary

The impact of climate change on Commonwealth fisheries is becoming increasingly evident. The effects of climate change on marine ecosystems are accelerating 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 could be rendered invalid[1].

AFMA has developed the Climate Risk Framework (the Framework) to integrate climate risk into management decisions for Commonwealth-managed species/stocks (herein referred to as species). The framework is based on a risk assessment approach, similar to that which has been utilised in other fisheries internationally to integrate ecosystem and environmental considerations and uncertainty into existing management frameworks.

The Framework involves a four-step process that seeks to:

1. Assess the overall risk to a species based on the impacts of climate change and the biological status of the stock using the best available information,

2. Consider whether there are sufficiently precautionary measures in the existing science, management or industry adaptation pathways to respond to the impacts of climate change,

3. Assess the residual risk to a species, and where required

4. Provide advice to the AFMA Commission on any additional measures required to respond to the impacts of climate change.

The Framework is structured to ensure risks and appropriate adaptation measures are considered on an annual basis, with a view to 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. It is intended as a transitional mechanism, to enable rapid integration of climate risk into decision-making processes until such time as climate impacts are more explicitly integrated into science and management processes, such as harvest strategies, stock assessments or Ecological Risk Assessments (ERAs). For data-poor species, the Framework will likely remain an appropriate tool to assess and respond to the impacts of climate change into the future.



[1] Duplisea DE, Roux MJ, Hunter KL, Rice J (2021) Fish harvesting advice under climate change: A risk-equivalent empirical approach. PLOS ONE 16(2): e0239503. https://doi.org/10.1371/journal.pone.0239503

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| 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 |

# 1 Introduction

Climate change is already impacting Australia's marine ecosystems and fisheries in a range of complex ways. Australian waters are becoming warmer and more acidic, sea-levels are rising, major ocean currents are changing, and extreme weather events are becoming more severe. The effects of climate change on marine ecosystems are accelerating 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 could be rendered invalid (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 Harvest Strategy Policy (HSP) and HSP Implementation Guidelines (the Guidelines) recognise that non-fishery effects can see species abundance 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.

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.*

To ensure that these objectives continue to be met, AFMA has initiated a dedicated program focused on incorporating climate change information and potential risks into our decision-making processes. By doing so, we aim to make fisheries management more adaptable to the evolving marine environment.

## 1.1 Impacts of climate change on Commonwealth Fisheries

An increasing amount of information, research and data is available on the sensitivity of fish stocks to climate change and associated impacts on current and future stock status. This information is being considered by AFMAs Resource Assessment Groups (RAGs), Management Advisory Committees (MACs) and managers when providing advice and making management decisions for Commonwealth-managed species and stocks (herein generally referred to as 'species').

Climate and Ecosystem Status Reports are available for key fisheries, drawing upon readily accessible climatic and environmental data and trends. The first iterations of these reports are relatively high level, containing hindcast and forecasts derived from information such as sea surface temperature, El Nino Southern Oscillation (ENSO) cycle status, water chemistry and fishers' observations. These reports are still in their infancy in terms of development and use in Commonwealth fisheries, however as the indicators are refined and their relevance and influence on stock abundance and distribution is better understood, these will also provide an insight into climate impacts and risks for some stocks.

Over time, the Climate and Ecosystem Status Reports could evolve to include more sophisticated population and environmental indicators of climate-influence. Several Australian researchers have been leaders in the field of identifying ecosystem indicators and have close connections with US and EU groups who are applying indicators in this way. Lessons gained from that network suggest it is a useful framework which can be adapted to Australian conditions and refined through time, as has occurred elsewhere.

Potential indicators that could be considered in the future, to provide more sophisticated insight into climatic impacts and ecosystem shifts, can be found in the Alaska Marine Ecosystem Status Reports and in a list proposed by the National Oceanic and Atmospheric Administration (NOAA) for US fisheries in Link, et al., 2021.

Ideally the influence of climate and ecosystem factors on stocks would be integrated quantitatively into stock assessments and harvest strategies, so that they would directly influence Recommended Biological Catches (RBCs). However, many of these approaches are complex and unlikely to be implemented in the near-term. A fully quantitative integration may also not be necessary, possible, or cost effective for many species.

## 1.2 A transitional mechanism to integrate climate risk and impact

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 the exercise of the precautionary principle. The precautionary principle requires AFMA to address uncertainty and account for known risk, and potential risks, in decision making[2].

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

While climate and ecosystem status reports provide valuable contextual information, AFMA must ensure that climate and ecosystem risks 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 (see Dorn and Zador 2020) is being utilised in Alaskan groundfish fisheries to support TAC decision making in the North Pacific Fisheries Management Council (NPFMC). In these fisheries, 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

[2] OECD Joint Working Party on Trade and Environment (2002) *Uncertainty and Precaution: Implications for Trade and Environment*, OECD, September.

biological catch' due to ecosystem/environment concerns (including climate impacts). The use of this 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 to assess the risk to Commonwealth-managed species from climate change utilising existing information, and then respond to or mitigate that risk using the tools that are available within the existing scientific, management and industry adaptation pathways. While this might be considered a transitional mechanism for some species as the science evolves and more sophisticated approaches are developed, it will likely remain an appropriate measure for many data poor species into the future.

Development of the Climate Risk Framework has been an iterative process, including trial application in several AFMA-managed fisheries during early development. Ongoing development and refinement will continue to be a focus as more information becomes available and the utility of the framework becomes apparent. This current version will continue to be used on a trial basis throughout 2024. A trial report is scheduled for early 2025 to include a review of the trial process, and recommendations for future implementation (Figure 1).

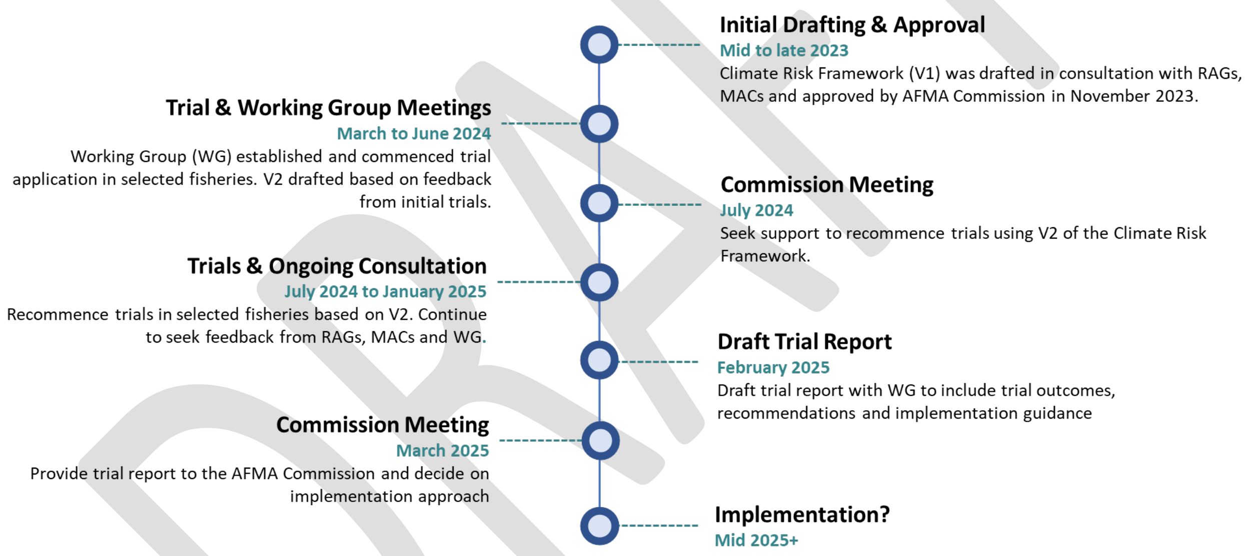



**Figure 1 Development timeline for AFMA's Climate Risk Framework**

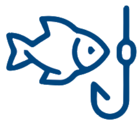
# 2 AFMA Climate Risk Framework for Commonwealth Fisheries

The Climate Risk Framework employs a risk-based assessment approach to identify and integrate climate impacts and uncertainty into formal decision-making processes. The process allows for rapid identification of expected climate-driven changes in productivity using readily available information, and then determine whether additional measures are required to respond to the identified change. The approach has been adapted to integrate with existing management processes (Figure 2) and utilise tools already available to fisheries scientists, managers, and industry.

Figure 2 Linkages between the Climate Risk Framework, Science and Research, Management & Regulation and Commercial Fishing Industry

**Climate Risk Framework**
The Climate Risk Framework is intended to integrate with and utilise the existing measures within the science, management and industry adaptation pathways to mitigate climate risks.

**Science and research**
Scientists estimate the size and health of fish populations and broader ecological effects of fishing to determine how much fish can be sustainable caught using information from commercial fishing, surveys, and modelling outputs.



**Commercial fishing**
Fisheries scientists and managers often work with fishers and fishing organisations to develop practical solutions for managing fisheries and collecting data.

**Management and regulation**
Based on scientific data and advice, fishery managers establish regulations such as quotas (limits on the amount of fish that can be caught) gear restrictions, and closed seasons, to conserve fish stocks and maintain sustainable fisheries.

The Framework involves a four-step process that seeks to:

1. Assess the overall risk to a species based on the impacts of climate change and the biological status of the stock using the best available information,
2. Consider whether there are sufficiently precautionary measures in the existing science, management or industry adaptation pathways to respond to the impacts of climate change,
3. Assess the residual risk to a species, and where required
4. Provide advice to the AFMA Commission on any additional measures required to respond to the impacts of climate change.

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

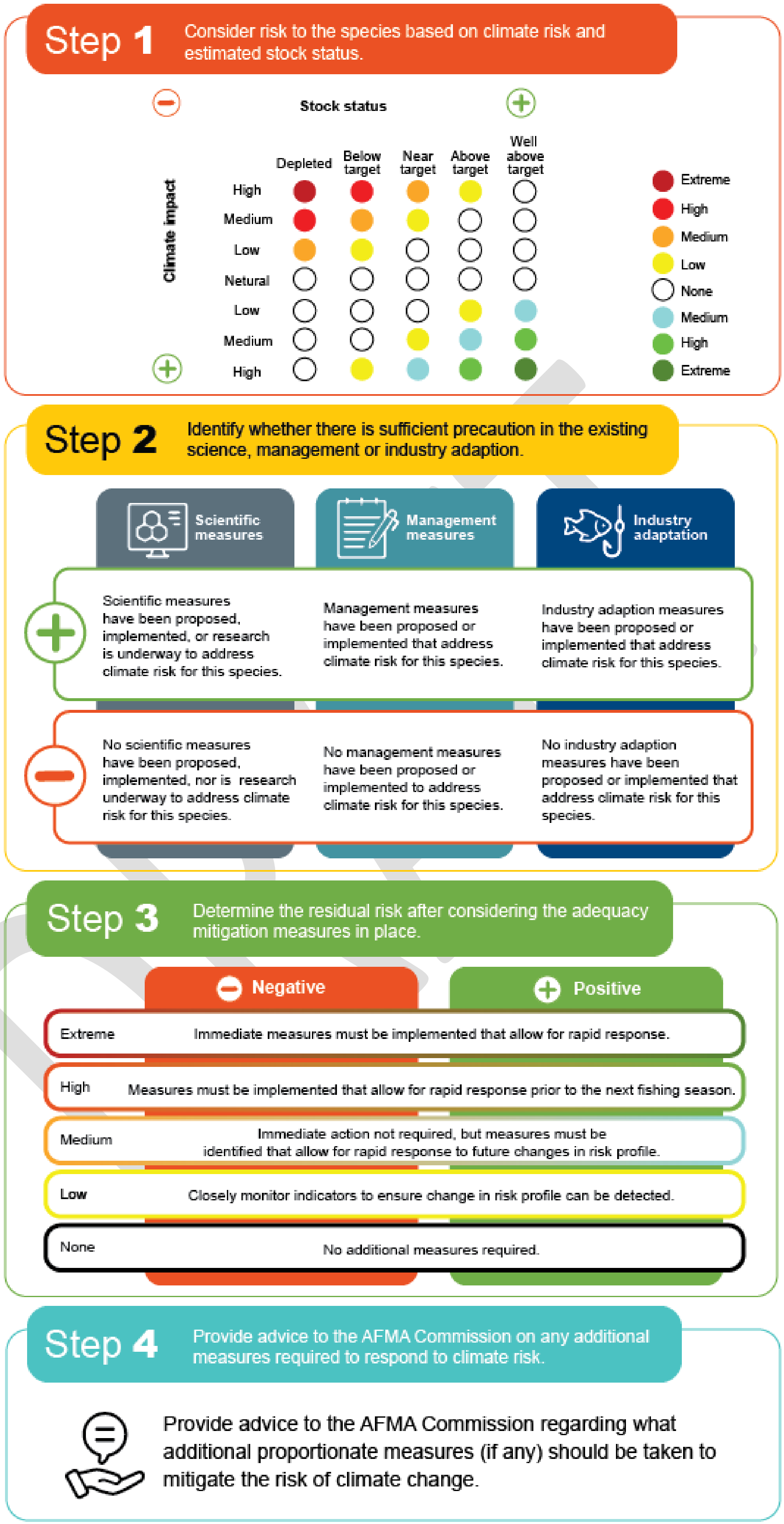



**Figure 3 The AFMA Climate Risk Framework 4-step process**

## 2.1 Implementation process

The Framework is designed to integrate with the existing consultation and advisory group processes and align with the annual TAC/E setting process. For each species, relevant RAGs and MACs (with support from AFMA management) will step through the process and provide advice to the AFMA Commission, prior to the start of the next fishing season. The Framework will be established as a guidance piece, rather than established as policy. This will allow for improvements over time, based on trials and implementation experience and as our understanding of climate impacts and appropriate mitigation evolves.

The RAG will complete Step 1 through to Step 4, including providing advice to the AFMA Commission. The MAC can review the risk ranking established at Step 1 but are largely responsible for validating or adding to the measures identified at Step 2, and then revising or validating the residual risk ranking at Step 3. Depending on the measures identified at Step 2, both groups should provide advice to the AFMA Commission at Step 4. It will be the responsibility of AFMA management to consolidate this advice and have it cleared by both groups, including where there is conflicting advice, and produce the Species Assessment Report (example at **Appendix A**).

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

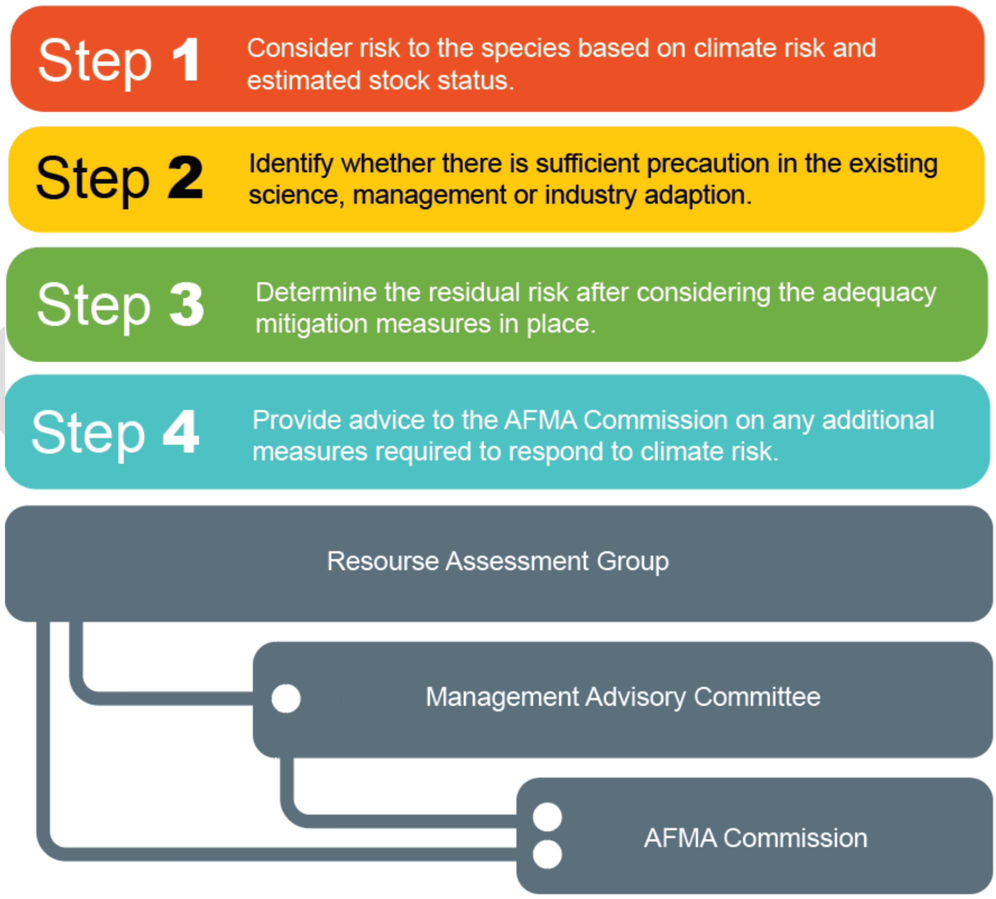



**Figure 4 The role of RAGs, MACs and the AFMA Commission in implementation of the Climate Risk Framework**

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

**Climate Risk**

The RAG, utilising the best available climate information for the species, undertake an assessment of the climate risk ranking using the criteria set out in **Table 1** below. The RAG should draw upon the most robust information source available for the species, listed here as categories 1-4.

1. Attribution studies of counterfactual simulations include sophisticated ecosystem modelling of existing and projected climate impacts. These and are available for some Commonwealth species, for example climate forced modelling using CSIRO Atlantis ecosystem simulations for key species in the Southern and Eastern Scalefish and Shark Fishery (SESSF) (Fulton, et al. 2024). Models of Intermediate Complexity for Ecosystem assessments (MICE) being undertaken for 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 abundance due to climate change is available for most Commonwealth fish 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.

3. Climate sensitivity based on an assessment of life history characteristics is also available for all fish 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.

Only a few species are likely to have attribution studies or counterfactual simulations available, while most species will have preliminary projections and climate sensitivity assessments available to draw upon. AFMA will support the RAG by ensuring the available information for the species of interest is available.

**Stock Status Risk**

It is important to understand the most recent estimate of stock status in the context of climate risk. For species that are above the Target Reference Point (TRP), the potential risk of climate change impacting sustainability is lower than that for a species that is near or below the Limit Reference Point (LRP).

Estimates of stock status vary across AFMA-managed 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/outputs do not reasonably align with the examples provided. (Derived from NOAA[3], ICES (2012) and Dowling, *et al*. (2016)).

1. Robust assessments of fishing mortality (F) and biomass (B) based on fishery-independent and/or fishery-dependent data. The models utilize statistical techniques to match information about age classes to assumptions about a stock's birth, growth, and death rates to estimate a stock's current size, harvest rate, and its management reference points associated with a target reference point. 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. Empirical or index-based models providing estimates of F (based on size and/or age data) or trends in relative abundance based on as indicator such 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., a target reference point).
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/E 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 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. In addition, 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.

[3] https://www.fisheries.noaa.gov/insight/stock-assessment-model-descriptions#stock-assessment-models

This framework does not propose to incorporate a buffer to account for time-induced uncertainty in stock assessments or climate risks, 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 (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 2000's. The median estimate of stock abundance is 38%$B_0$ – a decline from 41%$B_0$ at the time of the last stock assessment[4]. Assuming a target of 48%$B_0$ this stock would be ranked as 'medium' risk 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 risk ranking of 'high' more appropriate.

## Guidance notes – Step 1

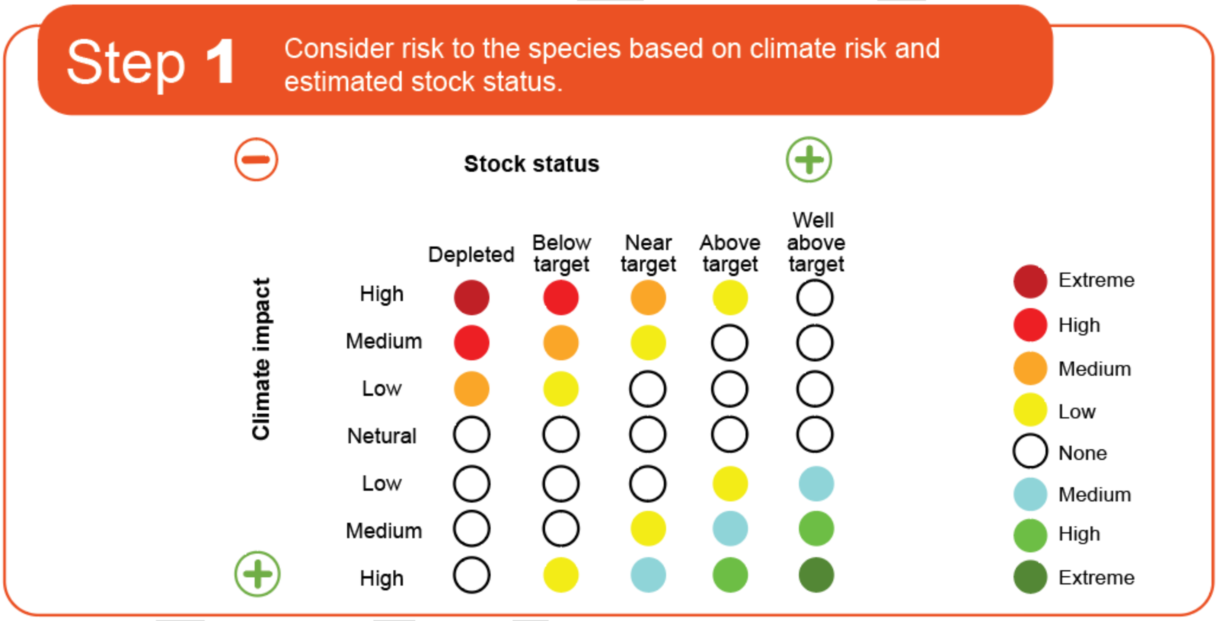



**Figure 5 (Step 1) Preliminary risk rankings based on climate risk and stock status risk.**

It is the role of the RAG to assess the overall risk to a species from climate risk (Table 1) and stock status risk (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 5, a preliminary risk score can be determined. These progress from 'Extreme Negative' where a species is below the limit reference point and highly susceptible to climate change, to 'Extreme Positive' where a species is near virgin biomass levels and expected to benefit from climate change.

**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.

[4] Revised in the most recent stock assessment.

**Table 1 AFMA Climate Risk Framework - climate risk ranking criteria**

| CLIMATE RISK | 1. Attribution studies or counterfactual simulations | 2. Preliminary projections of change in abundance | 3. Climate sensitivity assessment | 4. Climate and ecosystem indicators |
|---|---|---|---|---|
| **High** | Climate change is the primary driver of stock abundance. | >20% change by 2040 with moderate to high confidence, OR >40% change with low confidence. | If projections are not available, where climate sensitivity has been rated high. | Relevant climatic or ecosystem indicators show adverse/positive signals in the near history and in short-medium term predictions |
| **Uncertain** | Where no information is available, 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 by 2040 with medium or high confidence, OR 10-40% change with low confidence. | If projections are not available, where climate sensitivity has been rated medium. | General climatic or ecosystem indicators indicate some changes to system productivity (e.g., recent marine heatwave in the fishery region) |
| **Low** | Climate Change is only a minor contributor to changes in stock abundance. | Up to 5% change by 2040 with medium or high confidence, OR 5-10% change with low confidence. | If projections are not available, where climate sensitivity has been rated low. | General climatic or ecosystem indicators indicate negligible changes to system productivity. |
| **Neutral** | Climate change does not have an influence on the stock. | Projections predict relative stability in abundance. | | General climatic or ecosystem indicators indicate no change in system productivity |

Table 2 AFMA Climate Risk Framework Stock Status Risk Ranking Criteria

| STOCK STATUS RISK | 1. Robust assessments of F and B | 2. Empirical or index-based assessments | 3. Data-poor methods or weight of evidence approaches |
|---|---|---|---|
| **Depleted** | Biomass is estimated to be below the limit reference point (LRP). | Recent index of abundance is estimated to be below the LRP.<br>e.g., $CPUE_{REC} < CPUE_{LIM}$ | Available information suggests that the stock is depleted.<br>Assessed as extreme high risk in the most recent ERA. |
| **Below Target** | Biomass is estimated to be above the LRP, but less than $75\%B_{TARG}$.<br>e.g., $<36\%B_0$ relative to a $B_{48}$ target. | Recent index of abundance is estimated to be above the LRP but less than 75% of the TRP.<br>e.g., $CPUE_{REC} < .75*CPUE_{TARG}$. | Available information suggests the stock is not depleted or biomass is uncertain.<br>Assessed as high risk in the recent ERA. |
| **Near Target** | Biomass is estimated to be within 25% of $B_{TARG}$.<br>e.g., Between $36\%B_0$ and $60\%B_0$ relative to a $B_{48}$ target. | Recent index of abundance is estimated to be within 25% of the TRP.<br>e.g., $CPUE_{REC}$ is $0.75\text{-}1.25*CPUE_{TARG}$. | Available information suggests the stock is sustainable and not subject to overfishing.<br>Assessed as low risk in the most recent ERA |
| **Above Target** | Biomass is estimated to be more than 25% above the TRP.<br>e.g. $>60\%B_0$ relative to a $B_{48}$ target. | Recent index of abundance is estimated to be more than 25% above the TRP.<br>e.g., $CPUE_{REC}$ is $>1.25*CPUE_{TARG}$. | Available information suggests the stock has only been lightly exploited.<br>Assessed as low risk in the most recent ERA |
| **Well above target** | Biomass is estimated to be within 25% of virgin biomass.<br>i.e., $>75\%B_0$. | Recent index of abundance is estimated to be more than 50% above the TRP.<br>i.e., $CPUE_{REC}$ is $>1.5*CPUE_{TARG}$ | |

## Step 2: Review existing mitigation and adaptation measures

Once the risk to the stock has been determined, the RAG needs to consider whether the existing science, management or industry adaptation measures in place are sufficiently responsive to the impacts of climate change, be they positive or negative. 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 mitigate the risk of climate change for a species. Examples are provided here to illustrate how the impact of climate change on a species can be mitigated using measures this framework broadly refers to as 'science', 'management' or 'industry' adaptation.

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 quota (management) which may influence fisher behaviour (industry adaptation). The examples are not exhaustive, and in some cases are still being explored as concepts. In practice, a mix of the three will exist in most fisheries. Provided these measures are sufficiently articulated, and their impact understood, the category they fall into is less important.

While many measures can be expected to reduce risk, 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.

*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, sea-surface temperature could be used to modify the assumptions regarding life history traits, such as growth, used within a model. Careful consideration must be given to the resulting behaviour of the other standard parameter estimates.

**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 operation). HCRs are usually selected on the basis of Management Strategy Evaluation (MSE) testing.

**Management Strategy Evaluation (MSE).** 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, MSEs 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.** Can be used to account for shifts in productivity. Shifts in productivity (non-stationarity) can be addressed by defining stock status (i.e., spawning biomass relative to unfished spawning biomass) using 'dynamic $B_0$' – the spawning biomass that would be expected in the absence of fishing. The implications of adopting a dynamic $B_0$ approach differs among species, with quite major changes in stock status and catch limits for some species and negligible changes for others (Bessell-Browne, et al. 2022). It has been shown that, in some cases, application of dynamic reference points can lead to a higher risk. This needs to be considered.

**Ecosystem information provides 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., marine heatwaves or lower levels of primary production) then caution would be advised around any expansion of the fishing footprint or increases in recommended biological catch.

**Ecosystem modelling informs stock assessment processes.** This is where output from ecosystem modelling is 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.** For example, ecosystem models can be used to correct target F to account for food web interactions. Another example is when recommended catches from single species assessments are selected against ecosystem measures (such as the "green band") to check for distortive pressure on ecosystem structure.

**Monitoring and research.** While on its own will not reduce on-the-water risk to a species, 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 negligible 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 mitigate risk. These are likely to be case-specific but could include 'borrowing' 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 mitigation options. However, in larger and more complex fisheries, particularly multi-species and multi-gear fisheries, technical interactions (the catch of a mix of species using a single gear type) 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 options 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 survey 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 mitigate climate-fishery risks for 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 process 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** 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** may be considered an appropriate option to adjust the TAC/E 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 climate risk rating and stock status of the species,
- The impact climate change is having (or is predicted to have) on the species,
- The role of the species in the ecosystem and fishery,
- Other discounts already included in the development of the RBC, and
- Other mitigating factors 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 risks 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 actually 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 agency establish co-management agreements. While this typically involves collecting traditional biological data to support stock assessments (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** may occur in response to a change in a stocks size or distribution. This may occur in a change in the species mix rather than complete species shifts.

## Guidance notes – Step 2

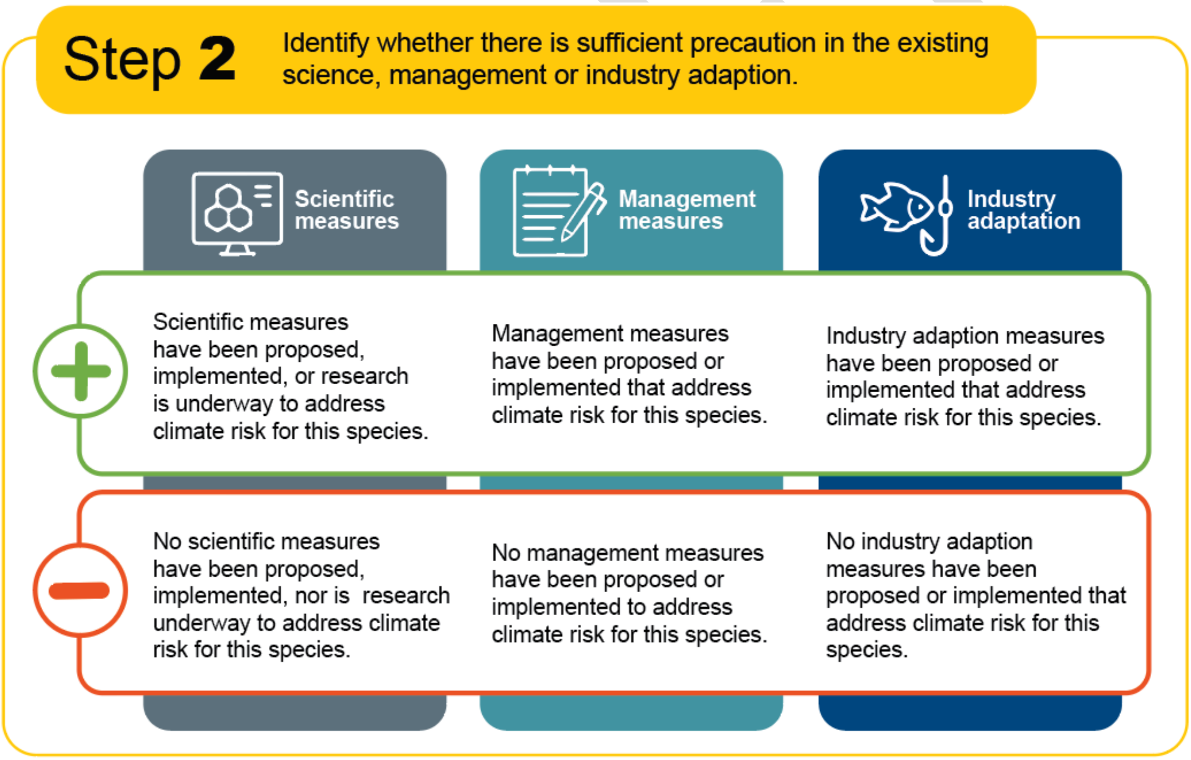



**Figure 6 (Step 2) Review of existing science and management measures**

The RAG should record the measures identified and how they translate to a reduction in risk for each species. This will not always be easily quantifiable, however, if there are instances where alternate scenarios have been forecast to understand their impact, this should be included. An example is provided at **Appendix A**.

Where a species is expected to benefit from climate change, the RAG and MAC should consider whether the arrangements are sufficiently responsive to potential productivity benefits. For example, can TACs be modified within season, or closures removed to allow full utilisation.

## Step 3: Determine the residual risk

Once the measures in Step 2 have been recorded, the RAG and MAC need to determine the residual risk ranking. Each residual risk ranking is associated with additional guidance (Figure 7) that should inform advice provided to the AFMA Commission at Step 4.

### Guidance Notes – Step 3

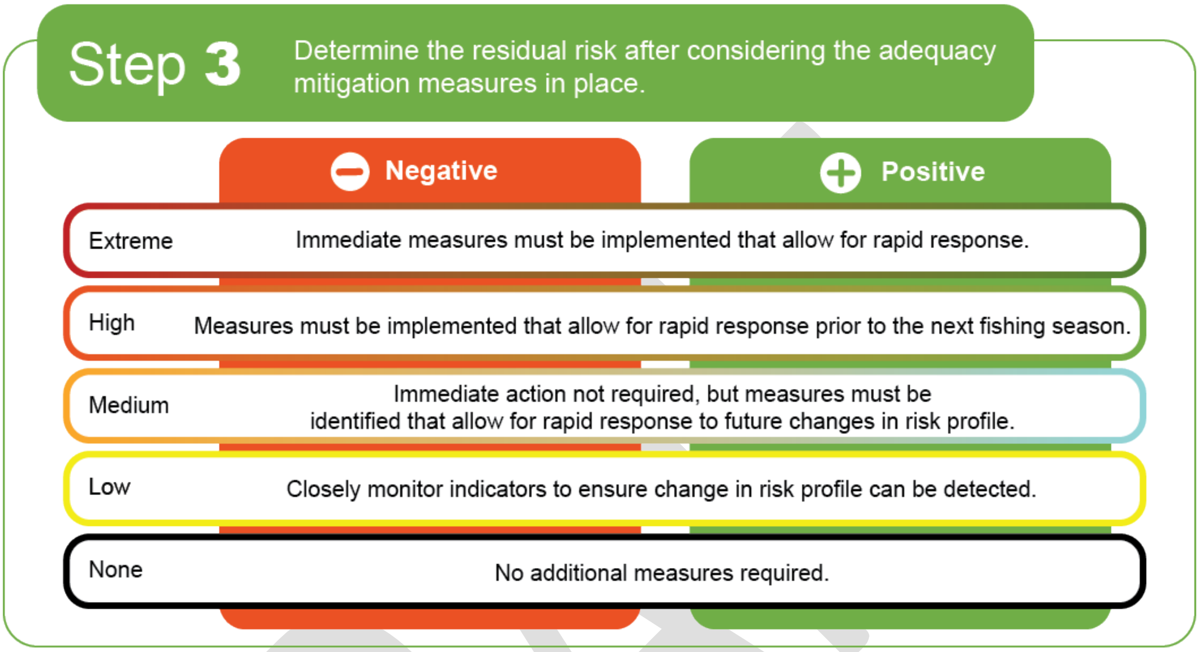



**Figure 7 (Step 3) Residual risk analysis rankings and associated guidance**

The risk profile can change where there are clear and demonstrable measures in place to mitigate or respond to the impacts of climate change for a species. The extent to which the risk changes is at the discretion of the RAG and MAC but should be supported by data or modelling where it is available. When providing advice to the AFMA Commission, there must be sufficient detail about how the measures identified at Step 2 are expected to take account of or mitigate 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.

Some examples are provided at **Appendix B** to demonstrate how risk could be adjusted (or not) at Step 3 based on measure identified at Step 2.

## 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 risk at Step 1 (where Steps 2-3 have been bypassed) 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 need to demonstrate and clearly articulate the reasons for that advice.

The intent of the Climate Risk Framework is to identify proportionate adjustments to mitigate climate risk. Some will be short-term measures, such as TAC reductions, while others will be longer-term, such as incorporating environmental variable in stock assessments.

Longer-term and more comprehensive adaptation plans are also being progressed by AFMA through the Climate Adaptation Program.

### Guidance notes – Step 4

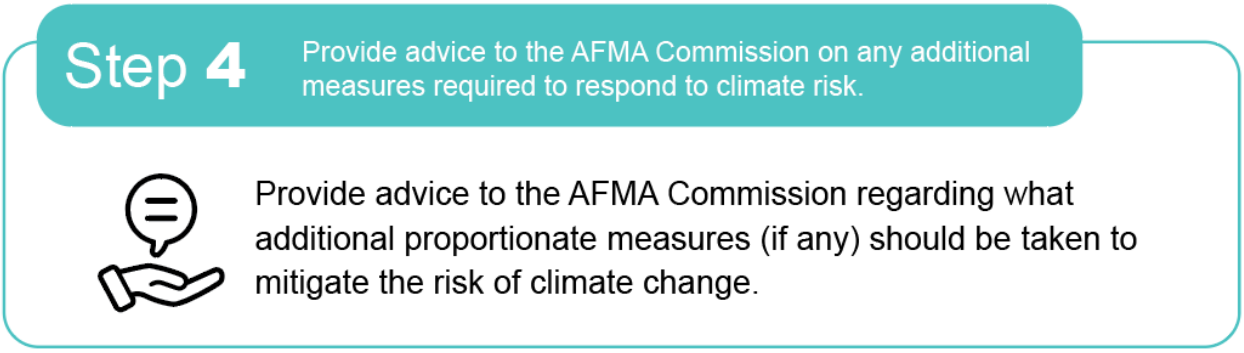



**Figure 8 (Step 4) Providing advice to the AFMA Commission**

A risk ranking of 'low' does not preclude the RAG or MAC from providing advice about additional measures, 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 proportionate measures to mitigate risk to the species. 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 mitigate risk.

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

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# Appendix A

## Species Assessment Report (Example)

| | |
|---|---|
| **Common Name** | Southern Kraken |
| **Species Name** | *Piscis Fictitious* |
| **Fishery** | East Australian Squid Jig Fishery |
| **Stock Assessment** | Sverre (2022) |

### *Step 1 – Consider risk to species based on climate risk and estimated stock status*

**Climate Risk**

High **(Negative)** (Criteria 1)

Atlantis modelling suggests that climate change has a major influence on the biomass and is contributing to a much lower biomass than would have occurred otherwise.

**Stock Status Risk**

Low (Category 1)

The 2022 Tier 1 stock assessment estimated the 2023 biomass to be 44%$B_0$.

**Overall Risk**

Medium **(Negative)**

### *Step 2 – Identify whether there is sufficient precaution in the existing science or management setting*

**Science**

A low recruitment scenario was used to project future catches on the basis that recruitment deviations are estimated to be below (albeit only slightly) the long-term average since 2012.

Additional model sensitivities were explored:

- Changing weighting on length and age data resulted in small changes to stock status estimates.
- Doubling and halving weighting on the survey index resulted in large changes to total likelihood estimates but had minimal impact on stock status (41% and 49% of $B_0$).
- All model sensitivities estimate the stock status to be at or above 40%$B_0$.

**Management**

No management measures have been proposed or implemented to respond to climate risk for this species.

| | |
|---|---|
| **Industry** | Industry has implemented a voluntary move-on arrangement. If catches include large amounts of juvenile fish, vessels will steam 3nm and not return to the area for 48 hours. |

### *Step 3 – Determine the residual risk after considering the adequacy of science and management measures in place*

| | |
|---|---|
| **Residual Risk** | Low **(Negative)** |
| **Comments** | Implementing the low recruitment scenario takes account of a potential shift in productivity and resulted in a lower TAC, allowing recovery towards the target reference point. While no specific management measures have been implemented (beyond a reduction to the TAC) additional industry move-on agreements should provide a level of protection to younger cohorts.<br>The next stock assessment is scheduled for 2025 which will provide an opportunity to review the indicators and effectiveness of these measures. |

### *Step 4 – Provide advice to the AFMA Commission on any additional measures required to respond to climate risk*

| | |
|---|---|
| **Recommendation** | The RAG and MAC are satisfied that the measures are proportionate to the risk identified for this species. No additional measures are required. The stock assessment will go ahead as scheduled in 2025 and the RAG will monitor fishery indicators. |

# Appendix B

## Residual Risk Examples

**Extreme → Medium (Negative)**: A species is ranked extreme (negative) risk because it was recently assessed as depleted (using a robust stock assessment) and is considered high risk from climate change. The stock assessment parameters were updated to include a revised estimate of natural mortality, and a low recruitment scenario was used to project biomass under various catch scenarios. A bycatch TAC was implemented based on catches that are expected to allow recovery, and a series of targeted closures were implemented to ensure total mortality is constrained. Recent catch and effort data suggests that total mortality is sufficiently low to allow recovery. This species' risk ranking could be reduced to medium because there are a number of science and management measures in place, and there is data to show total mortality has been constrained. The RAG and MAC might consider additional measures such as species-specific monitoring to closely monitor range shift and ensure spatial closures remain effective.

**Medium → Low (Negative)**: A species is ranked medium (negative) risk because it was recently assessed as being just above the limit reference point (using an empirical stock assessment) and is considered medium risk from climate change. The default reference period in the stock assessment was adjusted and is now based on a period considered to be comparable with current environmental conditions. The RBC is based on fishing mortality that is expected to allow recovery, however, this species is primarily caught as a byproduct species, and it is unclear whether total mortality can be constrained to this level. This species could be ranked as 'low' risk and the RAG should continue to monitor total mortality.

**High → High (Negative)**: A species is ranked as high (negative) risk because it was recently assessed as being just above the limit reference point (using an empirical stock assessment) and is considered high risk from climate change. The index of abundance has declined over the last two assessments, the estimate is considered uncertain, and the TAC is almost fully utilised. The RAG has recommended that an alternative and more robust stock assessment is pursued, and data collection has commenced. While data collection has commenced, it will be several years before the stock assessment is expected to yield results. This species should remain at high risk, and the RAG and MAC should consider additional measure to ensure risk is mitigated until a more robust assessment is available.

**High → Medium (Positive)**: A species is ranked as medium (positive) risk because it is expected to benefit from climate change and was recently assessed as being well above the target reference point – approaching virgin biomass. The estimate of spawning biomass is derived from estimates of daily egg production (survey) and species-specific fecundity. Adult reproductive parameters used in the assessment are based on research conducted approximately 15 years ago, and there is evidence to suggest that fecundity will increase due to recent and future expected environmental conditions. The RAG and MAC may consider a short-term increase to the TAC to promote fishing and support data collection that will enable revisions to life-history parameters. Stock status should be closely monitored.