Decadal scale projection of changes in Australian fisheries stocks under climate change

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Acknowledgments

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Executive Summary

Australia's oceans are undergoing rapid change and changes in fish distribution, abundance and phenology have been widely reported. A first step in ensuring that the fisheries of Australia adapt effectively to climate change is an understanding of the historical and projected changes in the species captured. This information will underpin development of industry and management responses and management systems that will allow negative impacts to be mitigated and opportunities that arise to be seized.

This project takes two approaches to understanding climate impacts on species that are captured in Australian fisheries - species sensitivity analysis (Part 1) and ecosystem modelling based on new climate projections (Part 2). Species level responses for each of the Commonwealth fisheries are detailed in both sections, followed by a concluding synthesis and list of recommendations (Part 3). The main objectives of the study were to:

1. Update CSIRO-held Australian ecosystem models with the system status information and the latest climate impacts information.
2. Run ecosystem projections out to 2050 using the latest Ocean Forecasting Australia Models (i.e. latest physical projections), noting ecosystem and species level effects at 5 or 10 year intervals/averages.
3. Distil the fine scale (where possible species level) projections for the Australian Commonwealth fisheries.
4. Provide advice on (i) likely impacts of climate in the short, medium and long term; and (ii) information gaps and priorities for tracking climate impacts on individual fisheries.

An overview of the major findings from each section are provided below.

Part 1 Species sensitivity assessments

This section of the project provides an Australia-wide synthesis of three existing species sensitivity assessments completed as part of the FRDC-NCCARF climate change initiative (Creighton et al. 2016). These assessments were for five regions of Australia – south-east Australia (Pecl et al. 2011), western Australia (Caputi et al. 2015), and three regions of northern Australia (Welch et al. 2014). These assessments provide a relative ranking to inform further research and management responses (Pecl et al. 2014).

The sensitivity assessments consider three aspects of the biology of exploited species that are relevant to fishers and resource managers: changes in distribution, abundance and phenology. Changes in distribution could require fishers to also change location to continue to harvest the same species, while management regulations may need to be updated or developed to cover the new regions. Likewise, changes in abundance and phenology mean that management may need to alter the harvest levels or the timing of fishing seasons.

Analysis of sensitivity by species, region and gear type were completed for approximately 100 species in five regions. These results suggest that fisheries with invertebrates are the most sensitive to climate change, a consistent pattern across regions. The sensitivity to particular gears was not consistent across regions, and although the sample size was smaller, this suggests taxa was a more sensible grouping than gear type. Sensitivity with regard to changes in phenology were typically scored higher than for distribution, followed by abundance. However, phenology and how it might respond to climate drivers, is amongst the most uncertain aspects of species ecology, while distributions are more readily observed and so are likely to provide for the easiest and most immediate changes to fisheries management. These results can be used to inform priorities for additional monitoring, data collection, research, and industry and management responses.

Part 2 Ecosystem modelling

This section of the project used 11 existing regional ecosystem models covering most of the Australian coastline and EEZ. These models utilised one of three platforms and were often built for different purposes. Results from an additional two global models using different frameworks (size-based and species distribution) were also assessed. All 13 models were updated where relevant and were forced with high-resolution (10km) climate projections from the CSIRO Climate model (Australian global eddy-resolving ocean general circulation model). Overall, the responses of 641 species or functional groups were simulated and examined at two time periods in detail (2020-25 and 2045-50), but full time-series are provided.

Model results highlighted likely impacts of a high emissions climate scenario (RCP8.5, 'business as usual') on commercially harvested, non-harvested, and threatened, endangered and protected species. Maps of species distribution were provided where available to give additional insight into ecosystem and where possible, species-level abundance changes for Australian fisheries based on the latest climate information and understanding. To try and tease out the effect of climate change alone, we present model projections for fishing only, climate and fishing, and climate only. For all but one regional model (Atlantis-AMS), we assume that current fishing pressure is applied into the future (constant fishing mortality). Model outputs are discussed separately to reflect true uncertainty (model and process) and because within a region different species are represented in different models. In using all these model outputs we are looking for consistent responses across models applied to the same assessment regions, or differences that reveal insight into model structure or resolution.

Commonwealth Fisheries Species synthesis

Here we compared the sensitivity scores from the vulnerability assessments with the outputs of regional and global ecosystem models for 24 Commonwealth fisheries species. This was not a trivial task due to the diversity of modelling approaches used, model uncertainty, and because sensitivity scores do not indicate the direction of change. At present, species sensitivity assessments are likely better at examining commercial invertebrates, while ecosystem models can provide better advice about changes in the abundance of commercial and non-commercial vertebrates, including threatened, endangered and protected species. Ecosystem models can be valuable tools to inform policymakers how combinations of drivers can affect regional marine ecosystems, but they need sufficient resources to be regularly updated and assessed with new knowledge and time-series data.

Results showed that overall there was reasonable agreement where there was high model confidence and where the models (regional or global) contained the main mechanisms that were being considered in the vulnerability analysis. There is moderate to strong agreement between the methods for blue grenadier, southern bluefin tuna, jack mackerel, sardine, anchovy, blue mackerel, redbait and flathead (South east Australia), and tiger prawns, banana prawns, king prawns (regions 2-5). In these circumstances, results can be considered more robust. The greatest divergences between the assessment methods were typically for shallow shelf demersal stocks and many of the invertebrates, which are often poorly constrained and only generally parameterised in the trophic models. Where there is strong disagreement, the ensemble could be used to flag (i) the potential ranges in outcomes and the uncertainty associated with the future of that species, and (ii) the need for more targeted information at the local to regional scale. With more refined information, statistical models of intermediate complexity (MICE models) could be developed as the most effective tools as they are focused on species, regions and driver and are formally fit to data.

Part 3 Conclusions and recommendations

Over the next century, fisheries governance is likely to face ongoing changes into the future as new shifts in ecosystems, the climate system and the broader socioecological system of Australia are realised. In this section we outline 8 recommendations for fisheries management, based on the findings of an ensemble of assessment tools used in this study:

(1) Management priority, based on short term sensitivity, should be given to: (i) northern invertebrate fisheries, and (ii) finfish fisheries with areas of regime change (e.g. Tasman Sea)
(2) Existing management strategies must be assessed in terms of their capacity to sustain long term ecological and resource management objectives.
(3) Flexible regulations and adaptive approaches are required to implement change as rapidly as needed in response to changing system state.
(4) Fisheries policy, management and assessment methods need to integrate the concept of regime shifts and extreme events for contextual management decision making.
(5) There needs to be greater recognition of non-static environmental conditions in fisheries operations and in the assessment and decision making processes.
(6) A cross jurisdictional management of stocks is likely imperative.
(7) It will be increasingly necessary to acknowledge that not all fisheries and operators will have equal adaptive capacity.
(8) Integrated management needs to be central to fisheries management.

Fundamental for any assessment tool used in assisting decision making and successful fisheries management is the availability of environmental and biological information. Regarding the assessment approaches used in this project, many aspects remain uncertain as scientific knowledge of system and species responses is incomplete. While we recognise that not all data forms can be provided, we recommend that priority should be given to attaining and assessing: (i) indicators of the physical state of the system; (ii) indicators of primary productivity and plankton community composition; (iii) high quality fisheries dependent data; (iv) independent surveys assessing broad system structure and function; and (v) non-traditional data sources, such as various citizen science platforms. The main foreseeable challenge will then be synthesising this information into a coherent message around system status and trends.

(ii) Keywords

Sensitivity analysis, Vulnerability, Ecosystem modelling, Climate variability, Adaptive management

Introduction

Australia's oceans are undergoing rapid change, with two of the world's most rapidly warming ocean areas located in the south-east and south-west, and much of the tropical waters of Australia warming at almost twice the global average (Lough and Hobday, 2011; Hobday and Pecl, 2014). Understanding what that change means for fisheries production and management is paramount if the resources are to continue to be sustainably managed (Fulton 2011). Ensuring that the fisheries of Australia adapt effectively to climate change will require the development of industry responses and management systems that will allow negative impacts to be mitigated and opportunities that arise to be seized (Creighton et al. 2016).

Changes in the distribution, abundance and species composition of our commercial fisheries resources as a function of changing climate is going to be unavoidable and our industries will need to adapt to minimise exposure to risks which, given constructive and timely adaptive actions, could be reduced (Madin et al. 2012; Creighton et al. 2016). Fisheries provide significant social and economic benefits globally, and early warning of changes in resource quality and/or availability is required to minimise social implications (e.g. as a function of changes in resource allocation) and societal costs (e.g. income redistribution and government restructuring) (Hobday and Pecl, 2014). There is strong evidence that climate change is impacting our fisheries on a time scale that is relevant to current fisheries management and strategic planning (Plagányi et al. 2011). It is imperative that industries and managers are proactive in positioning themselves to undertake a strategic and structured approach to adaptation planning and engage in subsequent actions to minimise losses and maximise opportunities arising from climate change (Norman-López et al. 2011; Pecl et al. 2014a). Successful adaptation planning is not just about implementing strategies to minimise vulnerabilities and potential losses, it is also concerned with ensuring adequate preparedness to maximise advantages offered by new opportunities. However, not all threats identified will be responsive to anticipatory actions and we need to focus on the threats posing the greatest future cost and that will be most responsive to anticipatory action (Pecl et al. 2014b).

Fishery managers, amongst others, have asked for a rapid and thorough update of existing tools and syntheses with the latest information so that they can base their strategic planning on the latest and best information [FRDC project 2016-059] and thereby help to make the Australian fisheries management system climate-proof to the current projected changes.

In delivering on these requests the approach taken has been to build on and extend the best of previous work with the most recent advances in scientific understanding of the topic. This project builds on previous climate impact and adaptation programs invested in by FRDC - e.g. Southeast Australia Program (SEAP) and the FRDC-NCCARF Marine National Adaptation Research Plan (1). The information generated by that suite of projects, in particular the physical (2) and biological projections (3) is now outdated due to the rapidly advancing nature of the field, and no longer represents the latest available information. The focus of much of that work was also at relatively long, multi-decadal time scales (e.g. 2060 to 2100), although shorter projections were attempted (Creighton et al. 2016). Since this work, climate models have also improved and can now provide finer spatial and temporal scale scenarios, which are more "real" for fisheries managers and stakeholders.

A reason for focusing on the period of 2020-2050 is that this is the scale most relevant to current industry and management planning, but it is also a period where all climate projections show relative insensitivity to the choice of climate scenario (Figure 0-1). As this figure shows, regardless of whether the world follows a high emissions trajectory or begins to shift to lower emissions footprints the long memory of the climate system means in terms of heat gain the scenarios are consistent until around 2050, after that they diverge and there are greater differences amongst the potential scenarios.

Given the implications of rapid warming, a lot of scientific attention has focused on the highest emissions scenario of RCP 8.5. This was the first of the new IPCC scenarios to be implemented in the CSIRO climate model, which is the model that best fits the Australia region. As this model has the greatest skill (the closest fit to observations) for the region, the fact that global emissions appear to still be closest to the assumptions for the RCP 8.5 scenario and as all scenarios are very similar out to 2050this report only considers the outcome for scenarios using the RCP 8.5 trajectory.

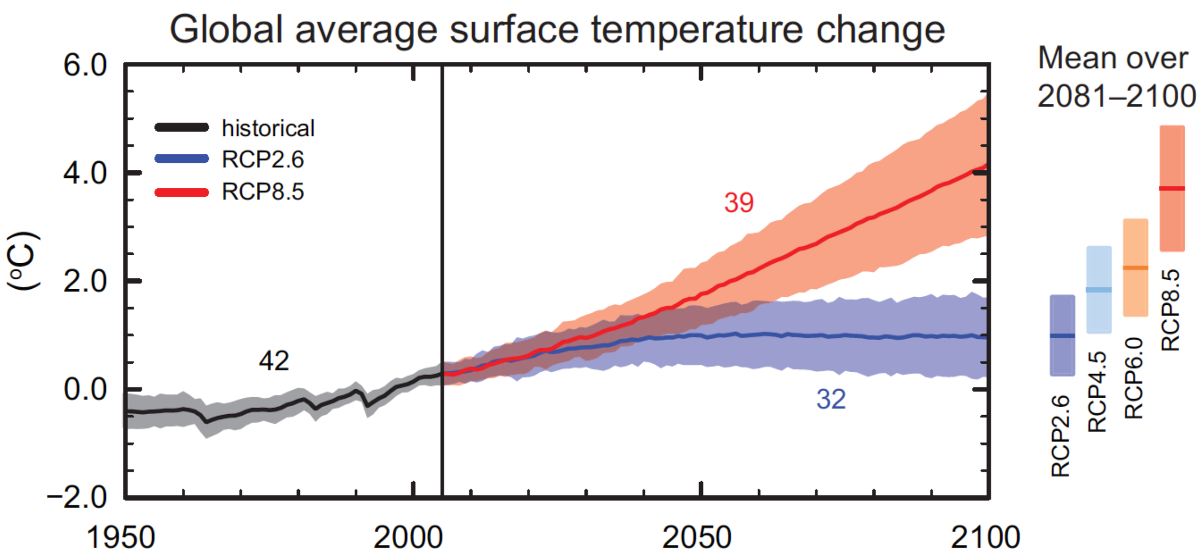


Figure 0-1. Projected surface temperature under the different emissions and climate scenarios with the band of potential outcomes based on a suite of IPCC-class climate models. Note the consistency of the trajectories through to around 2030 and the high level of overlap out as far as 2040-205. Source IPPC 2013: AR5 Summary for Policymarkers Figure SPM 7.

Objectives

This project takes two approaches to understanding climate impacts on fished species - species sensitivity analysis (Part 1) and ecosystem modelling based on new climate projections (Part 2), with a concluding synthesis (Part 3). The main objectives of the study were to:

1. Synthesise and update vulnerability assessments for key fished species in Australia (slightly altered from the original objective to: Synthesise existing climate vulnerability information and communicate this to management and other stakeholders)
2. Update CSIRO held Australian ecosystem models with the system status information and the latest climate impacts information.
3. Run ecosystem projections out to 2050 using the latest Australian OFAM models (i.e. latest physical projections), noting ecosystem and species level effects at 5 or 10 year intervals/averages.
4. Distil the fine scale (where possible species level) projections for the Australian EEZ from the FISHMIP model repository.
5. Provide advice on (i) likely impacts of climate in the short, medium and long term; (ii) information gaps and priorities for tracking climate impacts on individual fisheries.

Outputs from this study should be useful for input to the AFMA project ‘Adaptation of Commonwealth fisheries management to climate change’, for example with responses relative to distribution, abundance, and phenology. The adaptation project seeks to future-proof Australian fisheries governance structures.

Part I Species Sensitivity Assessments

1.1 Overview

This section of the project describes an Australia-wide standardisation and synthesis of three existing assessments of species sensitivity to climate change. The first of these sensitivity analyses (Pecl et al. 2011) was initially developed in the SEAP program (FRDC project 2009/070), and similar methods were then used in Western Australia (Caputi et al. 2015), and North-western Australia, Gulf of Carpentaria and Queensland East (Welch et al. 2014). Here we seek to synthesise these analyses and develop comprehensive sensitivity scores for species, taxa groups, gear types and Commonwealth fisheries as well as highlighting common patterns of response or regions of particular sensitivity.

The full vulnerability assessment puts considerable focus into assessing the dependence and adaptive capacity of the socio-economical components of fisheries. Revising this for changes that have occurred in the last few years was beyond the scope of the resources of this project and will receive at least some attention in the upcoming AFMA project ‘Adaptation of Commonwealth fisheries management to climate change’. Instead this project focuses on updating and synthesising the biological aspects of the vulnerability and sensitivity assessments. In particular, the biological aspects of exploited species that are relevant to fishers and resource managers: changes in distribution, abundance and phenology. Changes in distribution could require fishers to also change location to continue to harvest the same species, while management regulations may need to be altered or introduced to adequately consider the new regions. Likewise, changes in abundance and phenology mean that management may need to alter the harvest levels or the timing of fishing seasons. These changes in turn affect when and what fishers seek. These sensitivity assessments are risk-based methods, which provide a relative ranking to inform further research and management responses.

At present no species can be ruled completely free of climate risk, however it is clear that some species are more vulnerable than others and if focus is to be triaged these highly vulnerable species should likely receive explicit attention ahead of those that appear to be more robust.

1.2 Methods

1.2.1 Species sensitivity scoring

Climate change impacts can be expressed by a change in a species’ abundance, distribution, or phenology (i.e. the timing of life cycle events), as articulated further in Pecl et al. (2011). With regard to abundance, higher productivity species are considered to be less sensitive (more resilient, i.e. they can recover more quickly) to climate change stressors; low productivity species are considered more sensitive (less resilient, and slower to recover). Similarly, attributes (Table 1-1) were developed to estimate the sensitivity of species to realise changes in distribution. The third measure of sensitivity incorporated in the assessment was to develop attributes for estimating the sensitivity of species to changes in the timing of their life cycle events - phenological changes, such as spawning, moulting and migration. The conceptual model underpinning each of these changes is described in Pecl et al. (2014a).

Scoring of attributes in each category was limited to a scale of 1–3, representing ‘low’, ‘medium’, and ‘high’ (respectively), with significant consultation occurring in each of the broader project teams before, during and after the sensitivity assessment workshops to develop both the attributes and the criteria for scoring the three categories. Several attributes were applied for each of the three measures of sensitivity: abundance, distribution and phenology. Following previous methods, the scores for each group of attributes were combined (averaged) to yield separate scores for abundance, distribution and phenology. These scores were then summed and used to produce a ranking of sensitivity across the selected fishery species.

1.2.1 Data sources for species sensitivity

The fish sensitivity scores were collated for 5 regions, covering the Australian seas (**Figure 1-1**, Appendix A Table 1) from three different projects and for an additional set of species following feedback from AFMA:

- Region 1: the data for South east Australia were extracted from (Pecl et al. 2011) and also generated for an additional 10 species of interest by the project team
- Region 2: the data for Western Australia were extracted from (Caputi et al. 2015)
- Regions 3, 4 and 5: the data for north-western Australia, Gulf of Carpentaria and Queensland East coast were provided by David Welch (Welch et al. 2014).

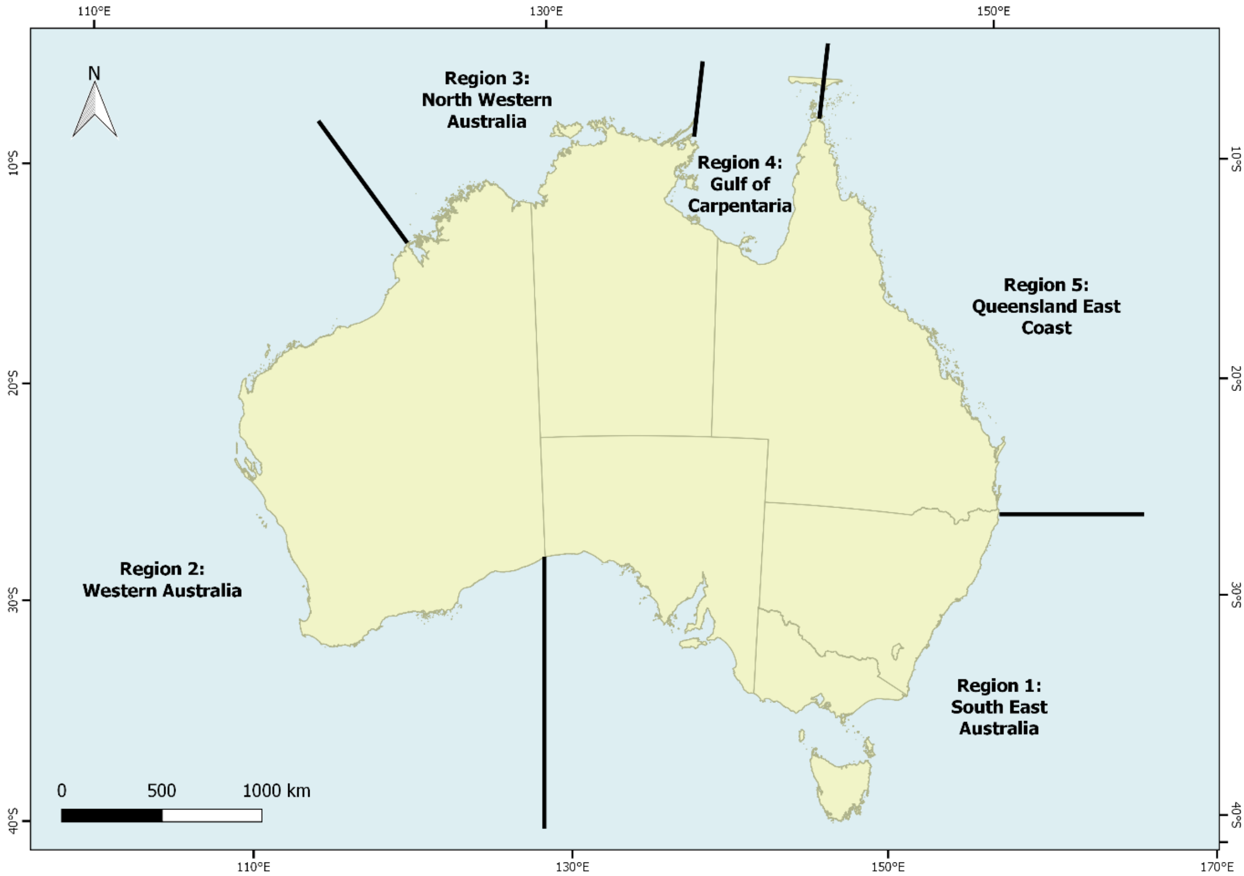


Figure 1-1: Map of Australia showing the five regions assessed in this report

Table 1-1: Attributes, criteria and risk categories used to assess climate change sensitivity for each species (from Pecl et al. 2011 Part 1 and Pecl et al. 2014a)

	Sensitivity attribute	Risk category (sensitivity and capacity to respond to change)		
		High sensitivity (3), low capacity to respond (higher risk)	Medium (2)	Low sensitivity (1), high capacity to respond (lower risk)
Abundance	Fecundity – egg production	<100 eggs per year	100–20,000 eggs per year	>20,000 eggs per year
	Recruitment period – successful recruitment event that sustains the abundance of the fishery.	Highly episodic recruitment event	Occasional and variable recruitment period	Consistent recruitment events every 1–2 years
	Average age at maturity	>10 years	2–10 years	<2 years
	Generalist vs. specialist – food and habitat	Reliance on both habitat and prey	Reliance on either habitat or prey	Reliance on neither habitat or prey
Distribution	Capacity for larval dispersal or larval duration – hatching to settlement (benthic species), hatching to yolk sac re-adsorption (pelagic species).	<2 weeks or no larval stage	2–8 weeks	>2 months
	Capacity for adult/juvenile movement – lifetime range post-larval stage.	<10 km	10–1000 km	>1000 km
	Physiological tolerance – latitudinal coverage of adult species as a proxy of environmental tolerance.	<10º latitude	10–20º latitude	>20º latitude
	Spatial availability of unoccupied habitat for most critical life stage – ability to shift distributional range.	No unoccupied habitat; 0 – 2º latitude or longitude	Limited unoccupied habitat; 2–6º latitude or longitude	Substantial unoccupied habitat; >6º latitude or longitude
Phenology	Environmental variable as a phenological cue for spawning or breeding – cues include salinity, temperature, currents, & freshwater flows.	Strong correlation of spawning to environmental variable	Weak correlation of spawning to environmental variable	No apparent correlation of spawning to environmental variable
	Environmental variable as a phenological cue for settlement or metamorphosis	Strong correlation to environmental variable	Weak correlation to environmental variable	No apparent correlation to environmental variable
	Temporal mismatches of life-cycle events – duration of spawning, breeding or moulting season.	Brief duration; <2 months	Wide duration; 2–4 months	Continuous duration; >4 months
	Migration (seasonal and spawning)	Migration is common for the whole population	Migration is common for some of the population	No migration

There were some differences in the processes of selection of the species in each of the three projects, however, this could be resolved to allow a combined analysis, as described below.

- Region 1 and 2 – (1) fishery experts in these regions prioritized a long list of fishery species (ad hoc) based on economic and management importance (Pecl et al. 2011; Caputi et al. 2015), and (2) then scored these species for sensitivity (Abundance/Distribution/Phenology, or A/D/P as per Table 1-1). We use these results, plus results for an additional 10 species of particular interest to Commonwealth fisheries as noted earlier.
- Region 3, 4, and 5 – (1) experts prioritised a list of species (ad hoc workshop), (2) then scored these species for sensitivity as for Region 1 and 2, then (3) modified the list and proceeded to a second round of scoring (with new criteria) for their final result (Welch et al. 2014). We use the list and scoring results from Step 2, for consistency with Region 1 and 2. Several species that were added at Step 3, but not at Step 2 were not included in our analysis (e.g. Blue swimmer crab).

1.2.2 Gear and Fisheries

Each of the species in the sensitivity assessment was captured in one or more commercial fisheries in one or more of the five regions described above at the time the assessments were originally conducted. As the fisheries in which these species were captured were not specified in the original reports, to classify these species into fisheries, a list of occurrence of species in a fishery was obtained from the Status of Australian Fish Stocks (SAFS) database for 54 of the species. Species could be listed in multiple fisheries, and both State and Commonwealth fisheries were included. Any fisheries that were closed or had no catch recorded for 2015 were not included in the SAFS database extract. Gear types were assigned to each fishery based on knowledge of the fisheries, reports and internet-based information on each fishery. In the case where multiple gear types are specified, we attributed the species-fishery to the single dominant gear type. Gear types were:

- Dive
- Dredge
- Gillnet
- Line
- Purse seine
- Trap
- Bottom Trawl
- Midwater trawl (Commonwealth fisheries only)
- Pelagic Longline (Commonwealth fisheries only)

1.2.3 Analysis

Analysis of sensitivity scores was completed by grouping species in five ways:

1. By region
2. By species within regions
3. By taxa group
4. By gear type

5. By Commonwealth fishery (there are some one hundred state fisheries for which analyses could also be grouped, however, this level of detail is difficult to justify. The species within state fisheries can be assessed by looking at analysis 1, 2, 3 or 4).

Sensitivity score by five taxa groupings were also considered:

- DC: demersal chondrichthyans
- PC: pelagic chondrichthyans
- DF: demersal fish
- PF: pelagic fish
- I: invertebrates

In addition to tables and graphs for the above groupings, a general lineal model (GLM) with a Gaussian distribution was used to investigate the scores among regions and taxa groups.

1.3 Results and Discussion

We synthesised assessments for 101 species from the three original reports plus 10 additional species (total is 111), in five major regions around Australia with sensitivity scores for each of abundance change, distribution change and phenological change. Each species can be caught in multiple fisheries or multiple gears, and for a subset of species where data were available, we also matched species to a fishery, and the major gear type used in the fishery. Thus, the same species score can be used in multiple independent combinations. We pay particular attention to species in Commonwealth fisheries, as a primary focus for the research project. In the following sections we report at a regional level, by gear type and by Commonwealth fishery and discuss implications for management.

We present results for both overall sensitivity (abundance + distribution + phenology) and individual abundance, distribution, and phenology scores in the following sections. These individual categories are all positively but non-significantly correlated, indicating they reveal different aspects about species sensitivity to climate change (Table 1-2). Distribution and abundance sensitivity scores were most correlated (R^2=0.16), while abundance and phenology had the lowest correlation (R^2=0.01). Distribution scores were most highly correlated with the overall scores (R^2=0.63), followed by abundance (R^2=0.50), and phenology (R^2=0.40). Individual scores for abundance can be used to consider management arrangements relevant to abundance, and so on for distribution and phenology. It is important to note that these scores are relative, and as such a score of 6 versus 8 shows that the species receiving the score of 8 is more sensitive than the species scoring 6. There has not been benchmarking of these scores to absolute risk and at present there is no clear break point in the risk ranking which demarcates those species that must receive attention versus those where a watching brief is sufficient.

Table 1-2: Correlation (R^2) between species sensitivity scores based on all species.

Correlation matrix (R^2)	Abundance	Distribution	Phenology	Overall score
Abundance	NA			
Distribution	0.16	NA		
Phenology	0.01	0.07	NA	
Overall score	0.50	0.63	0.40	NA

1.3.1 Sensitivity by region

1.3.1.1 Sensitivity for all regions and species combined - abundance, distribution, and phenology

For all species and regions combined, species sensitivity scores were lowest for abundance change, and higher for distribution and phenology (Figure 1-2). Less information is available for phenologial indicators, and so these sensitivity scores may be high due to uncertainty (missing information was scored high in the assessment process). This suggests that management should consider how changes in distribution affect fisheries as a higher priority than changes in abundance and more information is needed on phenology.

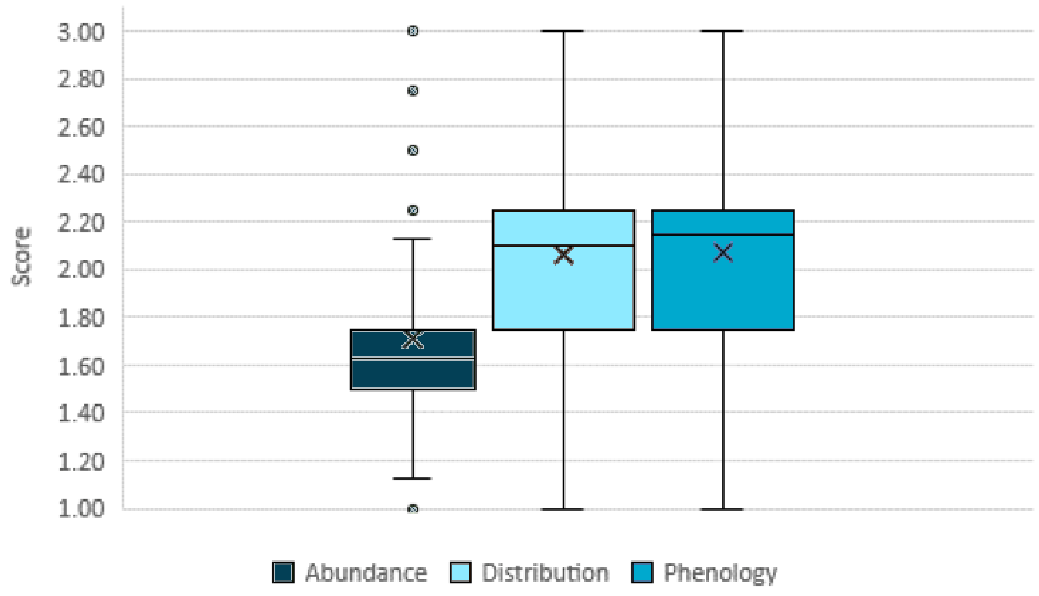


Figure 1-2: Box and whiskers sensitivity scores for all species and regions combined, grouped by sensitivity attribute. Dots show outliers, cross shows mean, line shows median.

1.3.1.2 Sensitivity by region - abundance, distribution, and phenology

A similar pattern was observed when considering sensitivity for species at the level of the five regions, species sensitivity scores were lowest for abundance change, and higher for distribution and phenology (Figure 1-3). Phenology was most sensitive for region 1 and 5, while distribution was higher for regions 2, 3 and 4 (Figure 1-4). The total score for the top 10 species in each region is shown in Table 1- 3with scores of all other species found in Appendix 1.

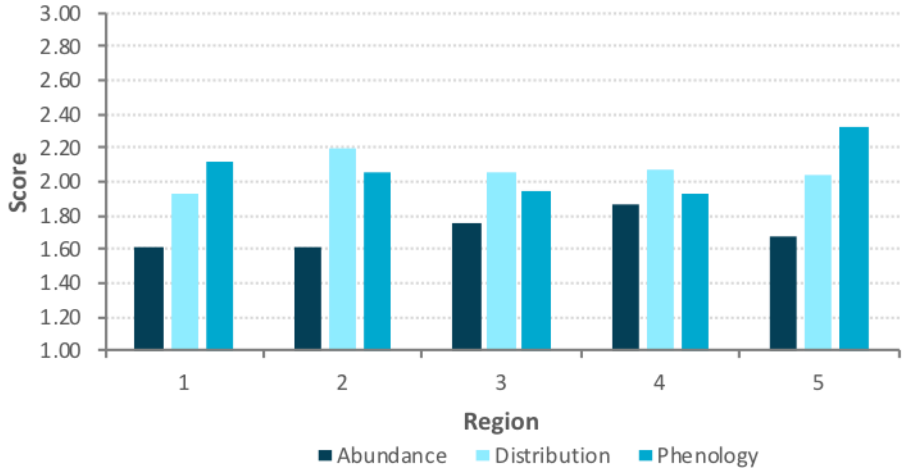
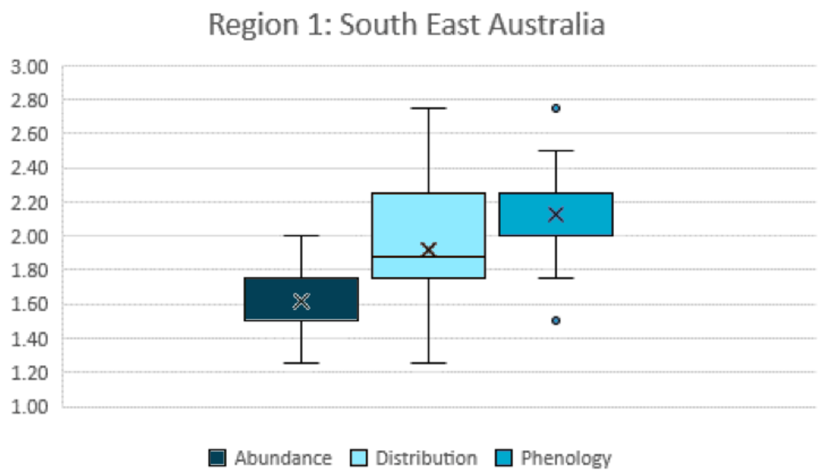


Figure 1-3: Sensitivity scores for all species, grouped by response category across regions. Region 1: south-east, 2: Western Australia, 3: north-west Australia, 4: Gulf of Carpentaria, 5: East coast Queensland.

(a)



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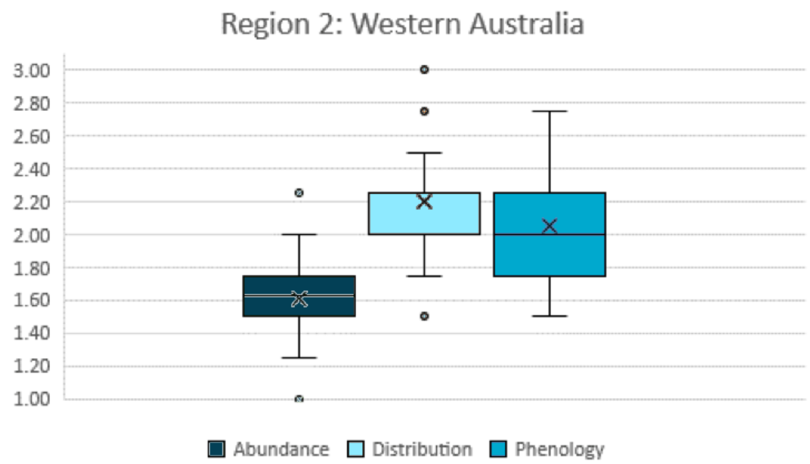

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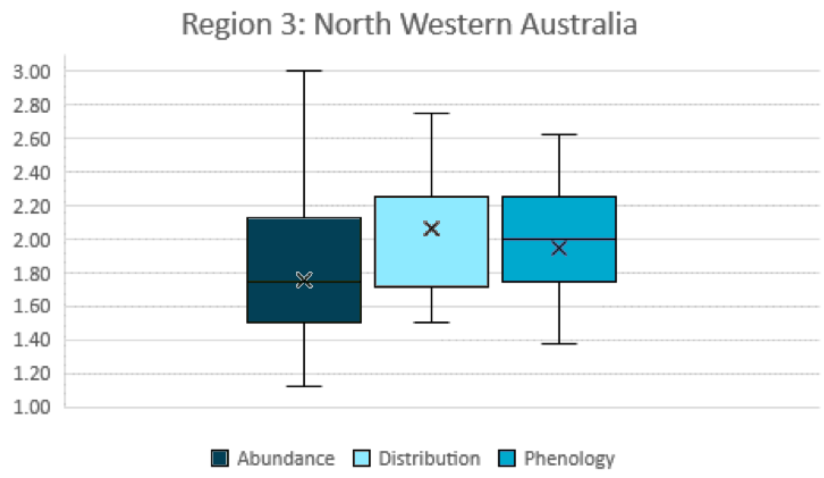

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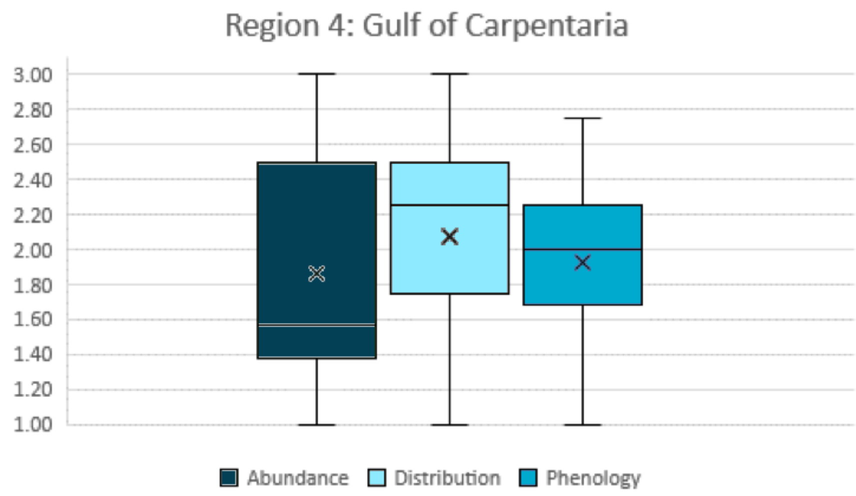

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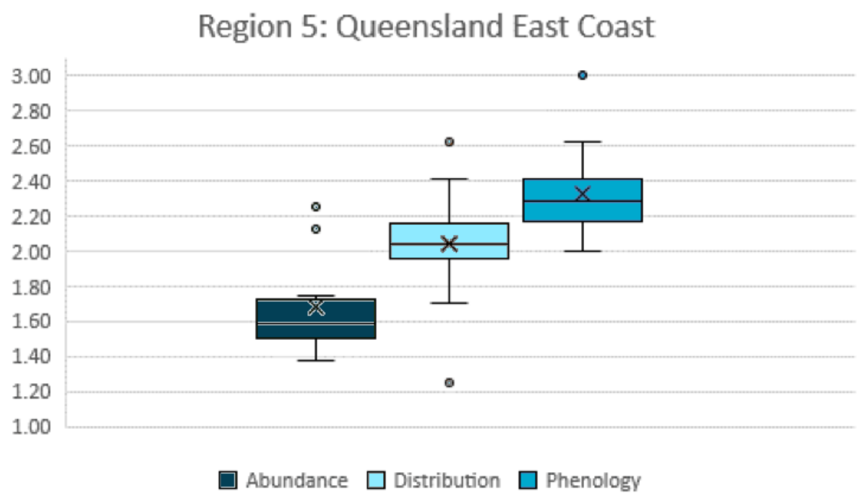


Figure 1-4: Box and whiskers plots for species in each region. Dots show outliers, cross shows mean, line shows median.

1.3.1.3 Sensitivity by region and taxa group – abundance, distribution and phenology

When all regions were combined and sensitivity by broad taxonomic grouping considered, the overall sensitivity scores were highest for invertebrates, and lowest for the pelagic fishes and chondrichthyans (Figure 1-5). For species composition in the relevant regions see Appendix A.

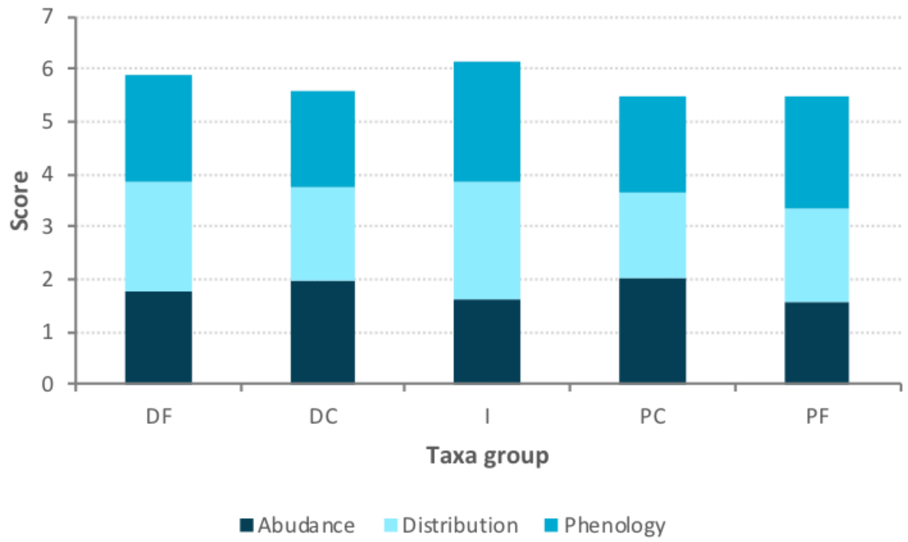


Figure 1-5: Sensitivity scores for species and regions combined by taxa groups. DF, demersal fishes, DC, demersal chondrichthyans, I: Invertebrates, PC Pelagic chondrichthyans, PF, pelagic fishes.

The sensitivity scores by taxa group for each region are shown in Figure 1- 6. In south-east Australia (region 1), phenology sensitivity is highest for invertebrates and pelagic fishes, followed by distribution and abundance. For demersal fishes and chondrichthyans, sensitivity scores were similar. No pelagic chondrichthyans were assessed in this region. In Western Australia, abundance sensitivity for demersal chondrichthyans was highest (the highest value observed across regions). No pelagic chondrichthyans were assessed in this region. In north-western Australia, phenology and distribution sensitivity scores for invertebrates were higher than for abundance, while distribution scores were highest for demersal fish. The Gulf of Carpentaria sensitivity scores for each taxa shows that distribution scores were highest for invertebrates. For the Queensland east coast, phenology sensitivity was scored as the highest for all groups, followed by distribution for three groups, and abundance for two.

These scores represent sensitivity to change and not vulnerability (which is “bad”). Changes in distribution and phenology are not inherently good or bad (high scores just indicate sensitivity to change). Management thus needs to consider how arrangements can cope with changes in distribution or phenology. With regard to distribution, pelagic species have flexible responses to changing environmental conditions, and can move large distances in search of suitable environments and thus have low sensitivity. Coastal demersal invertebrates have limited dispersal, spawning windows associated with particular environmental conditions, and are thus sensitive with regard to both distribution and phenology. Missing data were not a big influence on the scores described above.

Figure 1- 6: Scores by region and taxa groups (a-e). DC: demersal chondrichthyans; PC: pelagic chondrichthyans; DF: demersal fish; PF: pelagic fish; I: invertebrates.

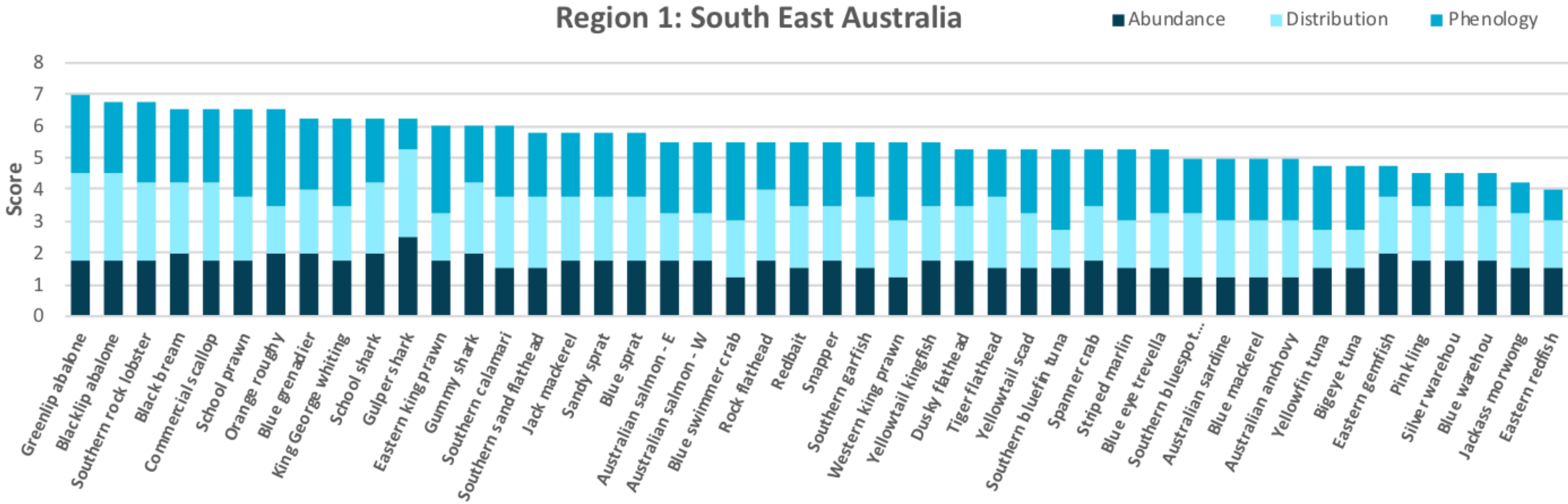
1.3.1.4 Sensitivity for each region - individual species

The most sensitive species based on combined abundance, distribution and phenology scores in each region are shown in Table 1- 3. In the south-east (region 1), two species of abalone and southern rock lobster were ranked as most sensitive, and there were three Commonwealth species in the top 10. In Western Australia (region 2), two small coastal fishes were most sensitive, with two abalone species also in the top 10. In Region 3 (Northwest Australia) sailfish was considered most sensitive while in the Gulf of Carpentaria (region 4) and the Queensland east coast (region 5) it was beche-de-mer. One Commonwealth species – Banana prawn – was in the top 10. Overall, the 10 species had a higher average sensitivity score for the Gulf of Carpentaria (region 4) and lowest for the south-east (region 1). The full sensitivity profile for each region shows the relative contribution of abundance, distribution and phenology by species (Figure 1- 7). Also note that the same species in different locations (e.g. Blacktip shark) can have different sensitivity scores due to minor differences in the scoring by different expert groups.

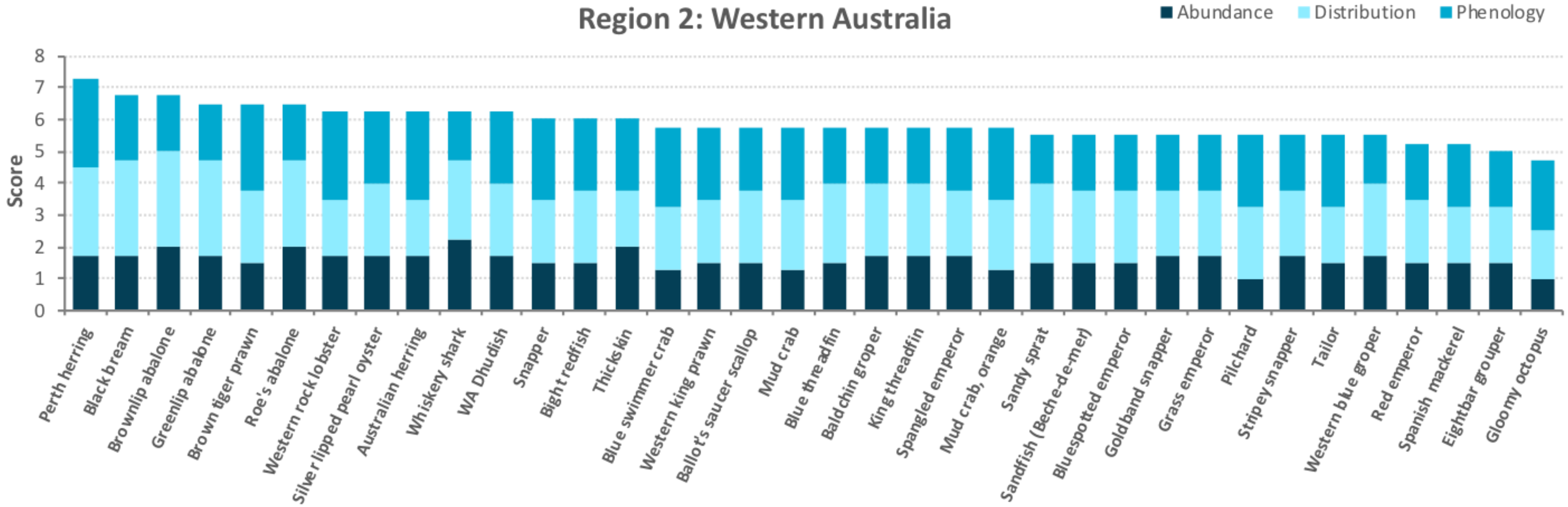
Table 1- 3: Top ten species by overall sensitivity score for each region. Overall scores mask dominant sensitivities in abundance, phenology and distribution, which are detailed elsewhere in the report (e.g. **Appendix A Table 1-10**). Species captured in Commonwealth fisheries are indicated by a *

Region 1		**Region 2**		**Region 3**		**Region 4**		**Region 5**	
Species	Score	Species	Score	Species	Score	Species	Score	Species	Score
Greenlip Abalone	7.00	Perth Herring	7.25	Billfish (Sailfish)*	7.50	Sandfish (Beche-de-mer)	8.00	Sandfish (Beche-de-mer)	7.38
Blacklip abalone	6.75	Black bream	6.75	Sandfish (Beche-de-mer)	7.13	Grass emperor	7.75	Tropical lobster	7.25
Southern rock lobster	6.75	Brownlip abalone	6.75	Crimson snapper	7.00	Red emperor	7.75	Pigeye shark	6.63
Black bream	6.50	Greenlip abalone	6.50	Tropical lobster	6.75	Spangled emperor	7.75	Scalloped hammerhead	6.63
Commercial scallop*	6.50	Brown tiger prawn	6.50	Golden snapper	6.63	Golden snapper	7.75	Blacktip shark 1 (*C. tilstoni*)	6.50
School prawn	6.50	Roe's abalone	6.50	Red emperor	6.50	Mangrove jack	7.75	Blacktip shark 2 (*C. limbatus*)	6.50
Blue grenadier*	6.25	Western rock lobster	6.25	Spangled emperor	6.50	Billfish (Sailfish)*	7.50	Spot tail shark	6.50
King George whiting	6.25	Silver lipped pearl oyster	6.25	Mangrove jack	6.50	Goldband snapper	7.00	Red throat emperor	6.38
Eastern king prawn	6.00	Australian herring	6.25	Grass emperor	6.38	Crimson snapper	7.00	Banana prawn*	6.25
Gummy shark*	6.00	Whiskery shark	6.25	Bug	6.25	Saddle tail snapper	7.00	King threadfin	6.25
Overall average	6.45		6.525		6.714		7.525		6.627

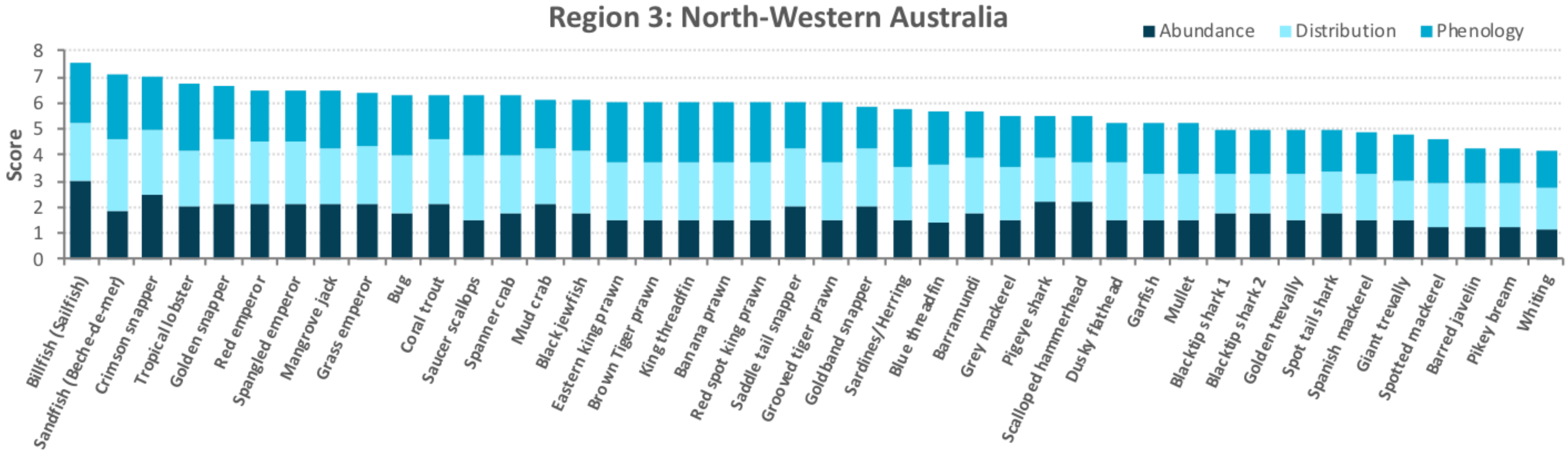
(a)


Region 1: South East Australia
Abundance
Distribution
Phenology
Score
0
1
2
3
4
5
6
7
8
Greenlip abalone
Blacklip abalone
Southern rock lobster
Black bream
Commercial scallop
School prawn
Orange roughy
Blue grenadier
King George whiting
School shark
Gulper shark
Eastern king prawn
Gummy shark
Southern calamari
Southern sand flathead
Jack mackerel
Sandy sprat
Blue sprat
Australian salmon - E
Australian salmon - W
Blue swimmer crab
Rock flathead
Redbait
Snapper
Southern garfish
Western king prawn
Yellowtail kingfish
Dusky flathead
Tiger flathead
Yellowtail scad
Southern bluefin tuna
Spanner crab
Striped marlin
Blue eye trevella
Southern bluespot...
Australian sardine
Blue mackerel
Australian anchovy
Yellowfin tuna
Bigeye tuna
Eastern gemfish
Pink ling
Silver warehou
Blue warehou
Jackass morwong
Eastern redfish

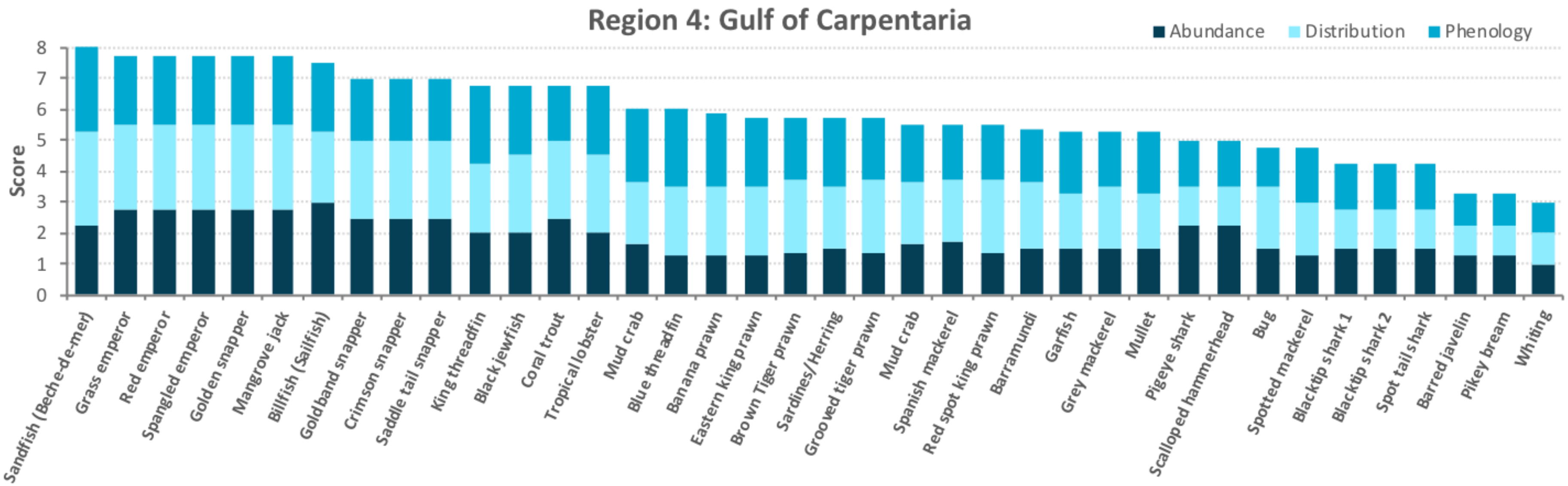
(b)


Region 2: Western Australia
Abundance
Distribution
Phenology
Score
0
1
2
3
4
5
6
7
8
Perth herring
Black bream
Brownlip abalone
Greenlip abalone
Brown tiger prawn
Roe's abalone
Western rock lobster
Silver lipped pearl oyster
Australian herring
Whiskery shark
WA Dhudish
Snapper
Bight redfish
Thickskin
Blue swimmer crab
Western king prawn
Ballot's saucer scallop
Mud crab
Blue threadfin
Baldchin groper
King threadfin
Spangled emperor
Mud crab, orange
Sandy sprat
Sandfish (Beche-de-mer)
Bluespotted emperor
Goldband snapper
Grass emperor
Pilchard
Stripey snapper
Tailor
Western blue groper
Red emperor
Spanish mackerel
Eightbar grouper
Gloomy octopus

(c)


Region 3: North-Western Australia
Abundance
Distribution
Phenology
Score
0
1
2
3
4
5
6
7
8
Billfish (Sailfish)
Sandfish (Beche-de-mer)
Crimson snapper
Tropical lobster
Golden snapper
Red emperor
Spangled emperor
Mangrove jack
Grass emperor
Bug
Coral trout
Saucer scallops
Spanner crab
Mud crab
Black jewfish
Eastern king prawn
Brown Tiger prawn
King threadfin
Banana prawn
Red spot king prawn
Saddle tail snapper
Grooved tiger prawn
Goldband snapper
Sardines/Herring
Blue threadfin
Barramundi
Grey mackerel
Pigeye shark
Scalloped hammerhead
Dusky flathead
Garfish
Mullet
Blacktip shark 1
Blacktip shark 2
Golden trevally
Spot tail shark
Spanish mackerel
Giant trevally
Spotted mackerel
Barred javelin
Pikey bream
Whiting

(d)


Region 4: Gulf of Carpentaria
Abundance
Distribution
Phenology
Score
0
1
2
3
4
5
6
7
8
Sandfish (Beche-de-mer)
Grass emperor
Red emperor
Spangled emperor
Golden snapper
Mangrove jack
Billfish (Sailfish)
Goldband snapper
Crimson snapper
Saddle tail snapper
King threadfin
Black jewfish
Coral trout
Tropical lobster
Mud crab
Blue threadfin
Banana prawn
Eastern king prawn
Brown Tiger prawn
Sardines/Herring
Grooved tiger prawn
Mud crab
Spanish mackerel
Red spot king prawn
Barramundi
Garfish
Grey mackerel
Mullet
Pigeye shark
Scalloped hammerhead
Bug
Spotted mackerel
Blacktip shark 1
Blacktip shark 2
Spot tail shark
Barred javelin
Pikey bream
Whiting

(e)

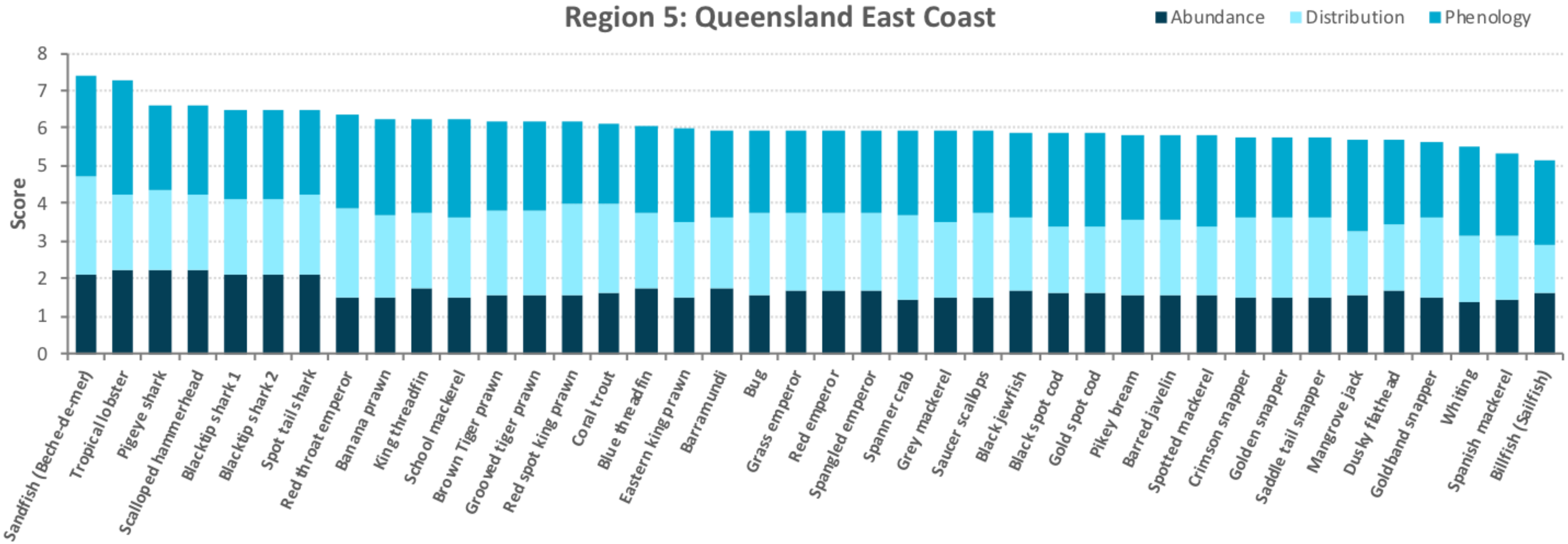


Figure 1- 7: Sensitivity scores by species by region. The colours show the different contribution by abundance, distribution and phenology to the overall score.

1.3.2 Sensitivity by gear-type

A total of 54 species could be allocated to a fishery and hence to a gear type (Table 1-4). The number of species per gear-type ranged from two (dredge) to 29 (gillnet). Each species could be allocated to more than one fishery and hence gear type.

Table 1-4: Species fished by gear type from fishing data available. Not including Commonwealth fisheries (which also have longline and midwater trawl)

Fishing Gear	Species	
Dive	Blacklip Abalone	Greenlip Abalone
	Brown Tiger Prawn	Silver Lipped Pearl Oyster
	Commercial Scallop	Tropical Lobster
	Dusky Flathead	Whiting
Dredge	Ballot's Saucer Scallop	Commercial Scallop
Gillnet	Australian Salmon - western	King Threadfin
	Banana Prawn	Red Emperor
	Barramundi	Snapper
	Black Jewfish	Southern Calamari
	Blacktip Shark 1	Southern Garfish
	Blacktip Shark 2	Southern Sand flathead
	Blue Mackerel	Spanish Mackerel
	Blue Swimmer crab	Spot tail Shark
	Dusky Flathead	Spotted Mackerel
	Goldband Snapper	Tailor
	Golden Snapper	Sandbar shark
	Grey Mackerel	Tiger Flathead
	Gummy Shark	WA Dhudish
	Jack Mackerel	Whiting
	King George Whiting	
Line	Black jewfish	Red Emperor
	Coral Trout	Red Throat Emperor
	Crimson Snapper	Saddle Tail Snapper
	Goldband Snapper	Snapper
	Golden Snapper	Southern Sand Flathead
	Grey Mackerel	Spanish Mackerel
	Gummy Shark	Tailor
	King George Whiting	WA Dhudish
Purse seine	Australian Salmon - eastern	Snapper
	Australian Sardine	Tailor
	Blue Mackerel	
Trap	Australian Salmon - western	Snapper
	Blacklip Abalone	Southern Calamari
	Blue Mackerel	Southern Garfish
	Blue Swimmer Crab	Southern Rock Lobster
	Goldband Snapper	Spanner Crab
	Gummy Shark	Tailor
	King George Whiting	Western Rock Lobster
	Red Emperor	Yellowtail Kingfish

Fishing Gear	Species	
Trawl	Ballot's Saucer Scallop	Gummy Shark
	Banana Prawn	Jack Mackerel
	Blue Mackerel	Red Emperor
	Blue Swimmer Crab	Saddle Tail snapper
	Brown Tiger Prawn	School Prawn
	Coral Trout	Snapper
	Crimson Snapper	Southern Calamari
	Eastern King Prawn	Southern Sand Flathead
	Goldband Snapper	Tiger Flathead
	Golden Snapper	Western King Prawn

1.3.2.1 Sensitivity by gear for all regions and species combined

The species captured by dive fisheries had highest sensitivity, followed by dredge species, with purse seine species lowest sensitivity (Figure 1-8). As with previous classifications, across the gear types, phenology sensitivity tended to be highest, followed by distribution and then abundance.

(a)

(b)

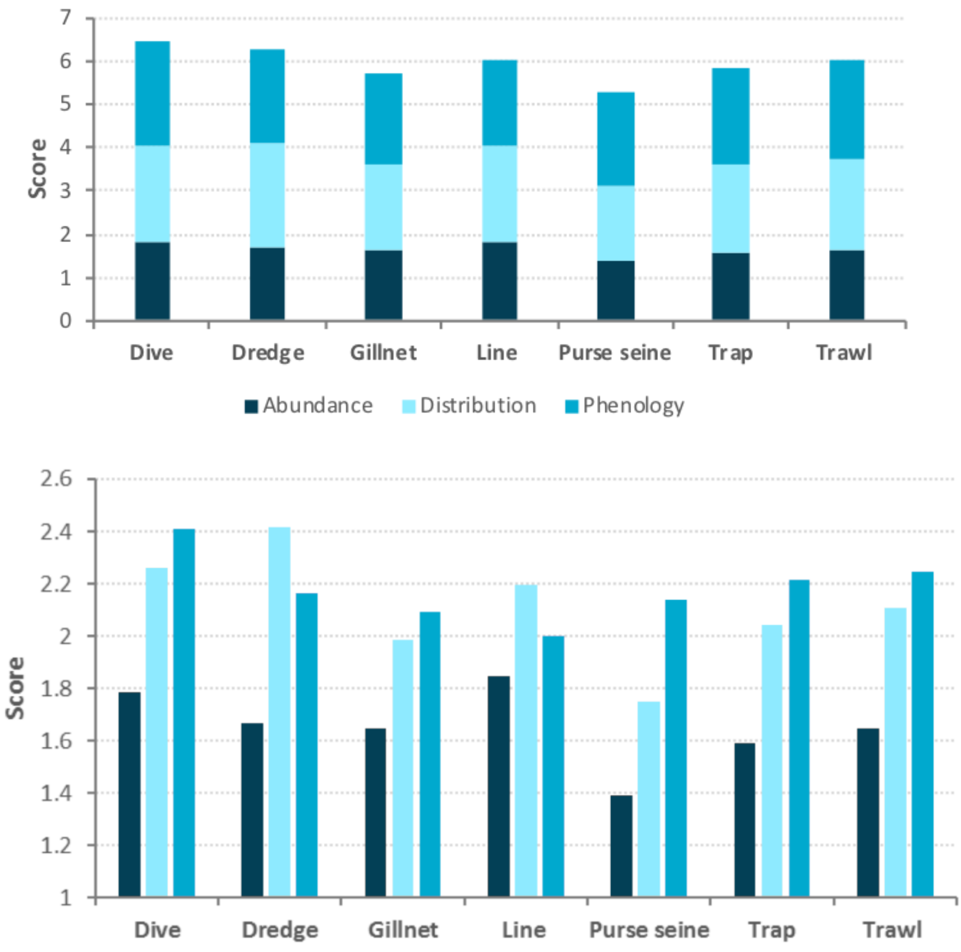


Figure 1-8: Sensitivity scores for all species and regions combined, by fishing gear type; (a) overall scores; (b) by abundance, distribution and phenology scores displayed separately.

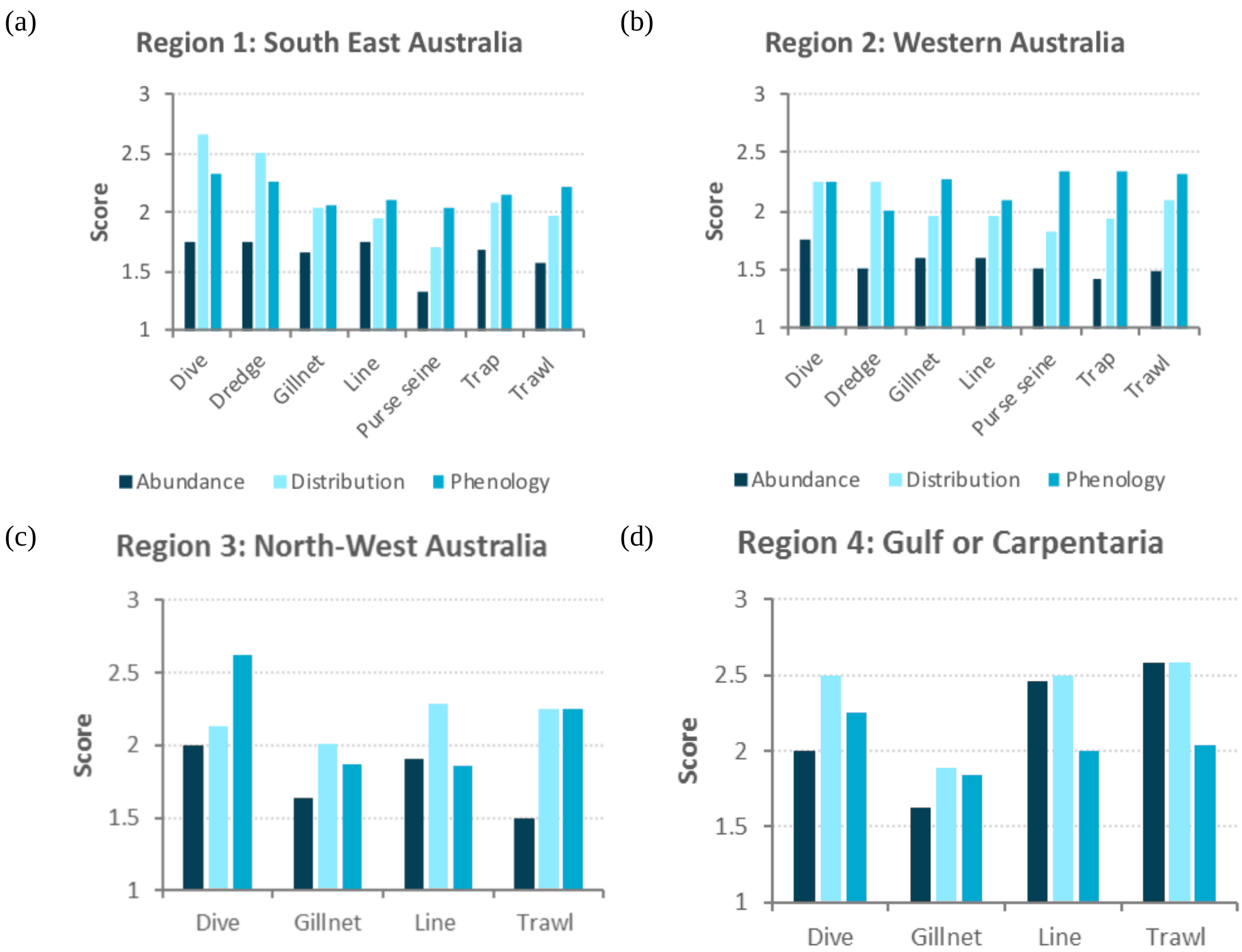
1.3.2.2 Sensitivity by gear type for each region

The species for each region that could be allocated to a fishery are shown in Table 1- 5. In region 2, for example, information on fisheries/gear data for most of the most sensitive species was lacking. When these species are also classified by gear type, the regional analysis shows similar patterns to the aggregated results, with some regional differences (Figure 1- 9). Abundance is more of an issue in the tropical regions of north western Australia and the Gulf of Carpentaria, whereas phenology and distribution sensitivity tends to dominate more in the other regions across all gear types.

Table 1- 5: Species considered per region which were matched to a fishery. *Species within the top 10 most sensitive species per region listed in **Table 1- 3**.

Region	Species	
South East Australia	Australian Salmon – eastern Australian Salmon – western Australian Sardine Blacklip Sbalone* Blue Mackerel Blue Swimmer Crab Commercial Scallop* Dusky Flathead Eastern King Prawn* Greenlip Abalone* Gummy Shark*	Jack Mackerel King George Whiting* School Prawn* Snapper Southern Calamari Southern Farfish Southern Rock Lobster* Southern Sand Flathead Spanner Crab Tiger Flathead Western King Prawn Yellowtail Kingfish
Western Australia	Ballot's Saucer Scallop Blue Swimmer Crab Brown Tiger Prawn* Goldband Snapper Red Emperor Silver Fipped Pearl Oyster* Snapper	Spanish Mackerel Tailor Sandbar shark WA Dhudish Western King Prawn Western Rock Lobster*
North-Western Australia	Banana Prawn Barramundi Black Jewfish Blacktip Shark 1 (*C. tilstoni*) Brown Tiger Prawn Coral Trout Crimson Snapper* Goldband Snapper Golden Snapper*	Grey Mackerel King Threadfin Red Emperor* Saddle Tail Snapper Spanish Mackerel Spot Tail Shark Spotted Mackerel Tropical Lobster*
Gulf of Carpentaria	Barramundi Black jewfish Blacktip Shark 1 (*C. tilstoni*) Blacktip Shark 2 (*C. limbatus*) Coral Trout Crimson Snapper*	Grey Mackerel King Threadfin Red Emperor* Saddle Tail Snapper* Spanish Mackerel Spotted Mackerel

Region	Species	
	Goldband Snapper* Golden Snapper*	Tropical Lobster
Queensland East Coast	Banana Prawn* Barramundi Black jewfish Blacktip shark 1 (*C. tilstoni*)* Blacktip shark 2 (*C. limbatus*)* Brown tiger prawn Coral trout Crimson snapper Dusky flathead Eastern king prawn Goldband snapper	Golden Snapper Grey Mackerel King threadfin* Red emperor Red throat emperor* Saddle tail snapper Spanish mackerel Spanner crab Spotted mackerel Tropical lobster* Whiting



(e)

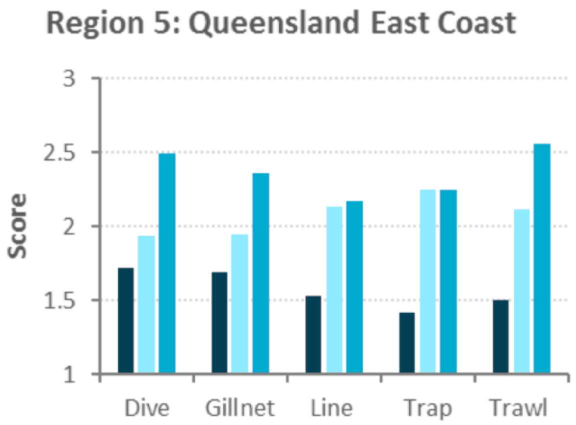
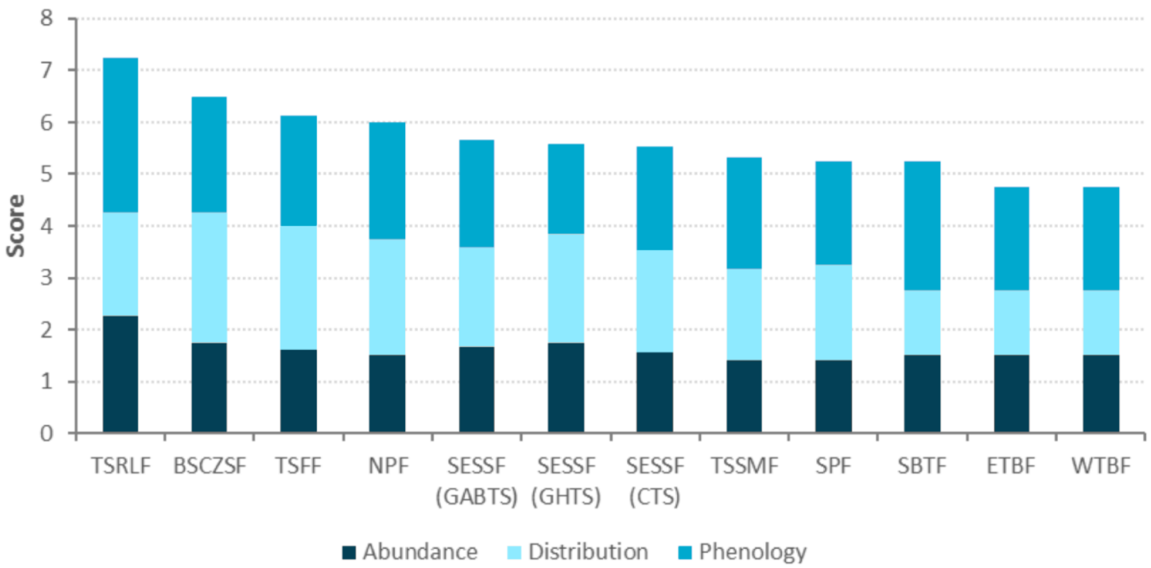


Figure 1- 9: Sensitivity scores for all species combined, by fishing gear for each region. The colours show the different contribution by abundance, distribution and phenology.

1.3.3 Sensitivity by Commonwealth fisheries

In total 28 species could be allocated to one of 12 Commonwealth fisheries (Table 1- 6). Inference is somewhat limited as the sample size per fishery is small, however, this analysis shows that the Torres Strait Rock Lobster Fishery targeting the Tropical rock lobster had the highest combined sensitivity score, while the pelagic tuna fisheries had the lowest (Figure 1- 10). This difference reflects the



individual scores for species within each fishery.

Figure 1- 10: Sensitivity scores for species combined for Commonwealth fisheries.

Table 1- 6: Commonwealth fisheries and targeted species identified from the focal species group.

Fishery	Abbreviation	Species fished
Bass Strait Central Zone Scallop Fishery	BSCZSF	Commercial Scallop
Eastern Tuna and Billfish Fishery	ETBF	Yellowfin Tuna Bigeye Tuna
Northern Prawn Fishery	NPF	Brown Tiger Prawn Banana Prawn Grooved Tiger Prawn
Small Pelagic Fishery	SPF	Australian Sardine Jack Mackerel Blue Mackerel
Southern and Eastern Scalefish and Shark Fishery (Commonwealth Trawl Sector)	SESSF (CTS)	Blue Grenadier Tiger Flathead Australian Sardine Jack Mackerel Blue Mackerel Southern Calamari Yellowtail Kingfish
Southern and Eastern Scalefish and Shark Fishery (Gillnet Hook and Trap Sector)	SESSF (GHTS)	Tiger Flathead Gummy Shark Yellowtail Kingfish
Southern and Eastern Scalefish and Shark Fishery (Great Australian Bight Trawl Sector)	SESSF (GABTS)	Blue Grenadier Jack Mackerel Blue Mackerel
Southern Bluefin Tuna Fishery	SBTF	Southern bluefin Tuna
Torres Strait Finfish Fishery	TSFF	Coral trout
Torres Strait Rock Lobster Fishery	TSRLF	Tropical Lobster
Torres Strait Spanish Mackerel Fishery	TSSMF	Spanish Mackerel
Western Tuna Billfish Fishery	WTBF	Yellowfin Tuna Bigeye Tuna

1.3.3 Statistical analysis of sensitivity results

While the preceding graphs indicate some differences between taxa and regions, these may be due to sample size, or may not be significantly different. To explore the robustness of the results, a GLM was fitted using a Gaussian distribution for the response variable and the link function identity:

$$\text{Score} = \text{Region} + \text{Taxa} + \text{Taxa:Region} \qquad (1)$$

This analysis showed that the interaction term (Taxa:Region) was not statistically significant, suggesting that the same patterns between taxa likely occur across all regions (Table 1- 7). There were significant differences in the sensitivity scores among taxa groups, but not regions. Invertebrates presented significantly higher sensitivity scores than the other taxa groups (Table 1- 8).

Table 1- 7: Results from Generalized Linear Models (GLMs). Significant differences are shown in **bold**.

Term in the model	Degrees of Freedom (DF)	Deviance	Residual DF	Residual deviance	p-value (Chi test)
Null			195	130.39	
Region	4	2.8084	191	127.58	0.3239
Taxa	4	10.7297	187	116.86	***0.0013*****
Region:Taxa	15	13.2318	172	103.62	0.1088

Table 1- 8: Post-hoc comparisons among taxa groups, the values presented are p-values from a t test. Significant differences are shown in **bold**. DF – demersal fishes, DC – demersal chondrichthyans, I – invertebrates, PC – pelagic chondrichthyans, PF – pelagic fishes.

	DF	DC	I	PC	PF
DF	XXXXXXXXX				
DC	0.2397	XXXXXXXXX			
I	***0.0586 .***	***0.0325****	XXXXXXXXX		
PC	0.2309	0.7686	***0.0558.***	XXXXXXXXXX	
PF	***0.0141****	0.6319	***0.0002******	0.9694	XXXXXXXXXX

1.4 Conclusion: Implications based on sensitivity analyses

These results suggest that fisheries with invertebrates are the most sensitive to climate change, a consistent pattern across regions. The sensitivity to particular gears was not consistent across regions, and although the sample size was smaller, this suggests taxa was a more sensible grouping than gear type. Sensitivity with regard to changes in phenology were scored higher than for distribution, followed by abundance.

These sensitivity results can be used to inform priorities for additional monitoring, data collection, research, and industry and management responses. For example, the species with highest sensitivity should be a focus for collection of data in logbooks or observer programs, or for simulation in modelling studies. Additional data can be collated to build the sensitivity results into vulnerability measures, as exists for the Torres Strait (Johnson and Welch 2016). They integrated both ecological and social indicators of exposure, sensitivity and adaptive capacity to identify fishery species with high, medium and low vulnerability to projected climate change in 2030.

Management prioritisation at an aggregate level, such as for a region or fishery can be made based on aggregate sensitivity scores. However, management responses at a species level should be considered relative to each of the distribution, abundance, and phenology categories, rather than using the combined risks across three categories. This is because a high score in a single category may be a problem even if the other two were low. For example, management regulations that affect distribution of fisheries should consider the most sensitive species in the distribution category, management regulations that affect abundance should consider the most sensitive species in the abundance category. This might involve refining jurisdictional boundaries for species that are expected to be sensitive to distribution changes, as they may be moving into new regions and retreating from current locations. Species for which abundance may be sensitive to climate change may need to be a focus for revisions of stock assessments, which might be using out-dated growth or biomass parameter values. This has been shown for Jackass Morwong (e.g. Wayte 2013).

Management regulations applicable to phenology should be examined to consider changes that might be necessary for the most sensntive species in that category. Examples of phenological management arrangements include closed seasons to protect molting, breeding or aggregating animals. If a species is changing the timing of reproduction (a phenological trait), then the closed season may no longer cover the critical time period.

Part II Ecosystem Modelling

2.1 Overview

Marine ecosystem and multi-species models attempt to represent that links between species – either through feeding or habitat use – and how these webs of connections can be influenced by activities such as fishing or environmental drivers such as changes in temperature or primary productivity. This means these models are useful tools for characterising food webs (e.g. their trophic structure and the relative abundance of the species in them). The models are also useful for synthesising and extending scientific understanding of how the ecosystems function, allowing the modellers to tease apart the effects of climate change and fishing on the entire system as well as individual species or groups of species (Plagányi et al. 2011). The models also offer a strategic tool for managers of natural resources, providing them with a testbed where they can explore the consequences of potential management options, testing potential solutions (management scenarios) and seeing how they play out; did they deliver as expected or where there unintended consequences?

Australia has a rich history of ecosystem modelling and a number of ecosystem models, using various modelling platforms, have been developed over the last two decades. Together these models now span nearly the entire coastline of Australia (Figure 2-1). These models were built for varying purposes, but are being increasingly used to provide information in support of fisheries management. A key example is the use of an Atlantis ecosystem model as a tool for evaluating alternative management strategies for the Southern and Eastern Scalefish and Shark Fishery; the information from this modelling exercise was one source of information drawn upon during the restructuring of the south-eastern Australian federal fisheries (Fulton et al. 2014).

As scientific understanding moves on and as the systems being modelled change in response to human activities and environmental drivers, the models need updating to remain relevant – to make sure they are the best possible representations of the system. Consequently, to continue being effective tools for management, these models need to be regularly updated, assessed and refined. In some instances, this means updating parameters, adding or removing species or incorporating improved representations of physical (climate) drivers and processes. Continuing this cycle of refinement will also greatly assist the future capability of these models to address aspects of climate change – both for ecological understanding but also of relevance to industry and management.

The aim of this section of the work was to update CSIRO held Australian ecosystem models and run ecosystem projections out to 2050 using the latest Australian climate change models (i.e. latest temperature and primary productivity projections). The diversity of modelling approaches that have been used in Australia meant a suite of modelling frameworks were used and assessed, which provides some protection against the results being a reflection of the model assumptions rather than a good reflection of scientific understanding. This suite of models included 11 models from three regional modelling platforms: Atlantis (Fulton et al. 2011), Ecopath with Ecosim (Christensen and Walters 2004) and models of immediate complexity (Plagányi et al. 2014). These regional models were supplemented by outputs from two global ecosystem modelling approaches - a size-based model (Blanchard et al. 2012) and an ensemble of species distribution models (Cheung et al. 2016).

2.2 Methods

2.2.1 Climate model projections

The climate projection for each regional model was derived from the recent CSIRO Ocean Downscaling Strategic Project. This project uses the modified Ocean Forecasting Australia Model version 3 (OFAM-v3) run under standard IPCC emissions scenarios to project future ocean states around Australia. These scenarios are taken from global ocean-atmosphere models (CMIP5 climate models; Zhang et al. 2016, 2017; Feng et al. 2017), which set the context for the finer scale OFAM-v3 model, which focuses on the Australian region in more detail.

The OFAM-v3 model was originally developed for upper-ocean short-range operational forecasting (e.g. ocean forecasts of the type found at the bom.gov.au website) and was adapted for climate change studies (Oke et al. 2013; Zhang et al. 2016). The downscaling simulations run with OFAM-v3 provide high-resolution (10km, 0.1º) outputs that can resolve important oceanographic features (e.g. eddies) and how these may change under future climate change. A biogeochemical model that represents nutrient flows and plankton components of the ocean food web (primary producers such as phytoplankton, some bacteria and zooplankton consumers) was coupled with OFAM-v3 to produce patterns of primary productivity, nutrient cycling and carbon fluxes that are consistent with observations. The OFAM3 outputs provide downscaled climate change projections for all common ocean state variables including currents, temperature (ºC), phytoplankton (mmol Nm^{-3}) and primary productivity (mmol C $m^{-2}day^{-1}$). These outputs were then used as input to the ecosystem models.

For the purpose of this study, OFAM-v3 was projected from 2006 to 2101 under two scenarios: (1) a high emission scenario (RCP8.5), and (2) a control scenario without emissions (control). Monthly climate data with spatial resolution of 0.1° (~10km) was stored for use in forcing the ecosystem models.

There is a huge computation demand in running these very fine scale oceanographic models (which track processes that occur on the scales of second to minutes to hours) and simulating many decades into the future. This has meant that until recently most attention has been put into exploring the RCP 8.5 scenario, where there are high emissions and the potential for severe climate change. Trajectories were not available for the other more moderate IPCC scenarios. As noted above this is not a problem in the context of this project as the focus was on the period out to 2050, which is of most interest to industry and management planning, but also happens to be a period when there is a high degree of overlap in the outcomes across scenarios.

2.2.2 Ecosystem model platforms

This project used extant models – drawn from five published and validated modelling platforms - to provide as full a coverage as possible of the Australian EEZ (Table 2-1). This included three regional modelling platforms: a dynamic process-based spatially explicit model, Atlantis (Fulton et al. 2011), a dynamic mass-balanced model, Ecopath with Ecosim (Christensen & Walters 2004), and models of immediate complexity (Plagányi et al. 2014). Two global ecosystem modelling approaches were also used, including a size-based model (Blanchard et al. 2012) and an ensemble of species distribution models (Cheung et al. 2016). These modelling platforms vary greatly in their structure (number of functional groups, size or age classes represented) and the level of complexity (the representation of space and time, ecological processes included) (Table 2-1 and Figure 2-2). In addition, each model was designed for a particular question or purpose and as such often only focuses on (or has high confidence in) particular components of the ecosystem (Table 2-2). This diversity is both a strength and a weakness. By taking different views of the ecosystem the diversity ensures that any results better reflect the true level of scientific understanding and are not unduly influenced by the assumptions of a single approach. However, equally there can be frustration as the differences between models can make comparisons challenging. For example, the degree of taxonomic resolution (group structure and whether the model represents individual species, groups of species with similar functional roles in an ecosystem, or a mix of the two) and the variety fishing gear types (gear structure or fisheries) included in each model can be very different; some models may be highly resolved containing many species and individual fleets using specific gears, whereas other models may have more aggregate functional groups or represent all fishing pressure simply in terms of gear type or a single aggregate fishery.

Another challenge is understanding, and accounting for, various types of model uncertainty in large dynamic and deterministic models. Uncertainty can be due to uncertainty about which parameter values to use for a specific ecological process (e.g. growth) for each species, but can go further to which species should be in the model (i.e. what are the important species in a system), how the species are connected (i.e. the form of the diet connections used) or what are the dominant processes in the system and they will change under climate change. The modellers have done their best to grapple with these uncertainties – for example the Atlantis model for SE Australia has been run under multiple plausible ecological parameterisations and with two different representation of the fisheries (one which assumes a fixed level of fishing pressure into the future, which is the common approach taken in Ecopath with Ecosim, but also a more dynamic representation of how fisheries and management processes actually operate in the SESSF). To assist stakeholders, each model developer provided an expert judgement regarding the degree of confidence associated with the responses of each functional group or species (low – medium – high) to climate and fisheries drivers in each region. These were mostly based on how well modelled biomass and catch trajectories fit the available data; where there were no time-series, biomass or catch data, with which to constrain the model and improve its performance functional groups were judged to have low confidence. Whereas species that had been fit to historical data and where effort had been put into transferring knowledge around physiological responses to climate change from experiments into the model were judged as having higher confidence. Note these judgements are best considered qualitatively and within individual models, they should not be quantitatively combined to give aggregate confidence scores when comparing across different model outputs. Although it is fair to say that if the same group is judged with low confidence (high uncertainty) in each model then overall it is safe to say there is low confidence in projections of its future state.

2.2.2.1 Regional models (Atlantis, EwE and MICE)

Each regional model has been implemented for a specific Australian marine ecosystem, with the combined set covering much of Australia's coastline (Figure 2-1) and representing all its major ecosystem types: Great Barrier Reef, Coral Sea, Gulf of Carpentaria, Northwest Shelf (off the Pilbara), Ningaloo Reef (Gascoyne coast), southwest Australia (e.g. Jurien Bay), Great Australian Bight, southeast Australia (both the entire coast and smaller regions along the New South Wales Coast and off Tasmania). These models each try to represent the entire ecosystem by including the key processes in the system, from physics to biology, and fisheries. However, there are vast differences in the assumptions, scale and resolution that are represented by the different modelling platforms (Table 2-2).

Atlantis is a processed based (or deterministic) modelling platform with high complexity. It uses a large number of parameters, represents a large number of ecological processes and is explicitly three dimensional, with vertical and horizontal habitats characterised at half daily time-steps (Fulton et al. 2011, Smith et al. 2015). This allows the model to be used to assess spatially explicit pressures, ecological consequences and fisheries management evaluation. Atlantis models contain the full spectrum of the food web with around 50-100 species or functional groups represented for a given ecosystem. Any species represented are typically those that are of key industry or conservation interest, while the functional groups represent the majority of the species, grouping them based on maximum size, feeding preferences, habitat use, ontogenetic shifts etc. For each species or functional group, the model tracks dynamic changes in the biomass, distribution and phenology (e.g. growth, condition, movement and recruitment) as well as the size and abundance at age (i.e. Atlantis uses age structured representations for large parts of the ecosystem). Atlantis models are forced by temperature, salinity, and physical oceanography which affect the growth rates and habitat distribution of functional groups based on understanding from the literature. Model inputs and outputs are often seasonal and area-specific. In addition to the ecological processes major human activities and influences can be represented to varying degrees of detail – riverine inputs or pollutant outfalls can be set as input to the model and fisheries (and other human activities) can be represented as either simple pressure-impact-response formulations (e.g. fishing mortality rates) or as more detailed process-level representations of effort allocation, operations and the assessment-management decision making cycle. For greater details on Atlantis models, see the user manual: Audzijonyte et al. 2017.

Ecopath with Ecosim (EwE) is a mass-balanced model that accounts for trophic interactions among organisms at multiple trophic levels by describing matter and energy flows (Christensen & Walters 2004, Colleter et al. 2015). The taxonomic resolution of EwE models is typically similar to that used in Atlantis, although it rarely includes the age and size structure Atlantis incorporates, instead it uses biomass pools to represent each group in the food web. Both the spatial and temporal resolution is often much coarser than Atlantis, with mean biomass trajectories produced for each functional group monthly or annually over an entire region. EwE models are easier to parametrize than Atlantis models, with just four data points required as initial conditions for each functional group (biomass, production, consumption and ecotrophic efficiency) as well as diet and catch/discard information. EwE models are forced by time-series of primary productivity, which then impact the amount of energy available for higher order consumers to grow and reproduce. The representation of fisheries in EwE models is fairly straight forward, based on fishing mortality rates per fisheries sector. For more details on EwE models, read: Steenbeek et al. 2016 and Christensen et al. 2005.

Models of intermediate complexity for ecosystem assessment (MICE), also referred to as minimally realistic models are built to represent the critical parts of the system. They take a different philosophy to Atlantis and EwE. These models take a broad view of the system and its constituents, using data fitting where they can but recognising that their skill will be limited for the poorer known species; this means they are best used in the role of strategic hypothesis generation around the relative performance of different management options or the potential ecosystem consequences of a particular action. They do not have the precision of MICE models, which are the intellectual descendants of stock assessment models and are focused on representing just a limited number of species (2-5) and the major physical (or chemical) processes interacting with those species. Because of their reduced complexity, MICE models are formally fitted to data and more explicitly account for uncertainty. Because of this, MICE models can be used as a fairly rigorous and tactical management approach (i.e. they could be used to make day-to-day operational management decisions), particularly when assessing climate change impacts (Plagányi et al. 2011).

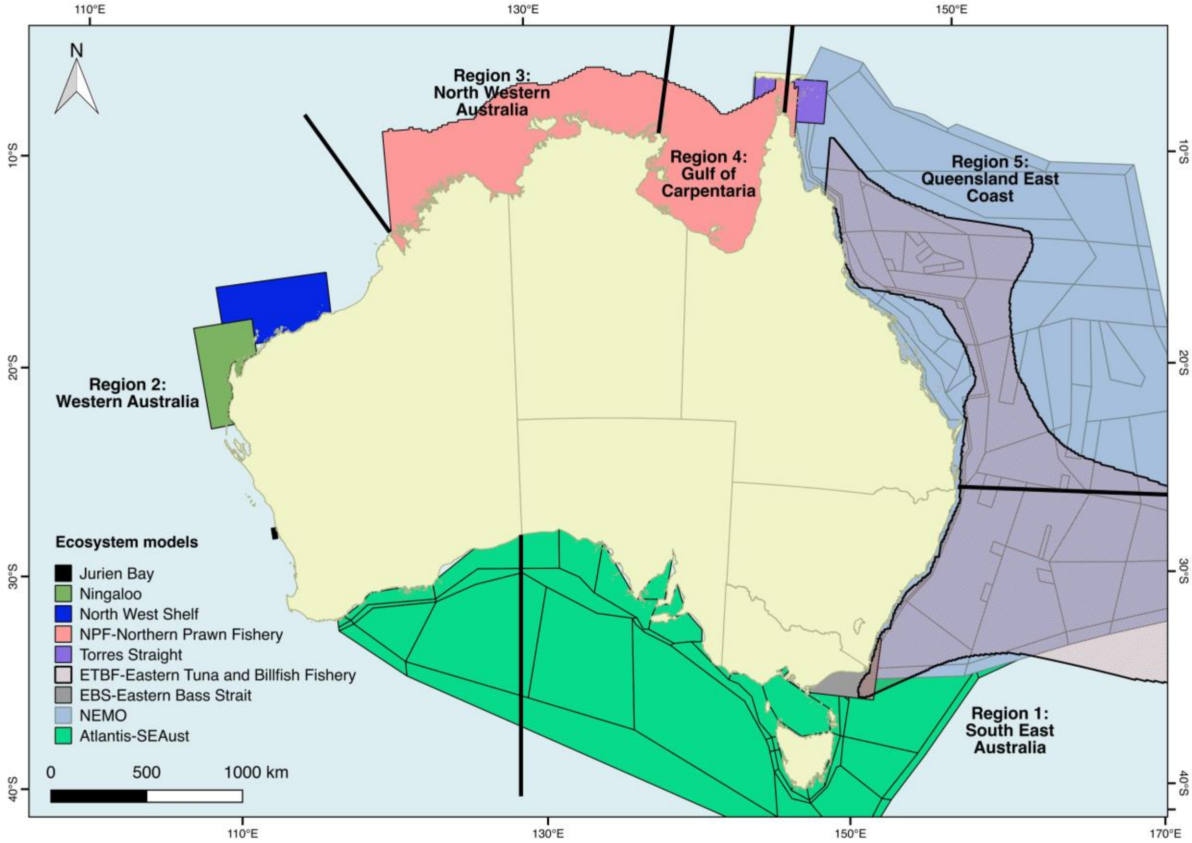


Figure 2-1: Map showing the ecosystem models within each of the 5 regions used in the sensitivity assessment. In addition, two global modelling platforms were used to provide information across the EEZ.

2.1.1.1 Regional forcing files

Depending on the type of ecosystem model, daily to monthly climate forcing files were created by extracting and interpolating the climate variables to the geometry of the model. Atlantis models were forced with an interpolated times series of forcing data of daily temperature, salinity and currents (oceanographic exchanges). To do this the original monthly climate data was overlayed onto the geometry of the Atlantis models to extract mean monthly climate values for each spatial box and horizontal layer in the model domain. Where there was no climate data, the average of the adjacent box values in the appropriate layer was used. The monthly value per box and layer was then interpolated to create daily forcing data. The species and functional groups within Atlantis then responded to these conditions – both through physiological rates (e.g. growth) that are conditioned on ambient temperatures and via modifying spatial distributions if conditions were beyond their tolerance.

The other ecosystem models had coarser temporal and (vertical and horizontal) spatial resolution (e.g. EwE and MICE). This mean that mean monthly surface values of climate data were the appropriate means of forcing those models. These forcing time series were calculated from the gridded data by extracting the data for the specific area of the model (Figure 2-1). EwE models were forced using primary productivity values (which then fed up through the food web), whereas the MICE models were forced with temperature projections (which influenced the groups in the model via response functions). Climate projections, and annual means, used as input forcing for each of the regional models are included in Appendix B Figure 1-2.

2.1.1.2 Global models (Size spectrum and species distribution)

To expand the ensemble of approaches used to consider future projections, two additional modelling platforms were included. These were global scale models that had contributed climate simulations to the Fisheries Inter-Model Comparison Project (FISH-MIP), which is a subset of the Inter-Sectoral Impact Model Intercomparison Project (Tittensor et al. 2017). These international initiatives ask modellers from around the world to run their models using standardised forcing time series (which represent potential future physical conditions under the IPCC scenarios) so that ensembles of model projections can be created. Comparisons across these model projections as well as the full envelope of outcomes across the ensemble are used to advise the IPCC (and national governments) on potential future climate effects under the latest RCP projections. The FISH-MIP repository (https://www.isimip.org/impactmodels/) contained model types beyond those represented by the regional models and so it was decided that an extract for the Australian EEZ region for these other model types should be used to supplement the findings from the regional models.

Size spectrum based models are process models which assume all taxa can be grouped on the basis of mean body size rather than species identity. This may sound a little counter to the way we observe the world (where we tend to group by species or role not size), but it does follow widely observed patterns of marine biomass – in particular distributions of gross community biomass-at-size. These models use food webs characterised by body size relationships – individuals are born into the smallest size class(es) and grow or age into larger size classes through time. Individuals in a size-class groups share similar rates of respirations and production, energy requirements, mortality rates and patterns of predation (Blanchard et al. 2009, Woodward et al. 2005). These models do capture observed community biomass patterns and are becoming a commonly used means of representing marine ecosystems. While size-based models are under development for specific Australian ecosystems, none are yet ready for inclusion in the regional model comparison. Consequently, we drew on the global model, extracting those grid cells covering the Australian EEZ. Climate change projections were run by linking the lower end of the size-based model to primary production time-series derived from biogeochemical models coupled to global climate models.

Species distribution models, such as *dynamic bioclimate envelope models (DBEM)* are based on statistical correlative relationships between a species current spatial range and environmental properties (Cheung et al. 2009). Future distributions are then derived by using climate projections of the environmental properties to project future distributions (and relative abundance) of species. These models are the most taxonomically resolved (to species level) but do not explicitly represent the interconnected nature of fish communities, treating each species as if they existed in isolation (i.e. no food web processes). DBEM models are widely applied, including in the IPCC assessments, as they are one of few quantitative tools to predict wide-scale patterns of climate impact on biodiversity. However, it has been recognised that DBEM models are likely not a good means of predicting effects at fine spatial scales. This is because they lack consideration of biotic interactions, population dynamics (e.g. density dependency), evolutionary change and species dispersal and assume that observed distributions are in equilibrium with their environment (Cheung et al. 2009). Nevertheless, we thought that the approach was worthy of inclusion as it is very different to other modelling approaches included in the study and because there was 100+ species distributions in the FISH-MIP repository. Moreover, for this project, we used the average results from an ensemble of three DBEM's in an effort to reduce uncertainty.

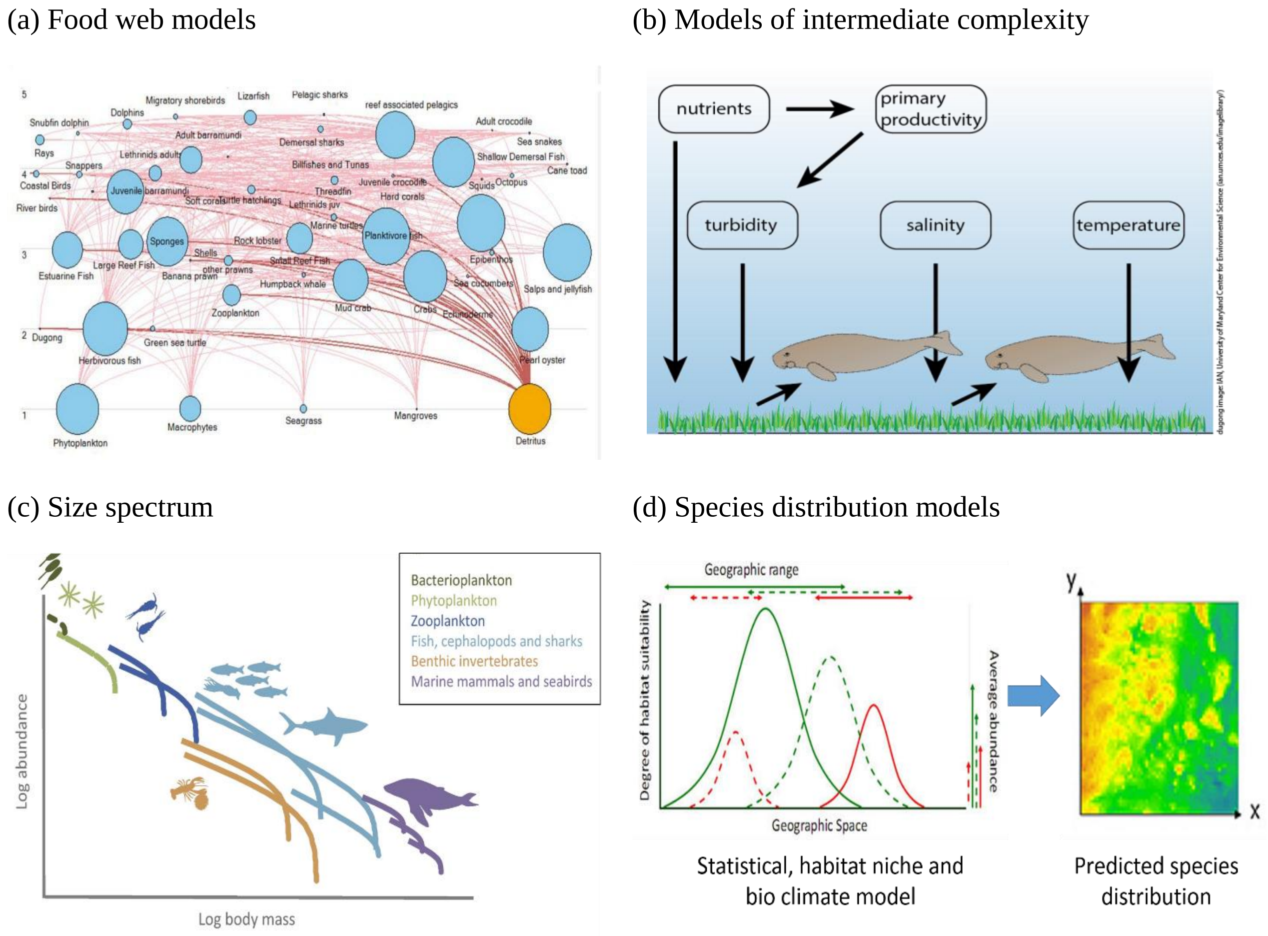


Figure 2-2: Conceptual representations of the different modelling platforms used in this study: (a) Species-based models including Atlantis and Ecopath with Ecosim (EwE), (b) models of intermediate complexity (MICE), (c) Size-spectrum models, and (d) Species distribution (bio climate) models. Reproduced with permission from 2017 Elsevier Ltd and Nature Education.

Table 2-1: Summary of the main differences between the 5 model frameworks used in this project to examine ecosystem responses to climate and fishing management drivers. Temp - temperature, PP - primary productivity.

Model framework	Main assumption	Climate drivers	Level of complexity			Attributes tracked	Dynamically Changing Aspects	Reliability
			Spatial	Temporal	Taxa			
Atlantis	Deterministic, species-based and size/age structured, whole system model	Temp, Salinity	3D (spatial boxes with vertical layers)	High (12hr)	Moderate (groups)	Biomass, Body size, condition Shifts in distribution Fishery yields	Spatial distributions, abundance, strength of trophic interactions, fisheries quotas and targeting, effort levels and distributions*	Good for strategic questions. Good skill where the species or functional are fit to data, poorer reliability where the model is not data constrained
EwE	Mass-balanced, species- based food web model	PP	Low (1 box)	Moderate (seasonal)	Moderate (groups)	Biomass Fishery yields	Realised diets (due to changes in relative biomass)	Good for strategic questions. Good skill if each group uses locally sourced and validated data, performance drops off if data are of poorer quality
MICE	Statistically fitted process model;	Temp	Low (1 box)	Low (annual)	High (species)	Biomass	Levels of fishing pressure	Good tactical models. Statistical fitting means reasonably high reliability and accuracy of the outputs
Size-spectrum	Empirical-ecological relationships; based on size – abundance relationships	Temp, PP	High (10°grid, no vertical)	Low (annual)	Low (6 size-based groups)	Biomass density		Good for strategic questions. Is being fit to data, but in this instance was course resolution so reliability is lower.
Species distribution	Statistical; based on environmental tolerances & physiology	Temp	High (10°grid, no vertical)	Low (annual)	High (species)	Relative abundance	None-based on fixed relationships and just remapping geographic location based on those assumed relationships	Good for strategic questions. Reliant on the quality of the data for that species. See Table B-8 for rating per species.

* The Atlantis model for SE Australia can also explicitly include evolution and acclimation. The simulations included in this report include acclimation but only a very simple representation for evolutionary change leading to parametric shifts within a single simulation (in actuality there is little shift of this kind in the SE Australian Atlantis on the time frames considered within this project).

Table 2-2: Summary of the 13 models used in this project to examine ecosystem responses to climate and fisheries management drivers.

Model framework	Model name	Model domain	Region	Main purpose	Fishing effort	Functional groups	Fished groups	Key reference
Atlantis	AMS/ SEAust	South-east Australia	1	F, E	Constant, Dynamic	64	34-36**	Fulton et al. 2011a, Fulton and Gorton 2014, Fulton et al. 2016
	NEMO	Great barrier reef	5	E	Constant	62	29	Hutton et al. 2012, 2017
EwE	EBS	Eastern Bass Strait	1	E, F	Constant	59	46	Bulman et al. 2006
	GAB	Great Australian Bight	2	R, E	Constant	75	44	Fulton et al. 2017
	Ningaloo	Ningaloo	2	R	Constant	53	40	Fulton et al. 2011b
	NWS	North west shelf	3	E	Constant	36	26	Bulman 2006
	JB	Jurien Bay Marine Park	2	E	Constant	82	33	Lozano-Montes et al. 2011, 2013
	NPF	Gulf of Carpentaria	4	F	Constant	53	42	Bustamante et al.
	ETBF	Eastern Tuna & Billfish Fishery	5	F	Constant	41	30	Griffiths et al. 2009
Size-spectrum	MIZER	Global; Australian box	1-5	E, F	Constant	6	NA	Blanchard et al. 2012
Species distribution	IPSL MPIMR GFDL	Global; Australian EEZ	1-5	E	Constant	138		Cheung et al. 2009
MICE	Seagrass Dugongs	Great Barrier Reef	5	E	Constant	2	NA	Dutra and Plagányi unpublished*
MICE	Lobster	Torres strait	4	F	Constant	1	1	Plagányi et al. 2017

** Depending on if the model was run under constant (F) or dynamic fishing.
E – Ecological understanding; F – fisheries management scenarios; R – Other resource management (including industry)
* Fit to data and validated but yet to complete the peer review process.

2.1.2 Model updates, simulations and analysis

Where possible regional ecosystem models were updated and re-calibrated with the latest information on the fisheries and ecosystem status and any new information on climate and acidification impacts available in the literature. For some models, additional model re-calibration was required due to the adjustment in forcing. Parameter estimates came from the study region wherever possible.

Control and climate forcing files were applied for a projection period of 40 years, from 2010 to 2050. The two Atlantis models were run for at least 10-20 years prior to the projection period of each simulation, this is standard for Atlantis as it allows for consistent model 'burn-in' so that transient effects of the initial conditions in the system do not unduly influence the projections. For the EwE models, observation data was used for at least 10 years before the projection period so that the short-term historical trajectories were reproduced – ensuring the ecosystems were conditioned to the correct biomasses rather than assuming an equilibrium state.

To evaluate the short and medium-term impacts of climate change, the series of 5-year averages of model derived biomass and fisheries catches were calculated and normalised relative to the values 2010. These averages were used rather than snapshot values so that there was not undue influence of inter-annual variation (i.e. the results were not skewed by the coincidence of a "poor" year with a reporting window).

In an effort to look at the impact of climate change alone (and not the combined effects of fishing and climate), an additional indicator was calculated where the output for the climate RCP8.5 scenario was calculated relative to the values from the control scenario, where the OFAM-v3 model was run without the emissions. For the FISH-MIP global models, only temporal anomalies of RCP8.5 were calculated as no control simulations were performed.

It is the experience of scientists working with climate change that anomalies are the best means of understanding change. That is instead of trying to grapple directly with an absolute value it is easier to say there has been a 2°C change or that something has shifted by 20% (for example). Ecosystem modellers have also found that while there may be potentially significant uncertainty around an exact biomass prediction from an ecosystem model, they are more reliable in terms of relative biomass or relative change. Consequently anomalies are used to consider the projected changes.

Three different anomalies were calculated to examine relative changes in biomass at a given time period (X_t):

(i) Combined impacts of fishing and climate at a given time:

1. $$\text{Climate + Fisheries projection} = \text{RCP8.5 projection} = \left(\frac{(X_{t,r} - X_{2010})}{X_{2010}}\right) \cdot 100$$

where $X_{t,r}$ is the value for that group at time t in the RCP scenario

(ii) Impacts of fishing alone at any given time:

2. $$\text{Fisheries only projection} = \text{Control projection} = \left(\frac{(X_{t,c} - X_{2010})}{X_{2010}}\right) \cdot 100.$$

where Xt,c is the value for that group at time t in the RCP scenario

(ii) Impacts of climate change alone at any given time:

3. $$\text{Climate impacts} = \left(\frac{\text{RCP8.5} - \text{Control}}{\text{Control}} \cdot 100\right)_t - \left(\frac{\text{RCP8.5} - \text{Control}}{\text{Control}} \cdot 100\right)_{2010}$$

For each model, we categorised all harvested and TEP (threatened, endangered or protected) species - based on the magnitude and direction of their projected rates of change – into the classes given in Table 2-3. We used a threshold of 10 or 20% change in biomass to define an acute change as smaller changes may constitute normal inter-annual or regional variation. Using this classification, functional groups were then grouped according to a rating system indicating how each responded to the high the emissions scenario. In addition, the influence of the climate driver on the kind of change – whether it enhanced or dampened any increases or decreases was also assessed using the classification system given below.

Table 2-3: Categories of percentage change (vs initial conditions) and the score given for comparisons with the sensitivity assessment. This method uses a change anomaly method – i.e. no change is 0%.

		negative		stable		positive	
RCP8.5 and	<-60%	-40 to-	-20 to -	-20 to	20 to	40 to	>60%
RCP8.5 - Control	<-30%	-30 to -	-20 to -	-10 to	10 to20%	20 to	>30%
Score ^	4	3	2	1	2	3	4

^ for comparisons with results from the sensitivity assessment.

Classification and description based on categorized rates of change

S	Stable – little change under control or climate	RCP=4, cont=4
PD	Positive divergent – increasing under climate but decreasing under control	Rcp>4, cont<4
P1	Positive damped – increasing under control, but less so under climate	rcp>4, cont>=4, rcp<cont
P2	Positive – increasing with no difference between the control and climate	rcp>4, cont>4, rcp=cont
P3	Positive enhanced – increasing under control and more so under climate	rcp>4, cont>=4, rcp>cont
ND	Negative divergent – decreasing under climate but increasing under control	rcp<4, cont>4
N1	Negative damped – decreasing under control, but less so under climate	rcp<4, cont<=4, rcp>cont
N2	Negative – decreasing with no difference under control and climate	rcp<4, cont<4, rcp=cont
N3	Negative enhanced – decreasing under control and more so under climate	rcp<4, cont<=4, rcp<cont

2.2 Results and Discussion

2.2.1 Climate projections in different regional model domains

There was a high degree of temporal variability in sea surface temperature and primary production projected by the climate model under both the control and RCP8.5 scenarios. Across all the model domains, under RCP8.5 scenario, mean changes in 2045-50 (compared to 2010-15) were +0.8°C for sea surface temperature, while integrated primary productivity declined by -5.8%. However, there were some regional trends worth noting. In the EwE-NWS model domain, primary productivity was projected to increase under the control scenario by 0.3 but rose by 9.3% for RCP8.5. Increased primary productivity was also projected under the RCP8.5 scenario (although not the control) for the EwE-Ningaloo and EwE-NWS model domains. The largest declines in primary productivity over the 40 year time span were projected for the EwE-ETBF (-25.9%) and EwE-GAB (-15.2%) model domains. Overall, larger increases in SST were observed in the south eastern Atlantis model domain (+1.0°C) than in the northeaster Atlantis-NEMO model domain (+0.8°C).

In most modelled regions, sea surface temperature is projected to increase while and ocean primary production decreases under the high emissions RCP8.5 scenario (Table 2-4). Mean differences in primary productivity between the control and RCP8.5 scenarios were projected to be largest for the EwE Great Australian Bight (GAB) model domain and smallest for the Eastern Bass Strait (EBS) EwE model domain, with an average decline of -34.4% and -1.7% respectively. Inter-annual variability in the mean primary productivity differences were projected to be largest for the GAB and smallest for the North West Shelf (NWS) EwE model domain. The situation was more variable in the Atlantis models with some locations and depths showing very little change and others (e.g. the Tasman Sea location) showing changed patterns of inter-annual variation as well as changes in mean temperature due to shifts in fronts and eddies in the oceanographic projections.

2.2.2 Overall patterns

Overall 497 species or functional groups – including 294 harvested groups and 53 threatened and protected species (TEPs) – were assessed from the 11 regional ecosystem models around Australia (with 2 variants of the SE Australia Atlantis modelling being considered). A further 6 trophic size-based and system level groups were assessed using the output from the global size spectrum model and 138 species were assessed from the ensemble of global species distribution models.

The regional models show that fishing is often the most important driver in many marine ecosystems, but that climate drivers can exert large responses from certain functional groups (positive and negative changes are possible, with the actual direction of change being species and system dependent). The models also show that the joint effects of fishing and climate are often non-additive as has been shown previously for south eastern Australia (Griffiths et al. 2012; Fulton and Gorton, 2014) and in other areas of the world (Mackinson et al. 2009; Shannon et al. 2008).

2.2.3 Regional outputs from regional models

Direct comparisons across the many regional models is difficult due to the way that different models function and are structured. However, the multi-model ensemble can be used to demonstrate the range of possible responses of the marine ecosystem to effects of continued (and dynamic) levels of fishing, projected climate impacts and the combined effects. Functional groups in the different modelled ecosystems showed a range of responses to climate and fishing, with some models more sensitive to climate drivers than others (Table 2-4). This was due to the way the different models were structured and to the different input forcing (whether primary productivity were used or daily temperature and salinity values. The least sensitive model (i.e. with the smallest changes, the smallest deviation from zero change in average biomass) was the EwE-EBS model, as the small projected change in primary production saw little flow on effects (see Appendix B Figure 1) for the forcing time series used). While the most sensitive model was the EwE-NPF model (which was one of the few domains where primary productivity is projected to increase under climate scenario RCP8.5 (compared to the control scenario) over time. In most instances the level of change in the climate drivers was a good indicator of the level of responsiveness of the model – larger changes in the driver led to larger model responses, with the exception of the EwE-NWS, EwE-NPF, and Atlantis-NEMO models where large responses resulted from relatively small changes in primary productivity.

Table 2-4: Different sensitivities of regional models to climate change (RCP8.5 vs control Anomaly) in 2045-50. The general level of change in the climate drivers (RCP8.5 projected changes in temperature and salinity, or primary productivity) and the sensitivity of the regional system to the climate drivers is reported on a scale from 0 (no significant change in the driver or no model response) to 3 (high degree of change or highly responsive).

Model	Names/regions	Climate drivers	Biomass	Climate	Model
Atlantis	South east Australia	2.3±1.8 (-0.6 to 5.9)	-3±27 (-52 to 168)	1	2
	North east Australia	3.1±1.3 (0.7 to 5.4)	17±86 (-17 to 618)	1	3
EwE	Great Australian Bight	-34.4±16.8 (-84 to -12)	13±118 (-46 to 978)	3	3
	Eastern Bass Strait	-1.7±5.9 (-15 to 10)	0±1 (-3 to 4)	1	0
	Ningaloo Reef	25.9±6.2 (13 to 38)	40±18 (-2 to 79)	1	1
	Jurien Bay, WA	7.3±11.1 (-20 to 27)	-4±34 (-100 to 177)	2	2
	North west shelf	18.9±4.3 (10 to 27)	135±225 (-73 to 924)	1	3
	Norther Prawn Fishery	27.6±2.4 (22 to 33)	2399±10010 (-53 to >5000)	1	3
	Eastern Tuna Billfish Fishery	-22.7±11.3 (-49 to -0.8)	-38±17 (-86 to -6)	2	1
MICE	Torres strait	3.5±1.4 (0.4 to 56)	-15±10 (-25 to -5)	1	1

The dominant direction of change in biomass differed between the regional models. Climate was projected to negatively impact, to various degrees, all functional groups in the EwE-ETBF model (region 5). In contrast, most groups included in the EwE-NPF (region 3) and EwE-Ningaloo (region 4) models responded positively. For all other models, most functional groups were projected to be relatively stable (column S in Table 2-5) and unaffected by climate change (with changes between -20 to 20% from initial biomasses), although there was a small number of groups that underwent much larger changes. Most groups that declined in relative biomass, saw enhanced decreases under the climate compared to the control (Table 2-6).

Responses of all harvested and TEP functional groups (positive or negative) to the combined effects of climate and fishing at years 2020 and 2050 are provided for each of the 11 regional models (Figure 2-3 to Figure 2-11). Time-series plots for each functional group are then provided for each model in Appendix C. While large changes, positive or negative, can result from climate change or indirect effects, where the drop in one species releases other species from predation or competition allowing their biomass to expand, the changes most likely to be of concern to management/industry are those to do with climate mediated declines (where a species decline only occurs, or is stronger, under climate change). Harvested and TEP groups projected to show negative enhanced (N3) or negative divergent (ND) responses to climate (i.e. where a decline is only expressed under climate change, but not under the control) in 2020 and 2050 are listed in Table 2-5. In the short term (2020-25), groups flagged to be of particular concern included rock lobster (region 1), reef associated zooplankton feeders (region 2) and shelf lutjanids and serranids (region 3). In the medium term (2030-35), groups flagged included lobster, morwong and gummy shark (region 1), reef associated zooplankton feeders and lutjanids (region 2), all the NPF prawn species (region 3), swordfish and sailfish (region 5). Projections for 2045-50 highlighted additional groups of concern – including small pelagics, pelagic and deep demersal sharks, piscivorous fish, and bight redfish (region 1), dhufish and pink snapper (region 2), and large sharks and marlin (region 5). The classification of all functional groups, based on the rating system described above and Figures 2.3-2.11, are provided in Appendix B Table 1 to Appendix B Table 5.

In south east Australia (region 1), all 3 ecosystem models showed that piscivorous shelf fishes, flathead (especially deepwater flathead), gemfish and demersal sharks were among the most negatively impacted by climate. All 3 ecosystem models showed that small pelagic fishes such as Jack mackerel, blue mackerel, anchovy, and sardine were among those projected to increase in biomass under increased climate change. In Western Australian (region 2) the EwE models projected that pink snapper, rays and dhufish would be negatively impacted, while reef associated zoobenthos, breaksea cod, tuna and billfish, mackerels would increase in biomass. In North western Australia (region 3) the EwE-NWS projected negative impacts of climate on bream, snappers (Lutjanids), carangids and lizard fish, and positive relative biomass shifts on tunas, seabass and groupers (Serranids), as well as red emperor. In the Gulf of Carpentaria (region 4) the EwE-NPF model indicated the relative biomass of most groups, including prawns and crabs, would likely increase with negative impacts only projected for reef associated carnivorous fish. For the Coral Sea (region 5) the Atlantis-NEMO model projected negative impacts on large pelagic sharks, lobsters, and small planktivorous fishes and positive impacts on macrobenthos and squid. The EwE-EBTF projected negative impacts on all groups, with the most impacted groups including spearfish, swordfish, and large mesopelagic fishes.

Looking beyond those species most heavily impacted by climate change, declines in biomass into the future were observed for a range of groups. In region 1 grenadier declined in some circumstances and declines were seen in other demersal fish such as pink ling and morwong, garfish and deepsea cod, as well as in demersal sharks (including dogfish and gulper sharks) as well as benthic invertebrates such as Macrobenthos (crabs and lobster), scallops and benthic grazers (e.g. abalone); fewer pelagic groups declined, though it was seen in some instances for Jack mackerel and offshore pelagic sharks. In region 2 reef associated species and coastal sharks (large and small) could decline under fishing pressure alone; whereas in region 4 non-climate declines could be seen in lobsters and other prawns. Region 5 could also see declines in deepwater prawns and demersal species such as urchins, tropical lobster, and filter feeding invertebrates shallow demersal fish and reef fish (e.g. herbivorous scrapers).

Protected species

For most regional models, the biomass of TEPS were either stable or showed a decline under projected climate change and under the combined effects of fishing and climate change at all three points considered 2020-2025, 2030-2035, 2045-2050 (Figures 2.3-2.11; Table 2-6). The groups projected to be the most impacted from climate change included albatross, bottlenose dolphins, and penguins (region 1), dolphins and dugongs (region 2), dugongs (region 4), and seabirds, leatherback and green turtles (region 5) (Appendices Tables B2.1-A2.3). There were no TEPS projected to show negative enhanced (N3) or negative decreasing (N2) responses to climate in 2020, but 6 species were indicated to be negatively enhanced in 2050 including various seabirds (region 1), dolphins (region 2) and Mako and white sharks (region 5) (Table 2- 7). While many of these protected species have begun to show stress by 2030-2035, the situation is more complicated in the GAB, where many of these protected species show a transitory increase in biomass before declining again as climate extremes become more common or severe.

2.2.3.1 Dynamic versus constant fishing and model confidence

Systems do not just show uncertainty to climate drivers, human responses can be some of the most uncertain pressures on ecosystems. In an effort to cover this uncertainty, while also maximising compatibility across the models used Atlantis-AMS (the Atlantis model for SE Australia) was run in two models. The first was under constant fishing mortality rates – i.e. in the same way as for EwE to maximise comparability between Atlantis and EwE models. The second was with fully dynamic representations of effort allocation and the management decision process. This second variant allows for consideration of how human responses to changing conditions can help or hinder ecosystem resilience and recovery. The differences in the results between the model variants can also be used to examine the robustness of model results – i.e. potential model reliability. Under dynamic fishing management there were fewer harvested species that were negatively impacted by climate over both the short and long terms (Figure 2-3). For example, Grenadier, Warehou, Jack Mackerel and School Shark fared better in the dynamic fisheries and management model. As a lot of effort was put into calibrating the model for these species there is moderate to high confidence in this result. In contrast, the results for invertebrates (e.g. lobster, scallop and benthic grazers) are highly uncertain as there is little confidence in those groups. TEP species are more mixed, with moderate to high confidence for the pinnipeds and better known mammals and seabirds but low for others such as sea lions (whose life history makes it incredibly difficult to represent well).

As the state and dynamics of the southeast of Australia is uncertain (e.g. as there has not been extensive collection of diet information across the region in over 20 years), multiple productivity and food web parameterisations were run for Atlantis-AMS. The parameter sets used were bounded so that they were constrained only to sets that produced plausible modelled systems given the available data and alternative possible system structures (the judgements of plausibility were based on a pattern-oriented modelling approach using the approach given in Kramer-Schadt et al. 2007). As outlined in Fulton and Gorton (2014), the alternative diet structure was expanded to allow for diets with the potential for the level of flexibility observed in the North Sea and on Georges Bank over the last century. All of the alternative parameterisations were then all carried forward in the simulations for both the dynamic and fixed F versions of Atlantis-AMS.

2.2.3.2 Predicted changes in distribution and phenology

Spatial output from the Atlantis-AMS and Atlantis-NEMO ecosystem models were visually assessed and characterised (Appendix B Figure 3 to Appendix B Figure10). In region 1, the Atlantis-AMS model predicted that primary production across the Tasman Sea could become much more variable with strings of very productive years interspersed by series of years with exceptionally low production. This was reflected in the patchy and shifting distributions, both vertically and horizontally, for jellies, forage fish functional groups (Jack Mackerel, Sardine and Anchovy) and mesopelagics. More recognisable distributional shifts were predicted in whiting, redfish, shelf dwelling piscivorous fish, baleen whales and Southern Bluefin tuna, which shifted away from more marginal environments. Localised changes in phenology and body size were predicted in some functional groups including Anchovy, Gemfish, Morwong, Cardinalfish, Grenadier and Gummy Sharks. School Shark was also effected, primarily through the contraction of pupping grounds, which meant there was more variable reproductive success. Blue grenadier was also found to be heavily influenced by recruitment variation and how that may play out into the future.

Table 2-5: Number of functional groups for each response under the high emissions scenario. S = Stable; P1 = Positive damped; P2 = Positive; P3 = Positive enhanced; N1 = Negative damped; N2 = Negative; N3 = Negative enhanced.

								2020									2050				
Region	Model	Group	n	ND	N3	N2	N1	S	P1	P2	P3	PD	ND	N3	N2	N1	S	P1	P2	P3	PD
1	AMS-F	All groups	57	2		5		29	2	12	1	6	3	1	13		16	2	20	2	
		Harvested	34			2		20	1	7	1	3	2	1	7		9	1	12	2	
		TEPs	7					3		4							3		4		
	AMS-Dynamic	All groups	57	1	1	10		28	1	13	3		1		11	1	16	4	20	4	1
		Harvested	34			4		18	1	8	3				6	1	8		16	2	
		TEPs	7					4		3							3	2	1	1	
	GAB	All groups	73	1	5	3		61		3			1	12	4	3	42	2	2	5	1
		Harvested	43	1	5	2		32		3			1	8	4	2	18	2	2	4	1
		TEPs	15			1		14						4		1	9				
	EBS	All groups	56			1		53			1	1			4		50		1		1
		Harvested	45			1		42			1	1			4		39		1		1
		TEPs	5					5									5				
2	JB	All groups	78	2	3	22		43		4	3	1	13	5	16	1	30	3	3	4	3
		Harvested	29	1	2	6		15		3	1	1	3	3	4	1	12	1	1	2	2
		TEPs	4			1		3						1			3				
	Ning	All groups	44					10			1	33					7			3	34
		Harvested	23					2				21					1				23
		TEPs	16					7			1	8					4			3	9
3	NWS	All groups	36	9			1	20	1		3	2	4			1	18		1		12
		Harvested	26	9			1	10	1		3	2	2			1	12		1		10
		TEPs	0																		
4	NPF	All groups	51	1	1	4		14			1	30	2		6		8		1	2	32

				2020									2050								
Region	Model	Group	n	ND	N3	N2	N1	S	P1	P2	P3	PD	ND	N3	N2	N1	S	P1	P2	P3	PD
		Harvested	37		1	4		9			1	22			5		5		1	1	25
		TEPs	5					3				2	1		1		1				2
5	NEMO	All groups	57		1	6		36		7	4	3	5	1	14	2	18		13	4	5
		Harvested	29		1	2		17		4	3	2	4	1	7	2	4		8	3	4
		TEPs	5					4		1							3		2		
	ETBF	All groups	42		16			26						36			6				
		Harvested	26		11			15						23			3				
		TEPs	4		3			1						4							
	MICE	Dugongs	1					1									1				
		Seagrass	1					1												1	
		Lobster	1					1						1							
	TOTAL		497	89	50	74	2	547	7	73	31	76	108	101	106	16	354	17	110	43	100

Table 2-6: List of harvested groups and species with biomass projected to be negative enhanced (N-3) or negative divergent (ND) under climate change in 2020 and 2050. A complete list of species for each model is provided in Appendix Tables B-1 to B-5. Groups in bold represent those species in the Commonwealth fishery. * represents groups with a high level of modeller confidence (i.e. appropriate levels of data were used to parametrise and assess the model projections).

		2020		2050	
Region	Model	Negative divergent	Negative enhanced	Negative divergent	Negative enhanced
1	Atlantis-AMS-F			Small Pelagic fish Pelagic Shark	Piscivorous Fish (S)
	AMS-D				Piscivorous Fish (S)
	EwE-GAB	Rock lobsters	Shelf demersal omnivores Garfish Large demersal piscivores (slope) Squid and cuttlefish (shelf) Crabs and bugs	Rock lobster Crabs and bugs Deep demersal sharks	Large demersal omnivores (shelf) Snapper Birds (Albatross*, Small petrels*, Gulls*, Shags and cormorants*) Tunas and billfish Bight Redfish
	EwE-EBS				
2	EwE-Ningaloo				
	EwE-JB	Reef ass. zoopl. feeders	Rays Dhufish	Reef ass. zooben feeders Pink snapper Western foxfish	Rays Dhufish Dolphins* Reef associated herbivores
3	EwE-NWS	Lutjanids (shelf) Ponyfish (deepwater)		Lutjanids (shelf) Serranids (shelf)	
4	EwE-NPF				
5	Atlantis-NEMO		Lobsters		Mako and white sharks * Epipelagic squid Reef herbivorous fish
	EwE-ETBF		+14 groups (see appendix Table B-5)		+27 groups (see appendix Table B-5)

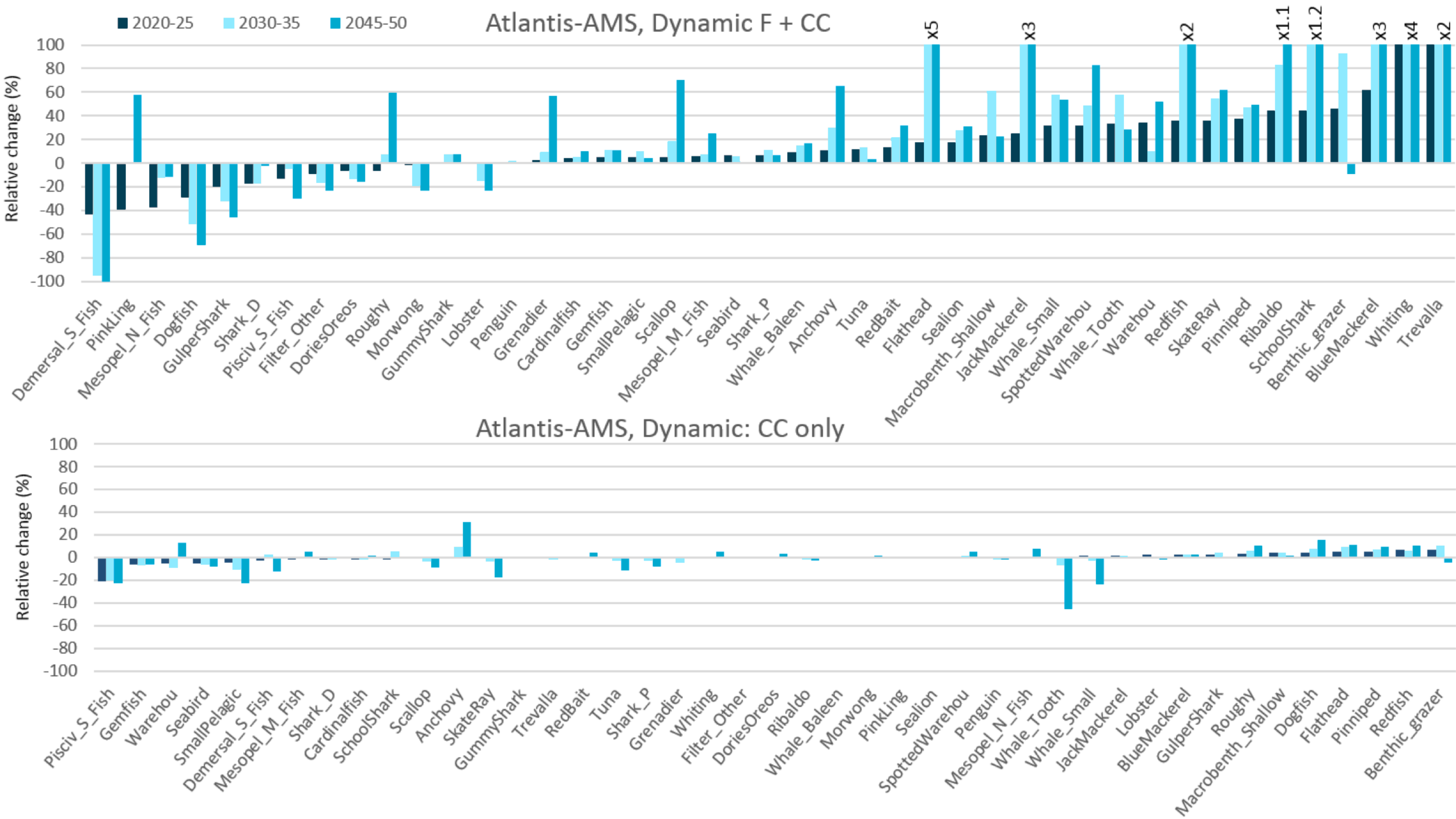


Figure 2-3: Relative changes in biomass of functional groups due to the impacts of (a) climate and fishing, and (b) climate, as predicted the Atlantis-AMS ecosystem model under dynamic fishing management covering much the entire south east Australia (Assessment Region 1, predominantly).

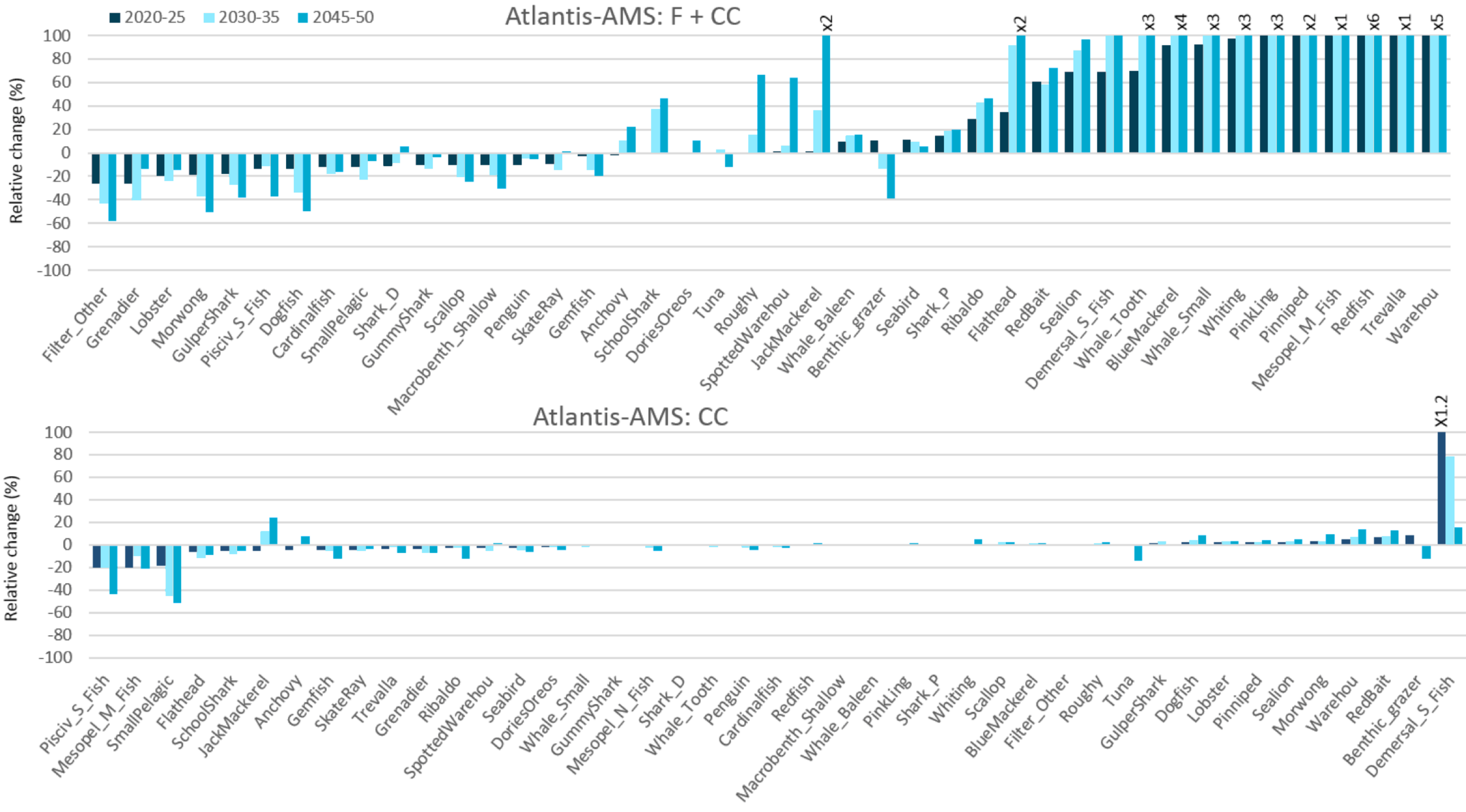


Figure 2-4: Relative changes in biomass of functional groups due to the impacts of (a) climate and fishing, and (b) climate, as predicted by the Atlantis-AMS ecosystem model covering much the entire south east Australia (Assessment Region 1 predominantly).

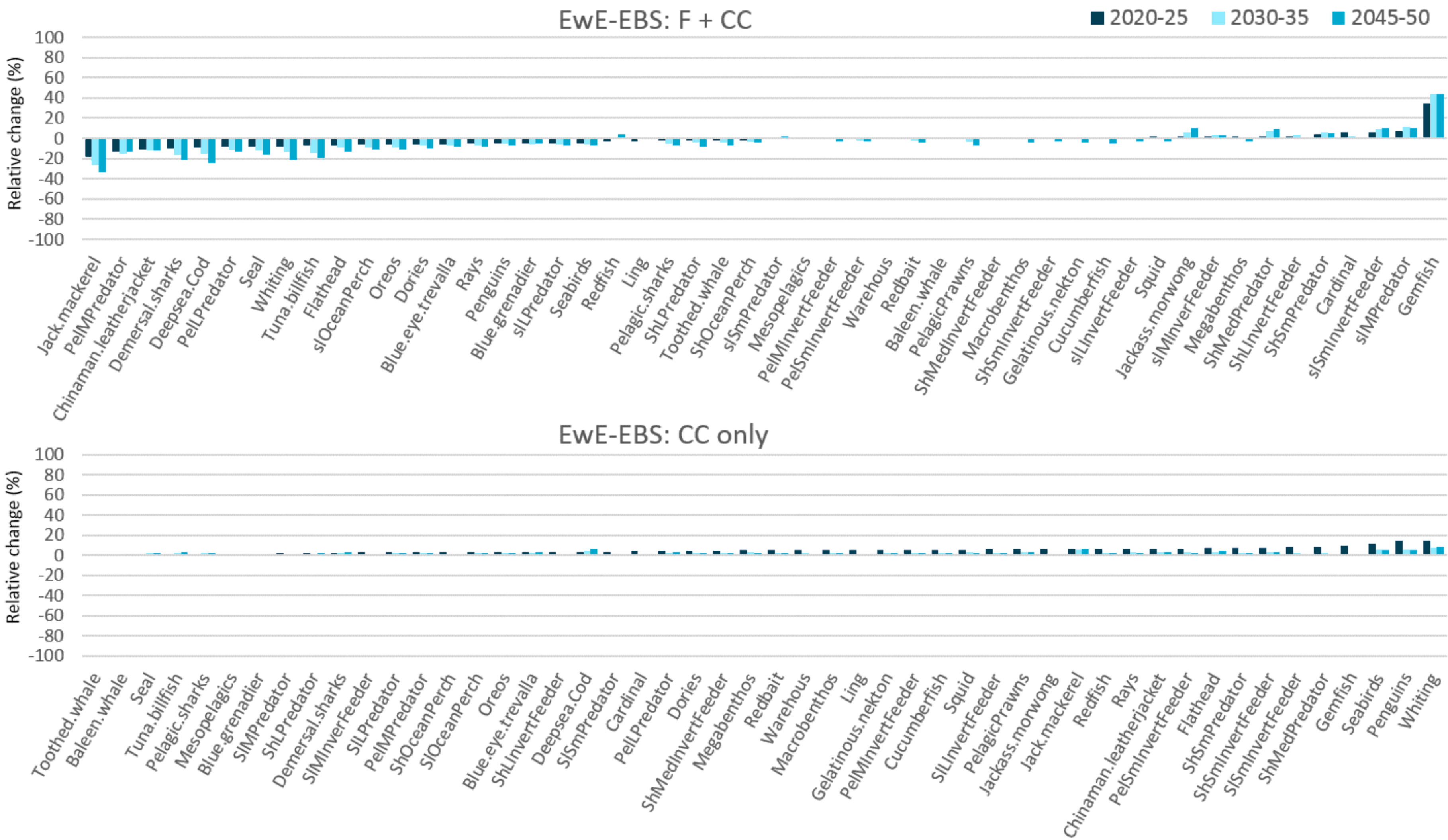


Figure 2-5: Relative changes in biomass of functional groups due to the impacts of (a) climate and fishing, and (b) climate, as predicted by the EwE-EBS ecosystem model with the model domain covering the Eastern Bass Strait (Assessment Region 1).

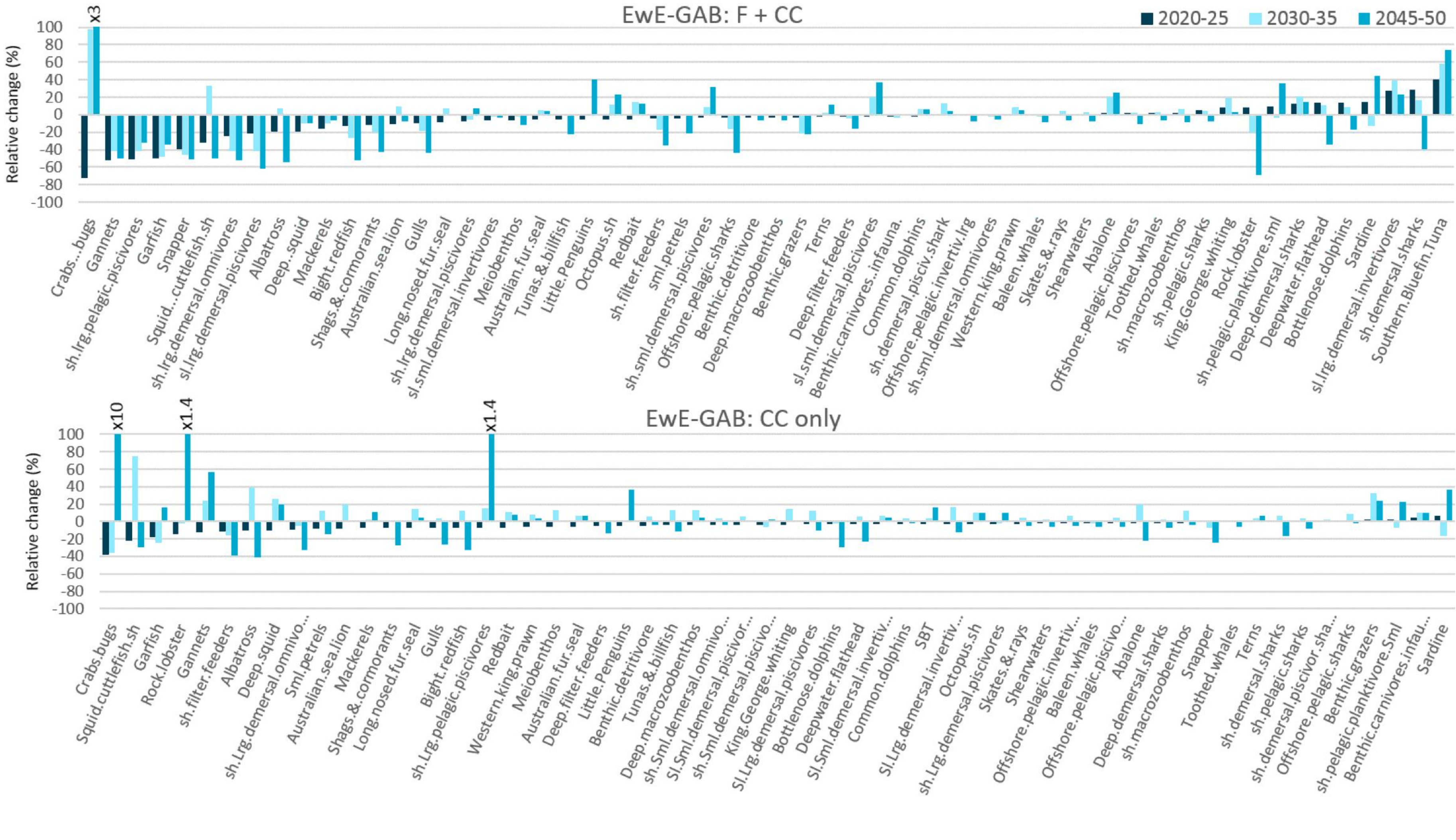


Figure 2- 6: Relative changes in biomass of functional groups due to the impacts of (a) climate and fishing, and (b) climate, as predicted by the EwE-GAB ecosystem model with the model domain covering the Great Australian Bight (Assessment Regions 1 and 2).

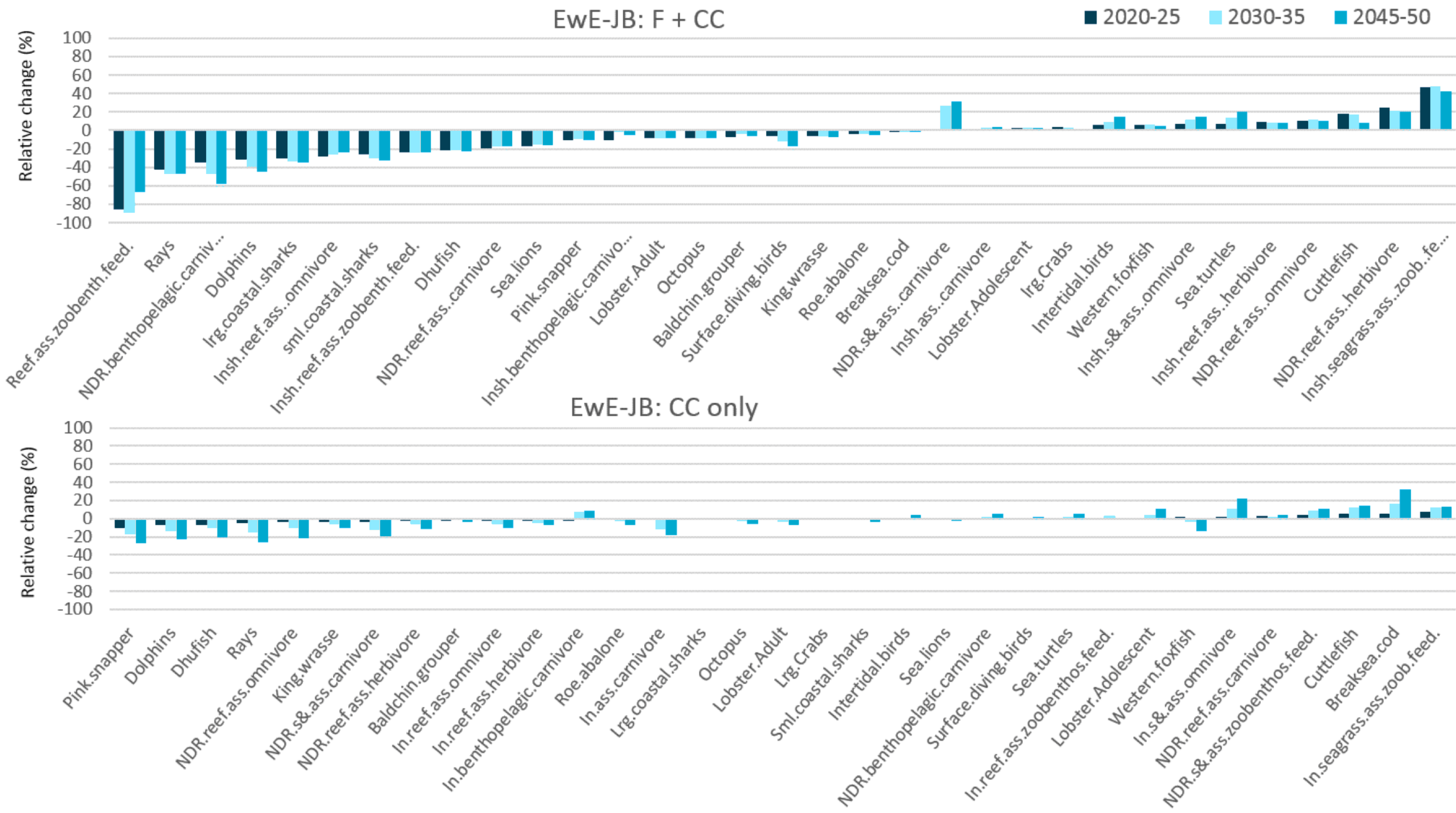


Figure 2- 7: Relative changes in biomass of functional groups due to the impacts of (a) climate and fishing, and (b) climate, as predicted by the EwE-JB ecosystem model with the model domain covering the Julian Bay off the west coast of Australia (Assessment Region 2).

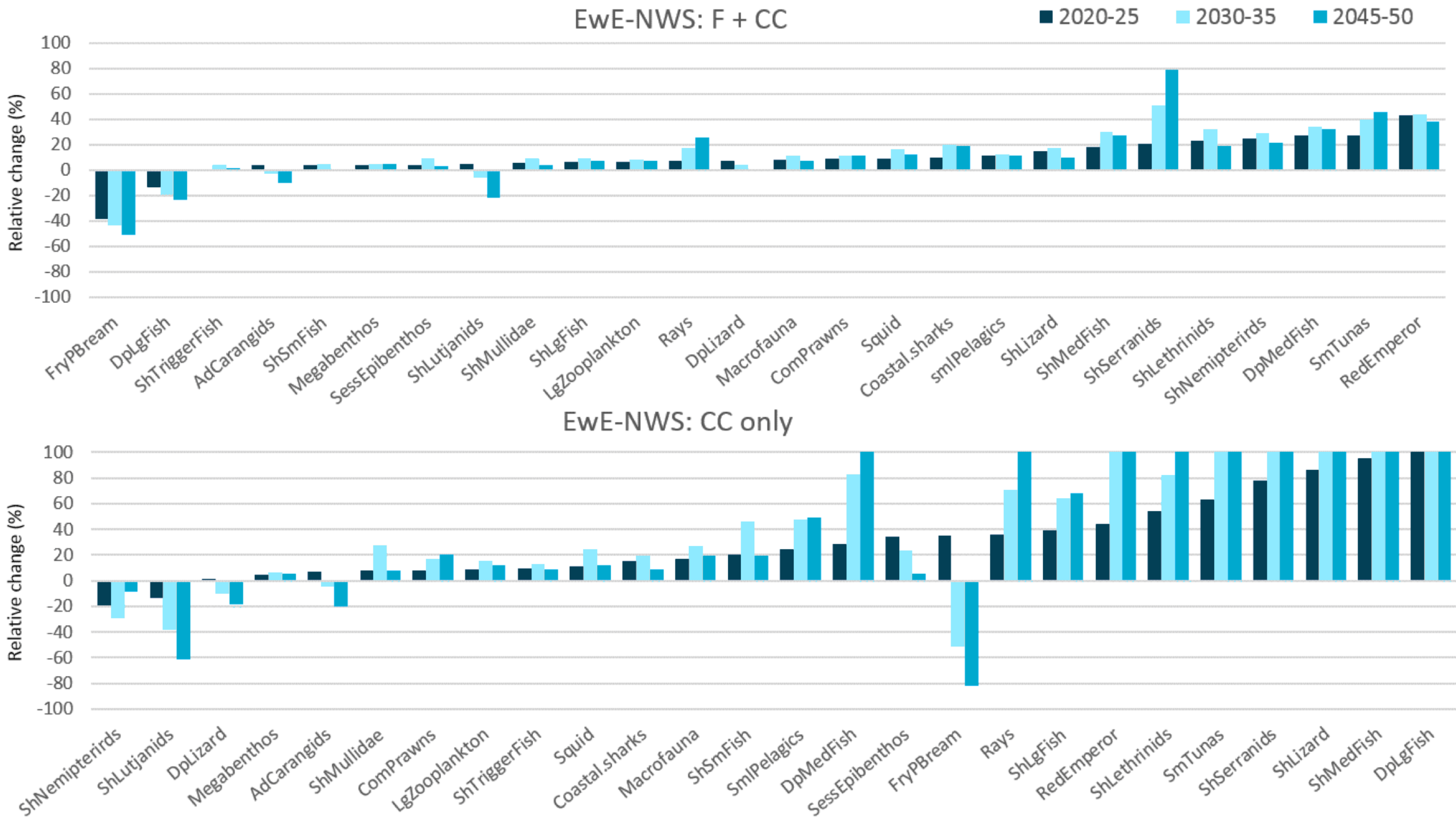


Figure 2-8: Relative changes in biomass of functional groups due to the impacts of (a) climate only, and (b) climate and constant fishing, as predicted by the EwE-NWS ecosystem model with the model domain covering the North West Shelf (Assessment Region 4)

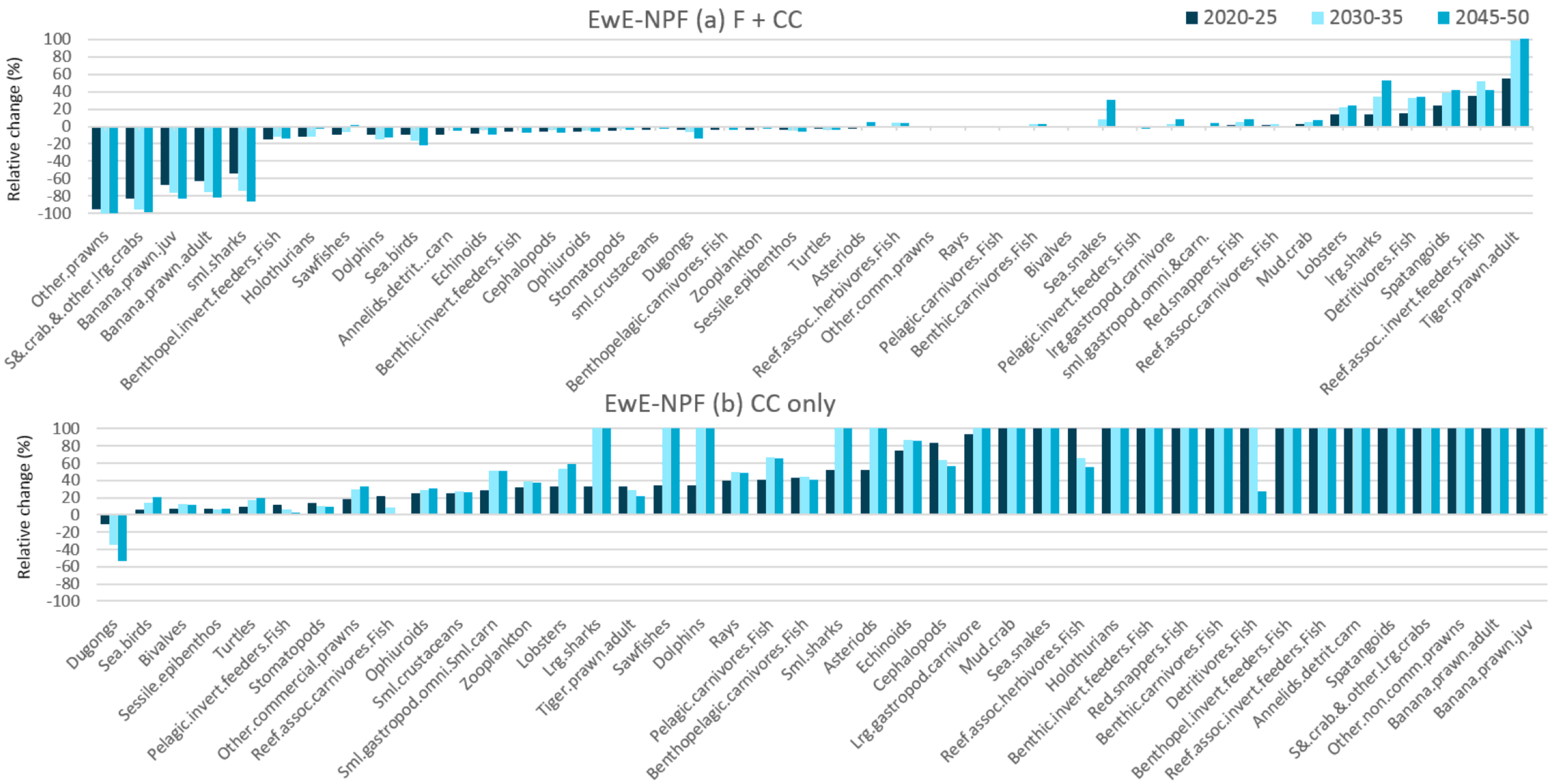


Figure 2-9: Relative changes in biomass of functional groups due to the impacts of (a) climate and fishing, and (b) climate, as predicted by the EwE-NPF ecosystem model covering the Northern Prawn Fishery in the Gulf of Carpentaria (Assessment Region 4).

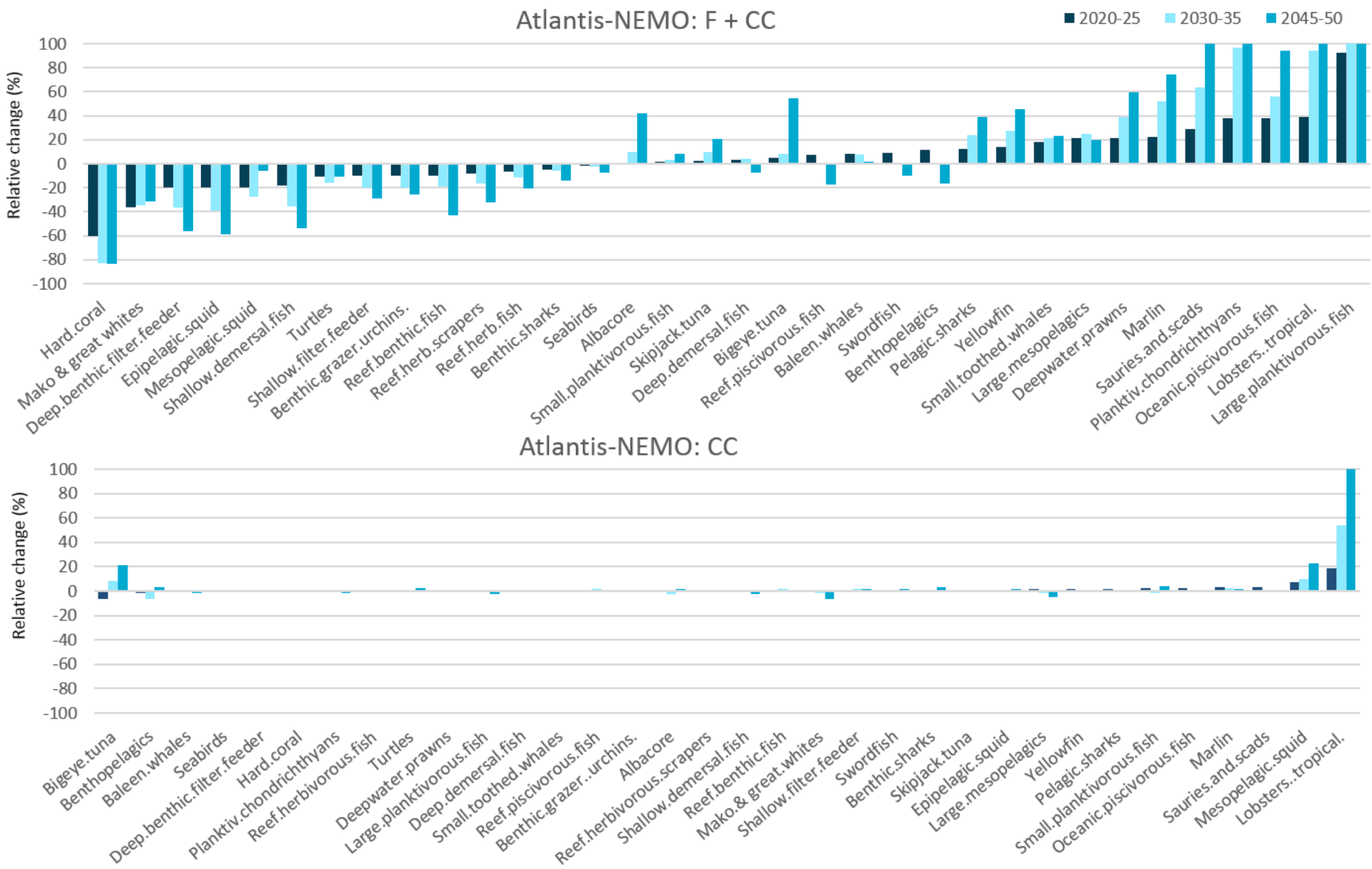


Figure 2-10: Relative changes in biomass of functional groups due to the impacts of (a) climate and fishing, and (b) climate, as predicted by the Atlantis-NEMO ecosystem model covering the GBR and south east Australia (Assessment Region 5).

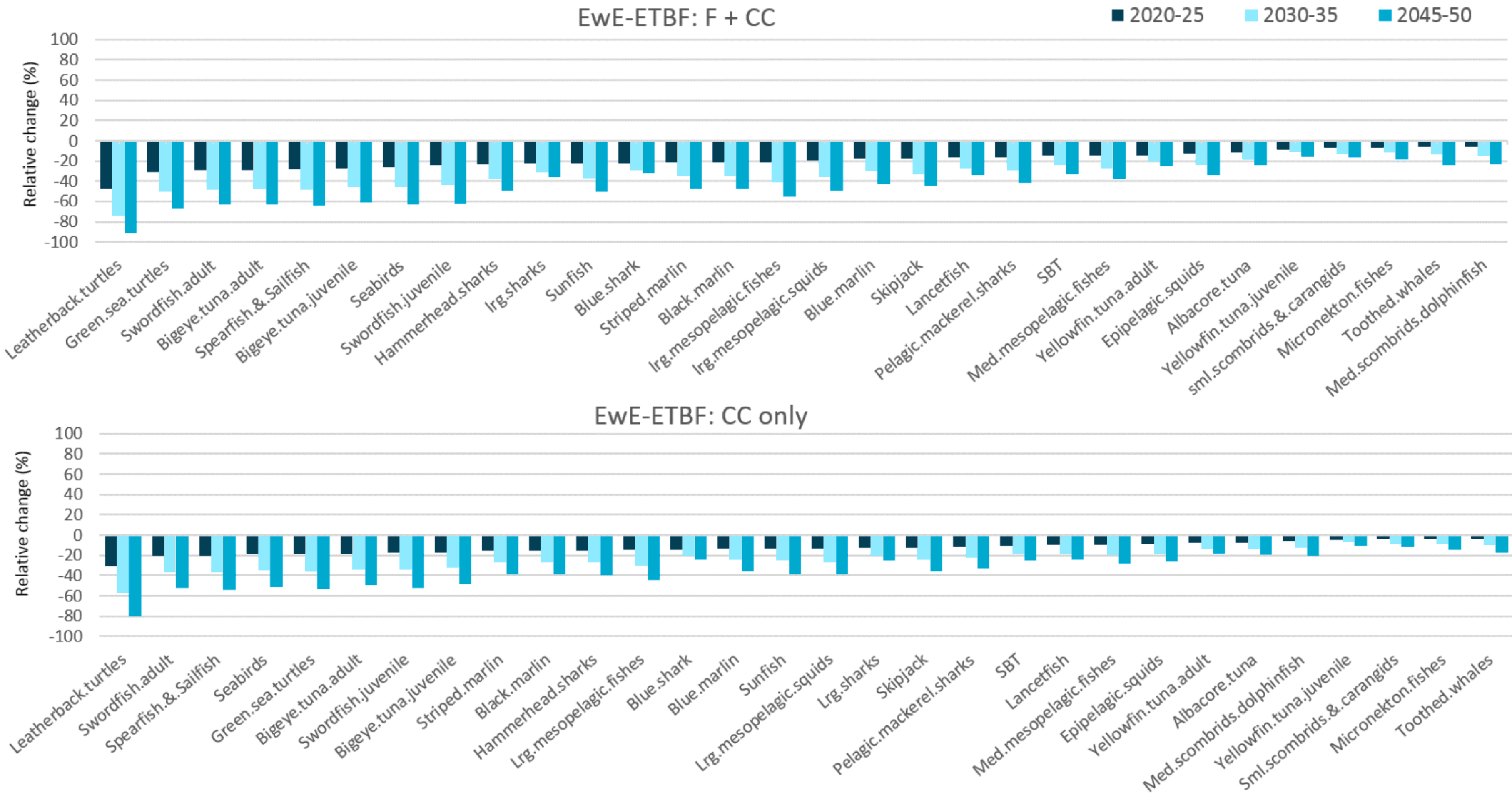


Figure 2- 11: Relative changes in biomass of functional groups due to the impacts of (a) climate and fishing, and (b) climate, as predicted by the EwE-ETBF ecosystem model of the Easter billfish and tuna fishery, with the model domain covering the south east Australia (Assessment Region 5).

In assessment region 5, the Atlantis-NEMO model predicted moderate to large distributional changes in tropical rock lobster, mesopelagic squid, large phytoplankton, small planktivorous fish, driftfish, skipjack tuna, and seabirds, with these species typically showing southwards shifts. Most other species showed no discernible spatial effects. Body size was projected to increase in planktivorous fish and decrease in turtles, reef fish, marlin, planktivorous sharks and deep and shallow demersal fishes.

2.2.4 Global ecosystem models run under RCP8.5

2.2.4.1 Size-spectrum

Projected temporal (5-year) changes in the relative biomass density (g C m^{-2}) of 6 ecological groups to the climate scenario (RCP8.5) where mapped for the whole Australian region and plotted (see the maps in Appendix Appendix C). The ecological group predicted to be the most negatively impacted across the broadest time period period was pelagic predators >10cm (all age groups combined) in all regions, except region 4 (the Gulf of Carpentaria), although the declines were relatively modest, typically <10% (Table 2- 7). In contrast, benthic detritivores >30cm were projected to increase in all regions, though again only by modest amounts (typically < < 10%). Total system biomass was projected to decrease in all regions, but region 4 (Gulf of Carpentaria), although finer scale patters were observed (
Figure 2- 12). Transient dynamics could also be strong, with sharp peaks in pelagic biomass in the 2020s before dropping back to around current levels.

Table 2- 7: Relative changes (%) in biomass density projected from size distribution model for different assessment regions at the end of year 2040 under RCP8.5 climate scenario.

Region	Benthic detritivores 10cm	Benthic detritivores 30cm	Pelagic Predators 10cm	Pelagic Predators 30cm	Total Consumable Biomass	Total System Biomass
1	-0.4	5.3	-4.6	-3.5	-2.5	-2.4
2	-1.2	6.5	-3.4	-4.8	-3.1	-2.9
3	-0.6	7.8	-5.9	0.1	-2.2	-1.9
4	13.6	28.7	5.7	19.3	-1.1	0.4
5	-0.8	1.0	-9.2	-7.9	-1.8	-1.6

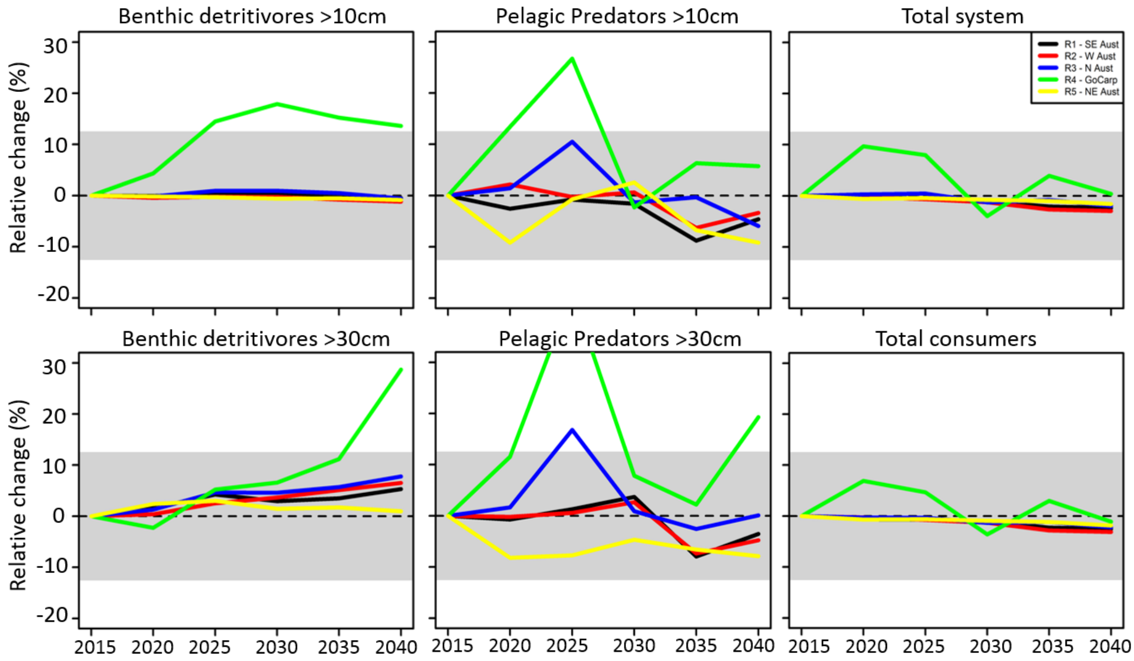


Figure 2- 12: Size-spectrum model projected changes in abundance and total system biomass density at 5-year intervals for each region.

2.2.4.2 Species distribution models

Three species distribution models were run under climate (RCP8.5) forcing for 137 species. The results per species were averaged across the three species distribution modelling approaches to give the final ensemble estimate of the impacts of climate change in terms of shifts in relative abundances for each assessment region (Table 2- 8). Distribution maps and time-series plots for the six size-groups modelled are provided in Appendix D. Visual assessments of how well the model simulated the distribution for particular species were undertaken using Codes for Australian Aquatic Biota (CAAB) distributional maps (Appendix D). Only 9 of the 137 species were clearly in error (either with incorrect spatial distributions or because the species does not in fact occur in Australia – perhaps indicating a taxonomic mis-identification). A further 40% of the species modelled were considered only partially reasonable projections as some part of the observed geographic distribution was missing or overstated.

For all regions, most species showed negative declines in relative abundance, with only 31 species projected to increase in a specific region. The 10 species with the most negative and positive changes in each assessment region are listed in Table 2- 9. The species, with high model confidence, that were projected to be among the most impacted from climate were: Blue Endeavour Prawn (*Metapenaeus endeavouri*) (regions 1, 3 and 4), Bartail Flathead (*Platycephalus indicus*) (regions 1, 2,3, and 5), Big Eye Tuna (*Thunnus maccoyii*) (region 3 and 5), Dusty Whaler (*Carcharhinus obscurus*) (regions 3 and 4), Golden Snapper (*Lutjanus johnii*) (region 2), Giant Trevally (*Carnx ignobilis*) (region 4), and Queenfish (*Scomberoides commersonnianus*) (region 5) (Table 2- 9).

Key Commonwealth fishery species predicted to see large positive increases in relative abundance, with moderate to high model confidence, included Sardine (*Sardinops sagax*)(regions 1 and 5), Gemfish (*Rexea solandri*)(region 1), and Blue Mackerel (*Scomber australasicus*)(region 5). Other species, with high model confidence, that increased included Barramundi (*Lates calcarifer*)(all regions), Oxeye Herring *(Megalops cyprinoides)*(regions 1, 2, 3 and 4), Thorntooth Grenadier (*Lepidorhynchus denticulatus*)(Region 2), Bullet Tuna (*Auxis rochei*)(region 4), and False Trevally (*Lactarius lactarius*)(regions 5) (Table 2- 9).

Table 2- 8: Impacts on species to climate (RCP8.5 simulation) projected by the global species distribution models (mean of 3 models: IPSL85, GFDL85, MPIMR85). Counts of all species that have changed within indicated range of % difference from 2010 relative abundances in the 5 assessment regions.

			Negative		Stable		Positive	
Region	n	<-60	-40 to-60	-20 to -40	-20 to 20	20 to 40	40 to 60	>60
1	134	4	15	35	77	0	1	0
2	127	3	10	34	79	1	0	0
3	99	3	14	34	48	0	0	0
4	95	1	11	23	59	1	0	0
5	101	5	7	25	55	5	2	2

Table 2- 9: Top ten species in terms of change in relative abundance (positive or negative) for each region – as identified from the extraction of the Australian EEZ results from the mean of 3 global species distribution models run under RCP8.5. The level of reliability or confidence are indicated for each species, from low (0) to high (3).

	Region 1		Region 2		Region 3		Region 4		Region 5	
	Species	**%**	**Species**	**%**	**Species**	**%**	**Species**	**%**	**Species**	**%**
Negative	*Mora moro (1)*	-100	*Lutjanus johnii (2)*	-89	*Metapeeus endeavouri (2)*	-76	*Metapeeus endeavouri (2)*	-77	*Paratrachichthys trailli (0)*	-100
	Metapeeus endeavouri (2)	-67	*Mora moro (1)*	-81	*Thunnus maccoyii (2)*	-74	*Carcharhinus obscurus (3)*	-58	*Regalecus glesne (1)*	-96
	Paratrachichthys trail (0)	-63	*Atractoscion aequidens (0)*	-76	*Seriola dumerili (0)*	-63	*Coryphae hippurus (1)*	-54	*Coryphae hippurus (1)*	-86
	Seriola dumerili (0)	-60	*Metapeeus endeavouri (2)*	-55	*Carcharhinus obscurus (3)*	-57	*Ruvettus pretiosus (1)*	-53	*Scomberoides commersonnianus (3)*	-71
	Coryphae hippurus (1)	-56	*Seriola dumerili (0)*	-54	*Isurus paucus (1)*	-52	*Prioce glauca (1)*	-52	*Seriola dumerili (0)*	-61
	Pseudocaranx dentex (2)	-56	*Platycephalus indicus (3)*	-52	*Platycephalus indicus (3)*	-51	*Isurus paucus (1)*	-48	*Carcharhinus brachyurus (2)*	-57
	Platycephalus indicus (3)	-52	*Carcharias taurus (1)*	-49	*Galeocerdo cuvier (1)*	-51	*Galeocerdo cuvier (1)*	-48	*Portunus pelagicus (1)*	-54
	Isurus paucus (1)	-51	*Seriola lalandi (0)*	-47	*Lutjanus johnii*	-51	*Epinephelus multinotatus (1)*	-47	*Carcharias Taurus (1)*	-52
	Galeocerdo cuvier (1)	-49	*Isurus paucus (1)*	-45	*Coryphae hippurus (1)*	-50	*Caranx ignobilis (3)*	-45	*Platycephalus indicus (3)*	-50
	Lepidopus caudatus (1)	-47	*Lutjanus argentimaculatus (2)*	-43	*Chelidonichthys kumu (1)*	-47	*Zeus faber (0)*	-43	*Thunnus maccoyii (2)*	-46
Positive	*Deania calcea (1)*	45	*Lepidorhynchus denticulatus (1)*	23	*Megalops cyprinoides (2)*	7	*Megalops cyprinoides(2)*	28	*Carangoides fulvoguttatus (1)*	207
	Squalus acanthias (1)	12	*Lates calcarifer (3)*	16	*Lates calcarifer (3)*	5	*Hilsa kelee (0)*	12	*Megalaspis cordyla (2)*	84
	Megalops cyprinoides (2)	11	*Megalops cyprinoides (2)*	15	*Epinephelus polyphekadion (1)*	4	*Lates calcarifer (3)*	12	*Sardinops sagax (3)*	52
	Pterygotrigla polyommata (2)	10	*Epinephelus polyphekadion (1)*	7			*Pomatomus saltatrix (1)*	10	*Lactarius (3)*	47
	Sardinops sagax (3)	7	*Eleutheronema tetradactylum (1)*	6			*Epinephelus polyphekadion (1)*	10	*Scomber australasicus (2)*	36
	Lates calcarifer (3)	5	*Epinephelus fuscoguttatus (3)*	5			*Auxis rochei (3)*	8	*Caranx sexfasciatus (1)*	35
	Pseudopentaceros richardsoni (1)	3	*Tegillarca granosa (3)*	4			*Anodontostoma chacunda (3)*	7	*Lates calcarifer (3)*	35
	Girella tricuspidata (1)	3	*Acanthopagrus latus (3)*	4			*Lepidocybium flavobrunneum (1)*	2	*Anodontostoma chacunda (3)*	22
	Pomatomus saltatrix (1)	1					*Eleutheronema tetradactylum (1)*	2	*Thunnus tonggol (2)*	20
	Rexea solandri (3)	1					*Euthynnus affinis (3)*	1	*Pello ditchela (2)*	19

2.3 Commonwealth Fisheries species projections

Here we discuss all the relevant model projections for species managed by Commonwealth fisheries (listed alphabetically). Based on the three anomalies calculated, we are able to isolate projected impacts due to fishing alone (control scenario), combined fishing and climate (RCP8.5 scenario) and climate alone (RCP8.5 vs control). We focus here on projected trends in biomass and fisheries catches. Gray bands represent changes of ±10%. For each modelled species, we have included the judged level of confidence (C = low, med, or high). Confidence intervals for the Atlantis-AMS model, varied greatly between species groups, but were on average around ±18% for harvest or TEP groups (Appendix C).

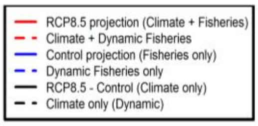
2.4.1 Bass Strait Central Zone Scallop Fishery (BSCZSF)

Biomass and catches of commercial scallop were predicted, by the Atlantis-AMS model, to decrease under constant (2010 level) fishing pressure and under the RCP8.5 climate scenario. Under the dynamic fishing management simulation, biomasses were predicted to increase under control conditions and less so under climate change (positive dampened).

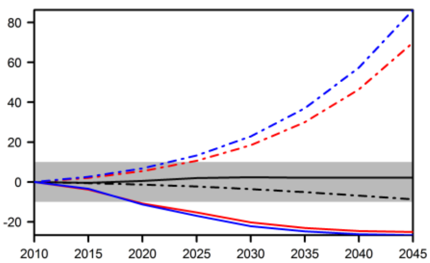
Species: Commercial scallop, *Pecten fumatus* and *Chlamys:* predicted to increase under constant fishing pressure with no discernible effect under projected RCP8.5 warming.

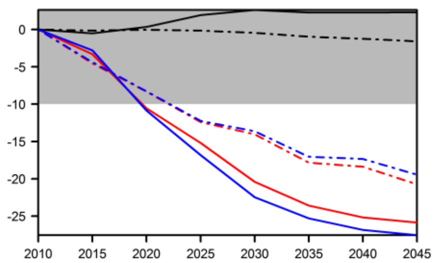
Model **Biomass** **Catch**

ATLANTIS -AMS



C = low

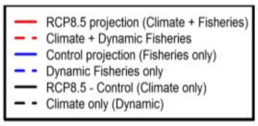
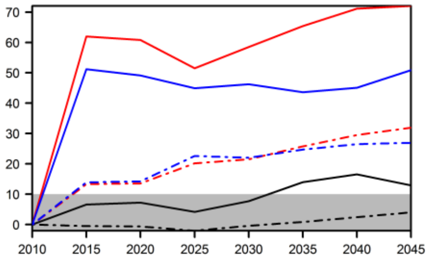
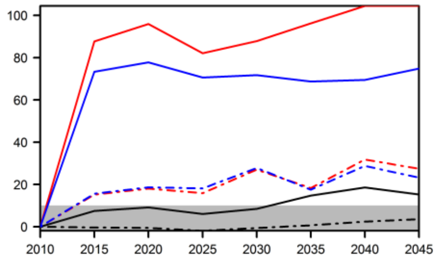
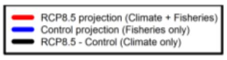
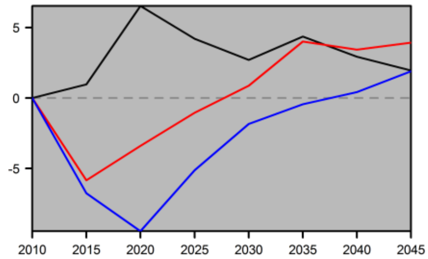
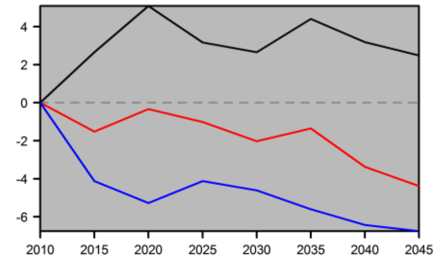
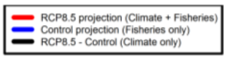
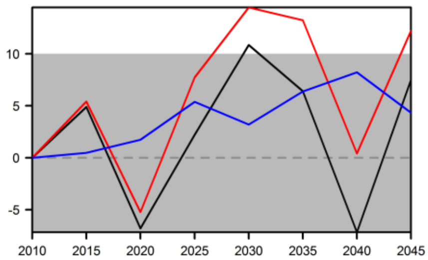
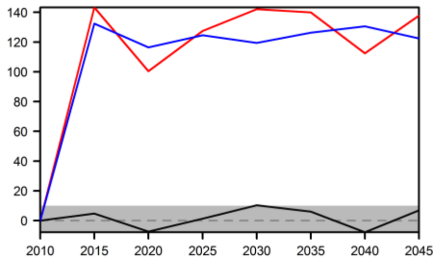
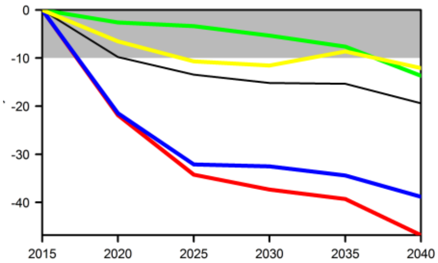




2.4.2 Small Pelagic Fishery (SPF)

Most regional ecosystem models predict that most species fished in the SPF will increase in biomass and subsequent catch from climate change and current fishing effort. However there were some conflicting model results; while the global species distribution model predicted an increase in the relative abundance of sardine, both regional and global models predicted some decline in other forage fishes including blue and jack mackerel and redbait in at least some regions.

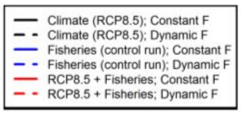
Species: Redbait (*Emmelichthys nitidus*): Conflicting model results concerning the effect of fishery drivers. Biomass was predicted to increase biomass under projected RCP8.5 climate drivers. Species distributions were predicted to moderately decline.

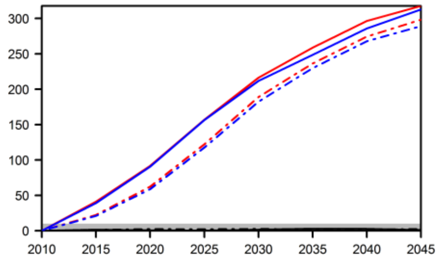
Model	**Biomass**	**Catch**
ATLANTIS –AMS  C = med-low		
EWE-EBS  C = low		
EWE-GAB  C = low		
Species distribution  C = low		

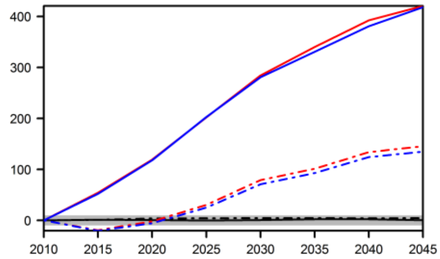
Species: Blue mackerel (*Scomber australasicus*): regional model simulation show large increase in biomass and catch as a result of 2010 fishing effort. There is little change in relative biomass under projected RCP8.5 climate drivers. Species distributions were predicted to marginally decline.

Model	**Biomass**	**Catch**

ATLANTIS –AMS

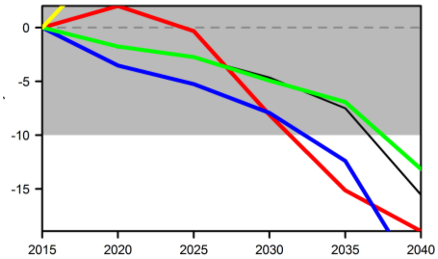






C = med

Species distribution

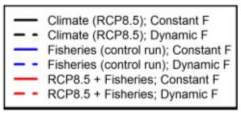


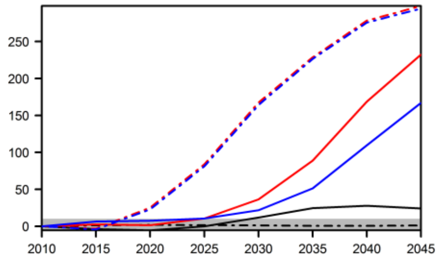
C = med

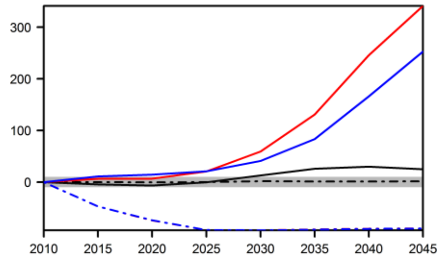
Species: Jack mackerel (*Trachurus declivis, T. murphyi*): Conflicting model results concerning the effect of fishery drivers. Projected RCP8.5 climate drivers were predicted to have minimal, slightly positive, effect. Species distributions were projected to moderately decline.

Model	**Biomass**	**Catch**

ATLANTIS –AMS

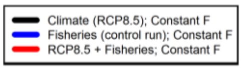


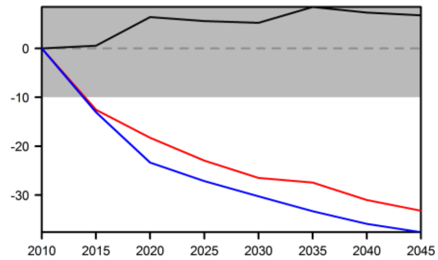


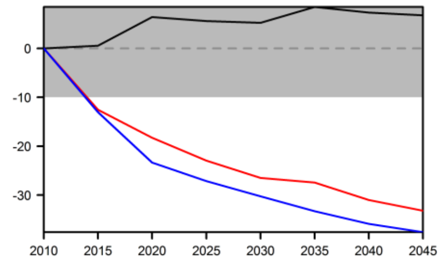


C = med

EWE-EBS



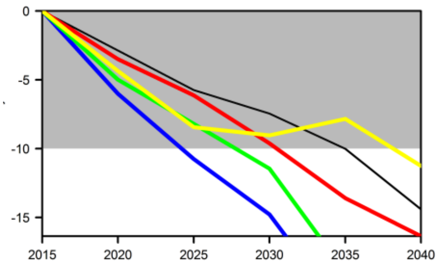




C = med

Species distribution

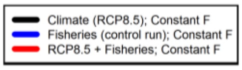
C = med



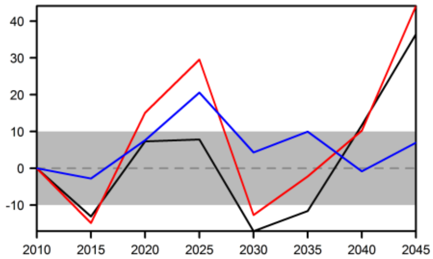
Species: Australian sardine (*Sardinops sagax*): EwE predicted variable yet minimal changes in biomass under projected RCP8.5 climate drivers and 2010 fishing effort. Species distributions were also projected to be relatively stable.

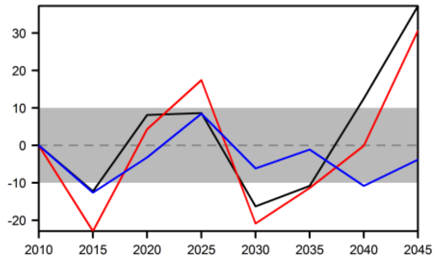
Model **Biomass** **Catch**

EWE-GAB



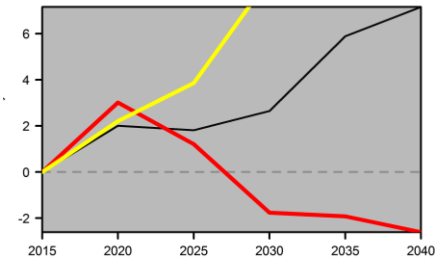
C = med





Species distribution

C = med

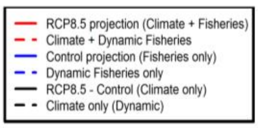


2.4.3 Southern and Eastern Scalefish and Shark Fishery (SESSF (GHTS))

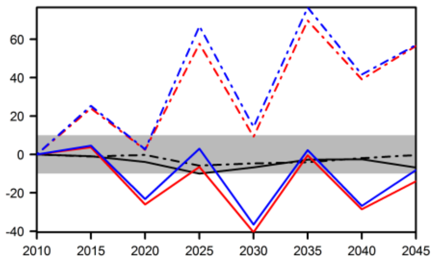
Species: Blue grenadier (*Macruronus novaezelandiae*): predicted to decrease under 2010 fishing effort but increase under dynamic fishing simulations. The additional impact of projected RCP8.5 climate drivers on biomass is predicted to be minimal. Species distributions were projected to marginally decline.

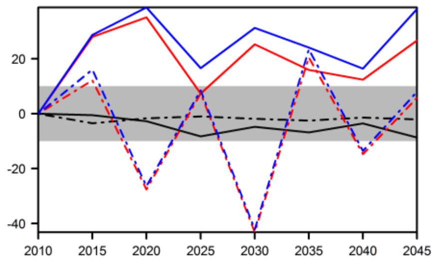
Model **Biomass** **Catch**

ATLANTIS -AMS

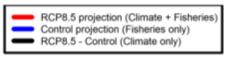


C = med

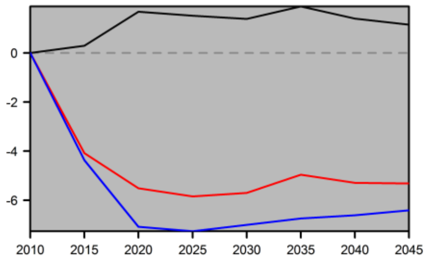


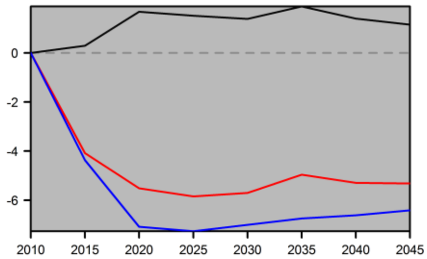


EWE-EBS



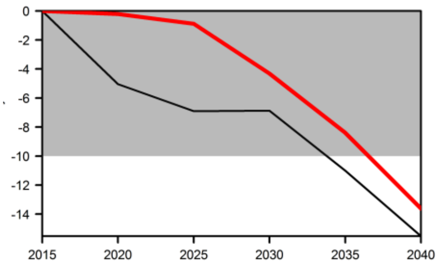
C = low-med





Species distribution

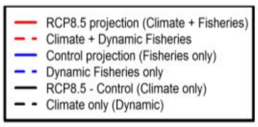
C = med



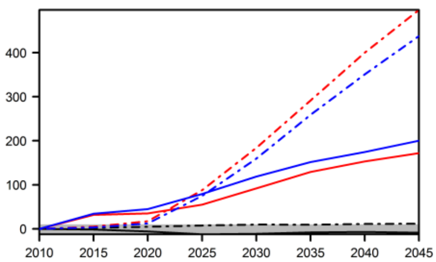
Species: Tiger flathead (*Neoplatycephalus richardsoni*): Conflicting model results concerning the effect of fishery drivers. Model agreement that biomass will increase under projected RCP8.5 climate drivers at low sensitivity.

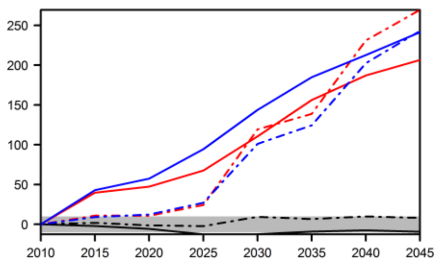
Model	**Biomass**	**Catch**

ATLANTIS -AMS

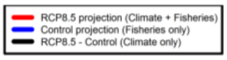


C = high

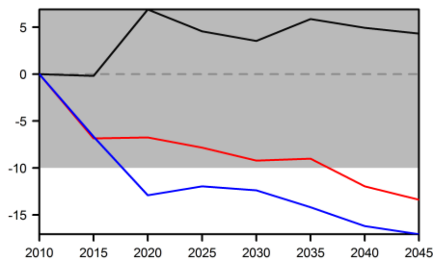


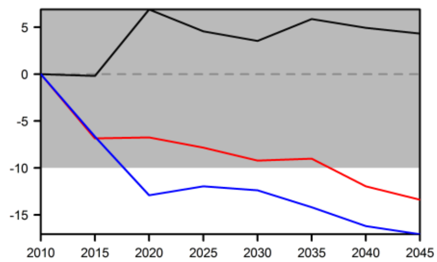


EWE-EBS



C = high

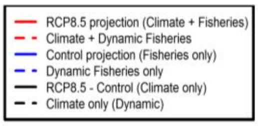


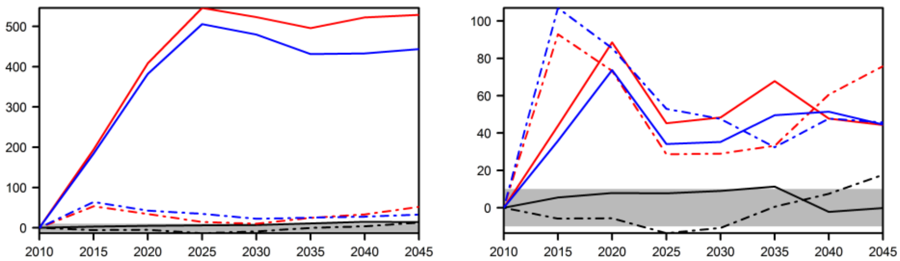


Species: Silver and blue warehou (*Seriolella punctate* and *brama*): Conflicting model results under fishing drivers with few discernible effects under projected RCP8.5 climate drivers.

Model **Biomass** **Catch**

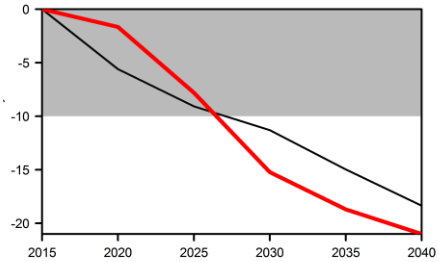
ATLANTIS -AMS





C = med-high

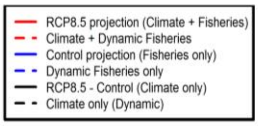
Species distribution

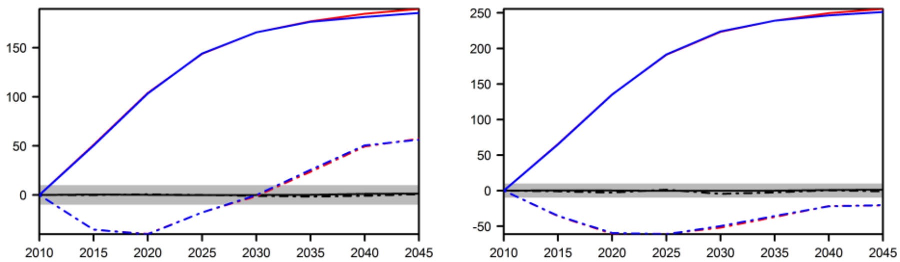


Species: Pink ling (*Genypterus blacodes*): declines in biomass predicted due to fishing effort. Little change in biomass under projected RCP8.5 climate drivers. Species distributions were also projected to decline.

Model **Biomass** **Catch**

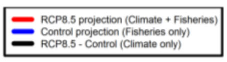
ATLANTIS -AMS

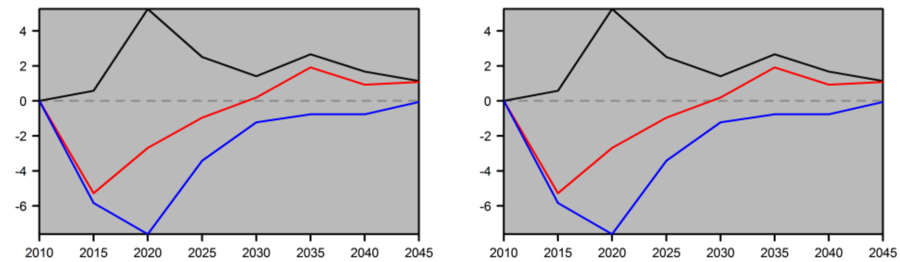




C = med-high

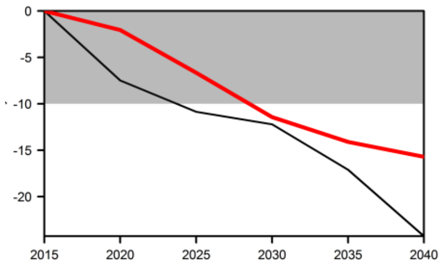
EWE-EBS





C = high

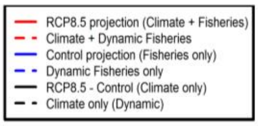
Species distribution

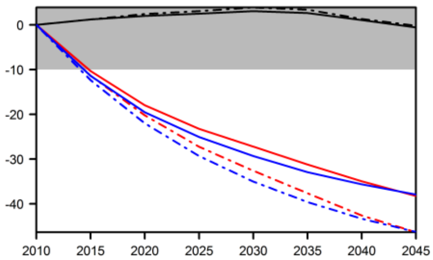


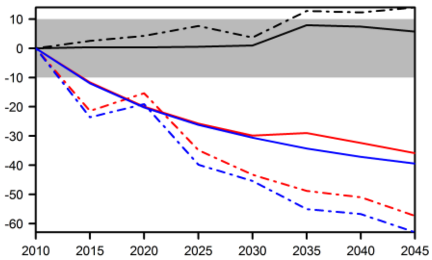
Species: Gulper shark *(Centrophorus granulosus):* predicted to decline under constant and dynamic fishing with a slight increase under projected RCP8.5 climate drivers.

Model **Biomass** **Catch**

ATLANTIS -AMS





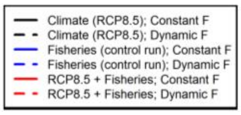


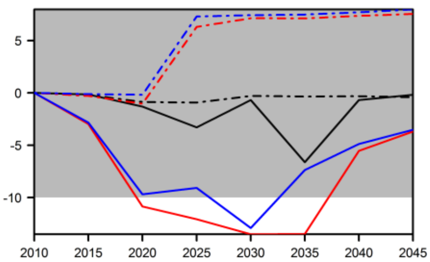
C = high

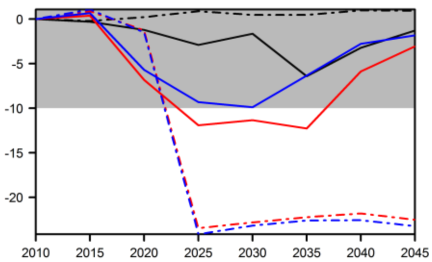
Species: Gummy shark (*Mustelus antarcticus*): Biomass predicted to show a marginal decline under constant fishing with a greater decline under projected RCP8.5 climate drivers. Under dynamic fishing, biomass is predicted to stabilise until 2020 before showing a 7% increase.

Model **Biomass** **Catch**

ATLANTIS -AMS





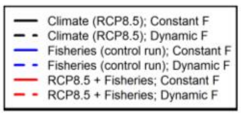


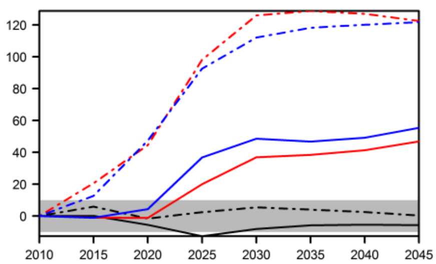
C = high

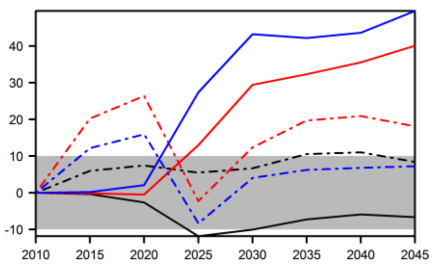
Species: School shark (*Galeorhinus galeus***)**: Biomass predicted to increase but less so under projected RCP8.5 climate drivers. Species distributions were also projected to decline.

Model **Biomass** **Catch**

ATLANTIS -AMS

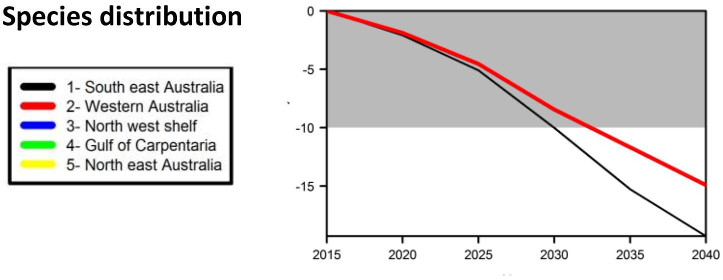




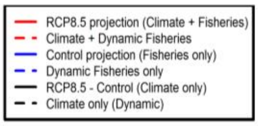
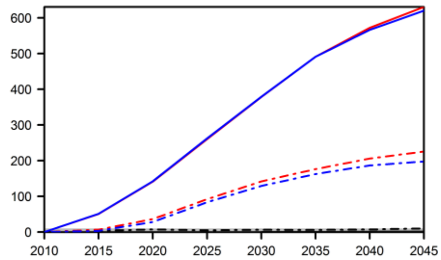
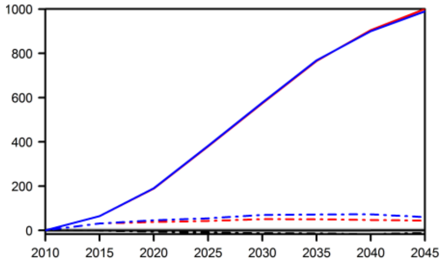
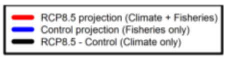
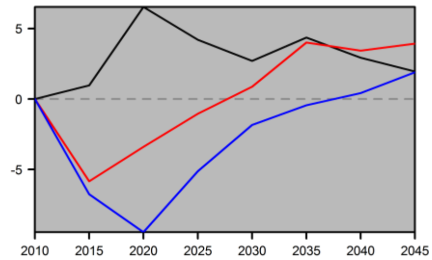
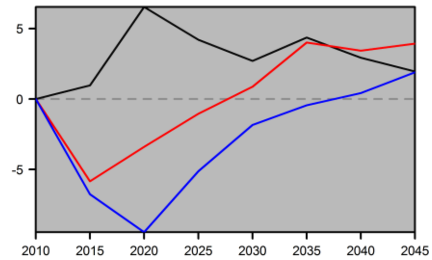
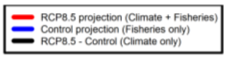
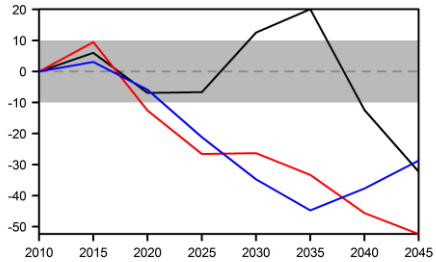
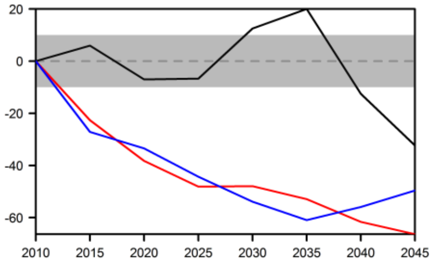


C = high

Species distribution



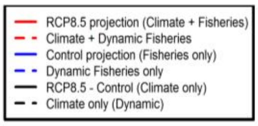
Species: Eastern redfish *(Centroberyx affinis*) and **bight redfish** (*C. gerrardi*): Conflicting model predictions under fisheries effort with large increases in biomass projected by the Atlantis model and declines projected by the EwE model. All models predict small biomass increases under projected RCP8.5 climate drivers.

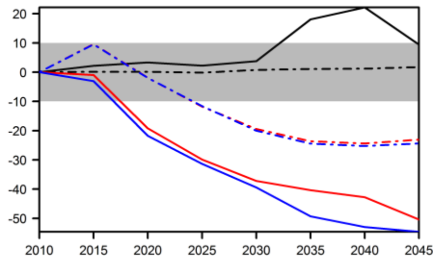
Model	Biomass	Catch
ATLANTIS -AMS  C = med-high		
EWE-EBS  C = med		
EWE-GAB  C = low-med		

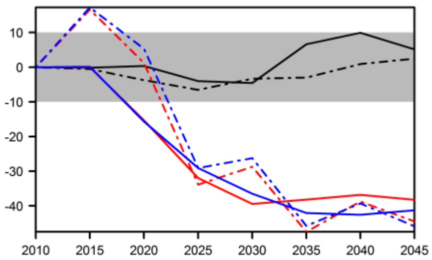
Species: Jackass Morwong (*Nemadactylus macropterus)*: predicted to decline under constant and dynamic fishing with a slight increase under projected RCP8.5 climate drivers. Species distributions were also projected to decline.

Model **Biomass** **Catch**

ATLANTIS -AMS

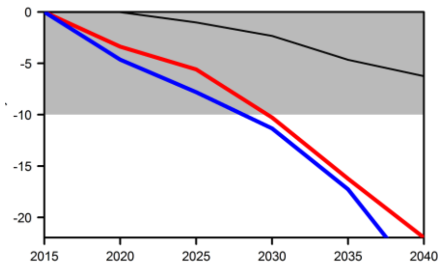






C = high

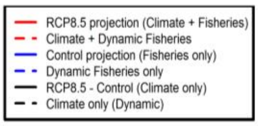
Species distribution

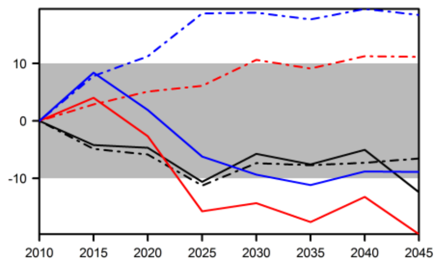


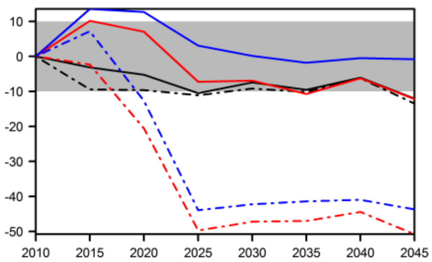
Species: Eastern Gemfish (*Rexea solandri):* Conflicting model results under fisheries and climate drivers. Species distributions were stable.

Model **Biomass** **Catch**

ATLANTIS -AMS

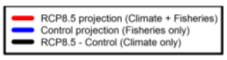


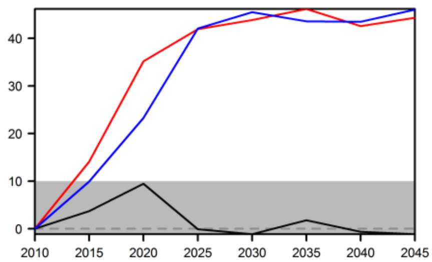


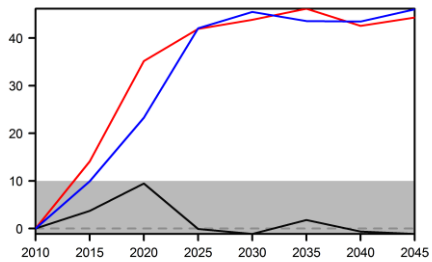


C = med

EWE-EBS

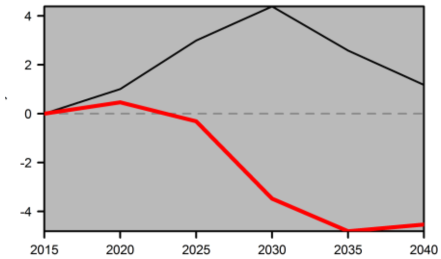






C = high

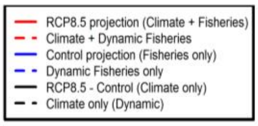
Species distribution



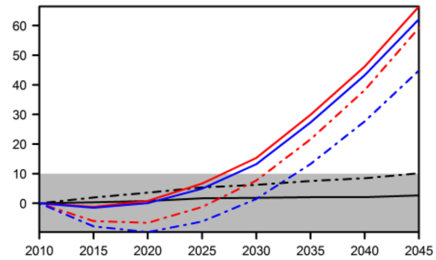
Species: Orange Roughy (*Hoplostethus atlanticus*): Biomass predicted to increase under current (2010, close to 0) fishing effort and slightly more so under projected RCP8.5 climate drivers. Species distributions were also projected to decline.

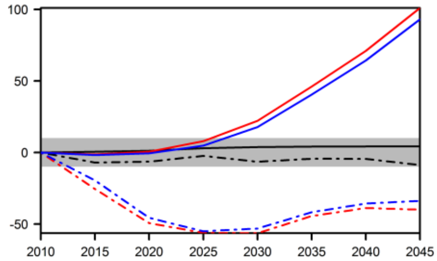
Model	**Biomass**	**Catch**

ATLANTIS -AMS

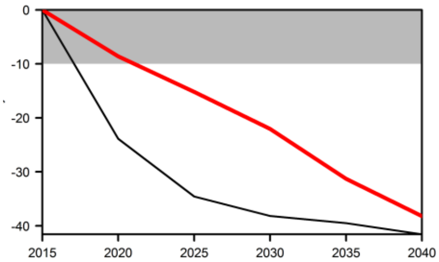


C = med-high





Species distribution

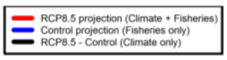


2.4.4 Southern Bluefin Tuna Fishery (SBTF)

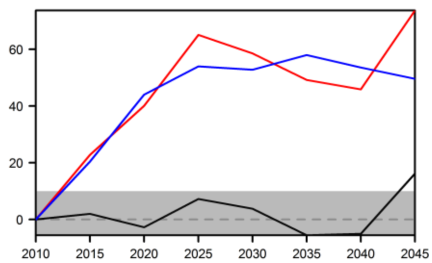
Species: Southern bluefin tuna (*Thunnus maccoyii):* Biomass predicted to increase under constant fishing with variable effects under projected RCP8.5 climate drivers. Species distributions were also projected to decline.

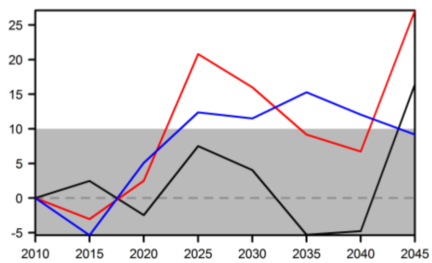
Model	**Biomass**	**Catch**

EWE-GAB



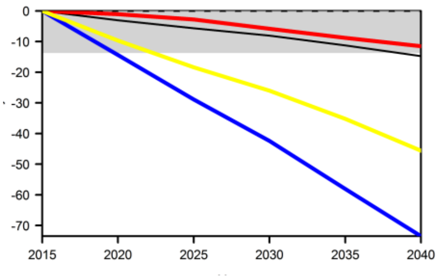
C = med





Species distribution

C = low

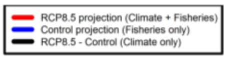


2.4.5 Eastern and Western Tuna and Billfish Fisheries (ETBF, WTBF)

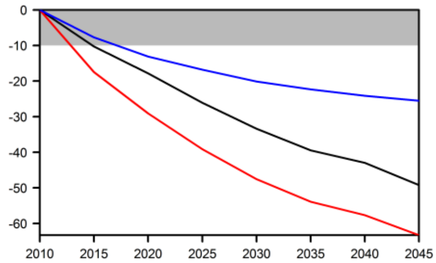
Species: Bigeye tuna *(Thunnus obesus):* Biomass projected to decline under constant fishing and even more so under projected RCP8.5 climate drivers. Species distributions were stable.

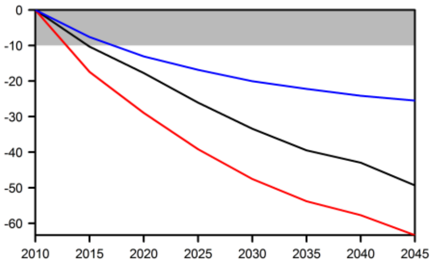
Model	**Biomass**	**Catch**

EWE-ETBF

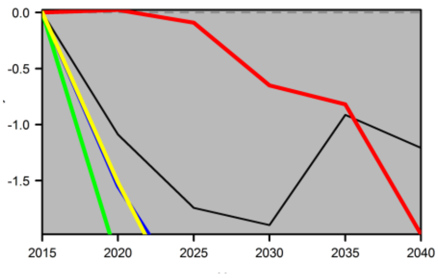


C = med





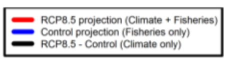
Species distribution



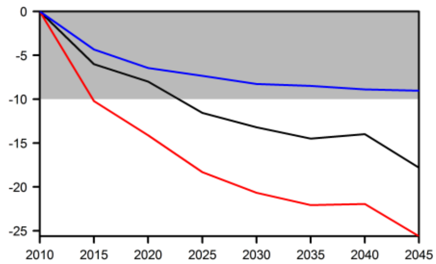
Species: *Yellowfin tuna (Thunnus albacares):* Biomass projected to decline under constant fishing and even more so under projected RCP8.5 climate drivers. Species distributions were stable.

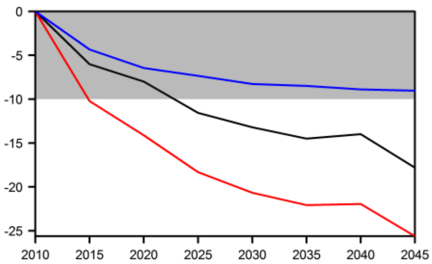
Model	**Biomass**	**Catch**

EWE-ETBF

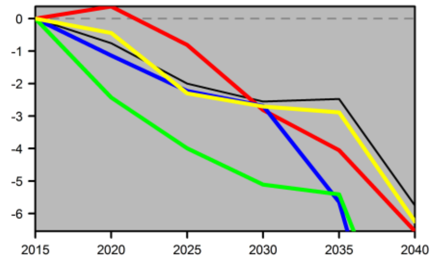


C = med





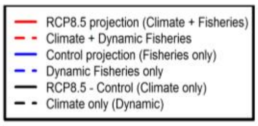
Species distribution



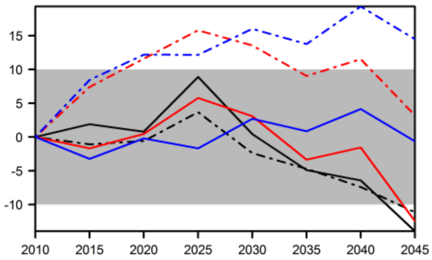
Species: Tunas and billfish (including *Bigeye tuna and yellowfin tuna):* Model agreement that biomass will decline under current (2010) fishing with variable effects under projected RCP8.5 climate drivers.

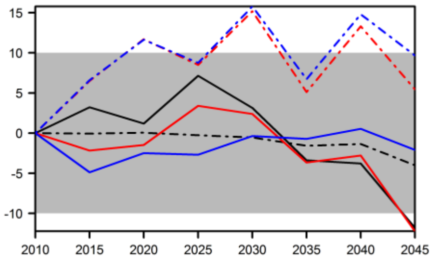
Model	**Biomass**	**Catch**

ATLANTIS -AMS

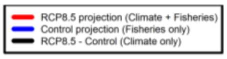


C = low-med

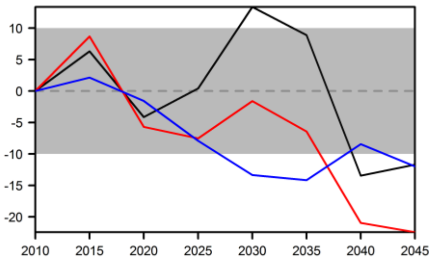


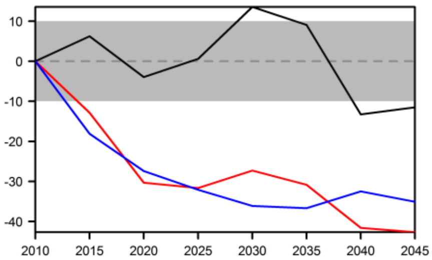


EWE-GAB

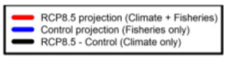


C = low-med

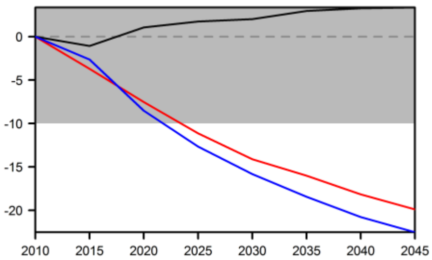


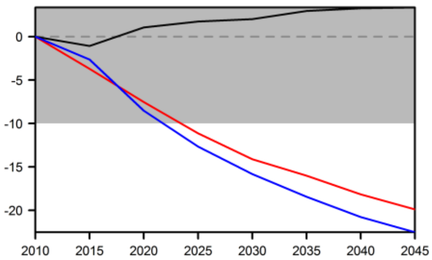


EWE-EBS



C =low-med



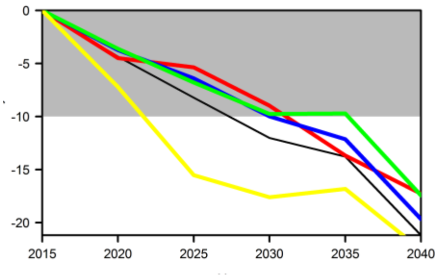


2.4.6 Northern Prawn Fishery (NPF)

Species: White Banana (*Fenneropenaeus merguiensis*): Species distributions were projected to decline.

Model **Biomass**

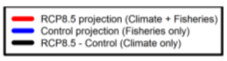
Species distribution



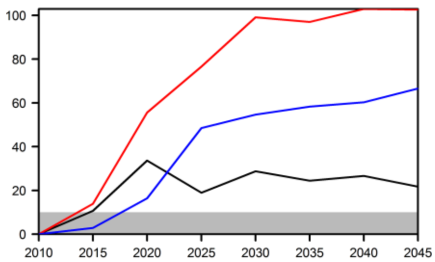
Species: Brown Tiger (*Penaeus esculentus*): Biomass predicted to increase under current fishing and even more so under projected RCP8.5 climate drivers.

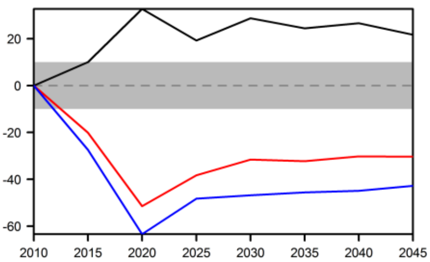
Model **Biomass** **Catch**

EWE-NPF



C = med

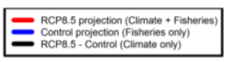




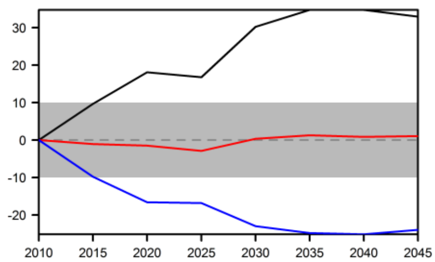
Species: Grooved tiger (P. *semisulcatus*), blue endeavour (*Metapenaeus endeavouri*), and red endeavour (M. *ensis*): Biomass predicted to increase under projected RCP8.5 climate drivers but decrease under 2010 fishing effort.

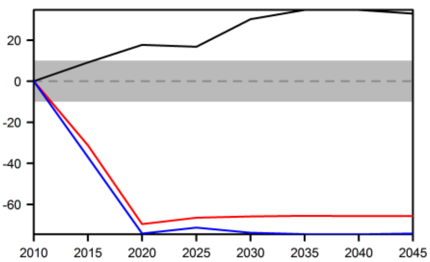
Model **Biomass** **Catch**

EWE-NPF



C = med



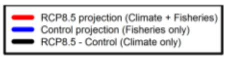


2.4.7 Torres Strait Finfish Fishery (TSFF)

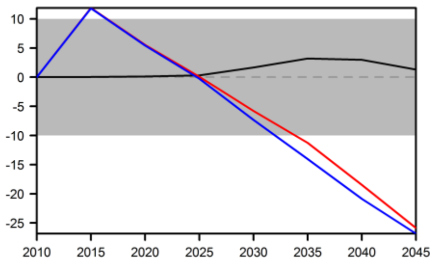
Species: Coral trout (*Plectropomus* spp.): initial increase followed by moderate decline with marginal additional effects under projected RCP8.5 climate drivers.

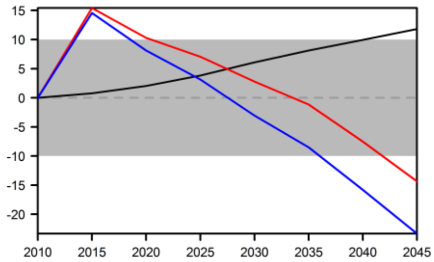
Model | **Biomass** | **Catch**

ATLANTIS-NEMO



C =low-med



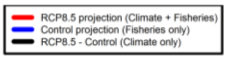


2.4.8 Torres Strait Rock Lobster Fishery (TSRLF)

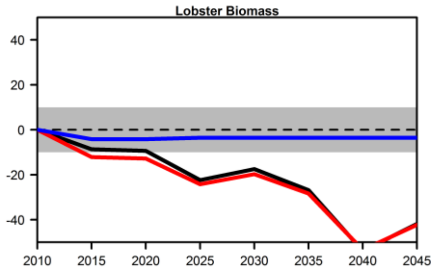
Species: Tropical rock lobster (*Panulirus ornatus*): biomass predicted to be stable under constant 2010 fishing effort but to greatly decline under projected RCP8.5 climate drivers.

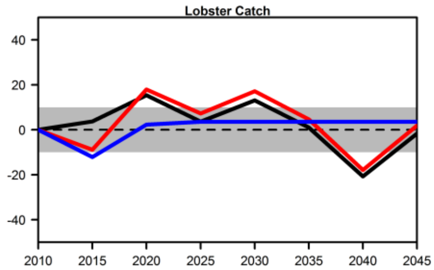
Model | **Biomass** | **Catch**

MICE



C = high





2.4 Economic implications

Using the simple approach of assuming current day prices hold going forward with no substantial shifts in relative value across species then economic implications of the changes in catch can also be projected.

While all fisheries and regions showed the potential for change in value, the direction of that change is uncertain (even without changes in prices) as the possibility for both increases and decreases were projected. Although the distribution of shifts was more toward a decrease overall. All the tropical fisheries showed a large range of potential outcomes (from at least a 35% drop, or more, through to a 10-20% increase). However, the greatest range was projected for the SESSF, which may see a 10-25% increase in value at one extreme, but may drop by 80% in value if a regime shift occurs an alternative target species cannot be caught or marketed. The west coast fisheries appear to be the most economically robust in the projections.

Table 2- 10: Range of relative value of the fisheries in the short and medium term, based on average relative catches (as projected by the ecosystem models) and assuming 2016 prices.

Fishery or Region	Relative value 2020-2025 vs 2016	Relative value 2030-2035 vs 2016
BSSS	0.88-0.95	0.80-1.05
CS	0.75-1.10	0.80-1.00
ETBF	0.65-1.08	0.60-1.10
NPF	0.57-1.19	0.52-1.19
SESSF	0.21-1.10	0.19-1.22
SPF	0.98-1.40	0.99-1.38
TS	0.50-1.20	0.30-1.30
East Coast	0.42-1.02	0.38-0.95
Gulf of Carpentaria	0.49-0.79	0.49-0.73
North-western Australia	0.12-1.24	0.11-1.34
SE Australia	0.83-0.99	0.78-0.99
W Australia	0.91-0.99	0.83-1.00

2.5 Modelling conclusions

Climate drivers can exert large impacts on certain functional groups with the direction of change being species and system dependent. In most instances the level of change in climate drivers was a good indicator of the level of responsiveness of the model – the largest changes in primary productivity and model projected biomass were in the Great Australia Bight EwE model domain. In contrast there were only small changes in climate drivers and biomass projected in eastern Bass Strait, Torres Strait, and Ningaloo reef.

Species related changes most likely to be of concern to management and industry are those to do with climate mediated declines (where a species decline only occurs, or is stronger, under climate change). In the short term (2020-25), groups flagged to be of particular concern included rock lobster (region 1), reef associated zooplankton feeders (region 2) and shelf snapper and groupers (region 3). In the medium term (2030-35) groups flagged included lobster, morwong and gummy shark (region 1), reef associated zooplankton feeders and lutjanids (region 2), all the NPF prawn species (region 3), swordfish and sailfish (region 5).Projections for 2045-50 highlighted additional groups of concern – including small pelagic fishes, pelagic and deep demersal sharks, piscivorous fish, and bight redfish (region 1), dhufish and pink snapper (region 2), and large sharks and marlin (region 5).

The threatened and protected species projected to be the most impacted from climate change included albatross, bottlenose dolphins, and penguins (region 1), dolphins and dugongs (region 2), dugongs (region 4), and seabirds, leatherback and green turtles (region 5).

The categorisation of the sensitivity of species groups to climate and fisheries drivers can be used to prioritise management decisions at a species and regional level. However, one must carefully consider the level of model confidence indicated, even where there is good model-model agreement. In particularly, caution should be taken to compare outputs from regional models to those of the ensemble of global species distribution model, which largely projected declines in the abundance of most species assessed.

While all fisheries and regions showed the potential for change in value, resulting from changes in catch, the direction of that change is uncertain. While both potential increases and decreases in value were projected across the different models, the distribution of shifts was more toward a decrease in total value. All the tropical fisheries showed a large range of potential outcomes (with a total change in potential value of -50% to +20%), but the greatest range was projected for the SESSF (-80% to +25%). The big drops in value would occur if catches of currently targeted species declined no alternative target species could be caught or marketed. The west coast fisheries appear to be the most economically robust in the projections.

Part III Method Comparisons

3.1 Comparison and synthesis of assessment tools

Over the next century, the marine ecosystems of Australia are expected to exhibit some of the largest climate-driven changes in the Southern Hemisphere. The effects of these changes on the communities and businesses of the Australian fisheries sector will depend, in part, on how well the fishing and aquaculture industries and their managers respond to the challenges that climate change presents. A risk-based approach will help to ensure the development of policies that allow industry to minimise adverse effects by optimising adaptation responses (e.g. by providing flexible management arrangements) and seizing opportunities as they arise (e.g. for species where productivity increases) (Pecl et al. 2017, Bonebrake et al. 2017).

To do this successfully will require good scientific tools. The ensemble of tools used in this project address specific issues related to climate drivers (changes in temperature and primary production) and the interplay with fishing on the ecosystem, but they remain uncertain as scientific knowledge of system and species responses is incomplete. Consequently, a diversity of approaches (which draw on different data sources and try to span different assumptions regarding those mechanisms) are required. Each of the different approaches has its own strengths, weakness and areas of particular usefulness (as outlined in Table 3- 1).

Table 3- 1: List of the modelling and assessment tools most appropriate for different system aspects and scales

Overall	System level understanding / indicators	Size-spectrum Regional ecosystem models
Regional	Invertebrates or data poor Data rich or species with strong interactions	Sensitivity analysis MICE and Regional ecosystem models
Fisheries	Invertebrates or data poor Data rich or species with strong interactions	Sensitivity analysis MICE and Regional ecosystem models
Species abundance	Commercial invertebrates	Sensitivity analysis
	Commercial fish	MICE and Regional ecosystem models
	TEPS and non- commercial groups	MICE and Regional ecosystem models
Species distribution	Commercial invertebrates	Sensitivity analysis Species distribution models Atlantis regional models MICE (if implemented spatially)
	Commercial fish	Sensitivity analysis Species distribution models Atlantis regional models MICE (if implemented spatially)
	TEPS and non-commercial groups	Sensitivity analysis (if performed for those groups) Species distribution models Atlantis regional models MICE (if implemented spatially)
Species phenology	Commercial species and vertebrate groups	Sensitivity analysis Atlantis MICE (potentially)

Our synthesis considers the key species in several ‘hotspots’ for marine climate change, which are currently displaying signs of perturbation and where further shifts, shrinkages and expansions of ecosystems and species distributions are expected. Collectively we consider species that constitute up most of Australian fisheries by volume/value. Overall, the sensitivity assessment (Part 1) identifies fisheries species at highest risk from climate change, and many of these most sensitive species are also those with the highest economic importance to their respective regions (e.g. Pecl et al. 2011). While the ecosystem modelling was not able to verify these findings for many of the southern temperate invertebrate species it does concur for the tropical species and for other key teleosts. This suggests that the coming decades may prove to be challenging for Australian fisheries operators and managers.

It is challenging to directly compare the sensitivity analysis and the modelling approaches as there was only patchy overlap in the species considered by both methods and because it is difficult to compare assessments which treat a species in isolation versus when it is dynamically part of an interconnected system. Nevertheless the sensitivity scores and type of trajectory were compared for 24 Commonwealth fisheries species for which there is high model confidence (comparing functional groups containing the species if a species was not explicitly represented in the model) – see Table 3-2 and Table 3-3.

As the sensitivity assessment does not give an indication of the direction of change, simply potential sensitivity (which may result in an increase or decrease) it is hard to compare the veracity of the direction of change in the models with the sensitivity assessment (Table 3-3). Although it is clear that few species remain stable in the regional models even when ranked as having low sensitivity across multiple aspects of the sensitivity assessment. It is interesting that those species showing an enhanced effect of climate (P3 or N3 rating) or a divergent response (i.e. responding in the opposite direction to climate and fishing vs fishing alone) were also those species ranked as having a high sensitivity to distribution or phenology in the sensitivity assessment. It is also worth noting that around a third of the commonwealth species represented in the global species distribution models increased in the regional models but declined in the species distribution models.

Comparing the sensitivity rankings with the magnitude of change in biomass for individual species or functional groups and the climate contribution to that trajectory (the black lines in the plots in Appendix C and the trajectories in Appendix D) gives some insight into the comparability of the approaches (Table 3-3). The degree of agreement varied region to region, but overall there was agreement for key species that were the focus of the regional models (i.e. species for which special effort had been made to fit to data) and where the models (regional or global) contained the main mechanisms that were being considered in the sensitivity analysis. For example, Atlantis-AMS in region 1 (SE Australia) was able to capture many of the distributional and phenological aspects leading to the sensitivity ranking for Blue Grenadier, Jack Mackerel, Snapper, Sardine and Southern Bluefin Tuna. In contrast, the EwE models do not currently include estuarine drivers (such as rainfall and run-off) and so struggle to capture some of the key drivers on estuarine species such as Barramundi. Although the success with which the approach has been applied in the NPF shows that when suitable drivers are included EwE can be a very effective modelling approach.

Amongst the Commonwealth species there is moderate to strong agreement between the methods for:

- Region 1: Blue Grenadier, Southern Bluefin Tuna, Jack Mackerel, Sardine, Anchovy, Blue Mackerel, Redbait and Flathead
- Region 2-5: Tiger Prawns, Banana Prawns, King Prawns and Sandfish (except for sandfish in region 5).

The greatest divergences between the methods were typically for shallow shelf demersal stocks and many of the invertebrates, which are often poorly constrained and only generally parameterised in the trophic models. Habitat dependent species (such as emperors and snappers) also require additional effort to represent well, which is likely why they display such mixed performance – agreeing for the models where the habitat connections had been built into the models and disagreeing in models where habitat connections were not included or were a secondary consideration. Similarly, while the species distribution models often showed great agreement with the sensitivity analysis for species where the distribution model was a good match for current observations, it was in disagreement for abalone and estuarine species (Barramundi and Pikey bream) in particular. Moreover, the species distribution models generally tended to suggest higher sensitivity than the other approaches.

Some of the differences between the different approaches is likely due to the patchiness in available data for some key groups. For instance, while much work has been done for cephalopods and chondrichthyans (e.g. around aspects of life history) they are still not as well understood as teleosts, particularly with respect to the form of their responses to climate drivers. Consequently, the more qualitative sensitivity assessment may be capturing more of the existing knowledge than the models which demand more stringent quantified parameterisations. This is particularly important for cephalopods, and other invertebrates, as the responsiveness of their life history is both a strength and weakness. They typically have high productivity and relatively short life spans, meaning they can respond quickly, but often have little buffering capacity. Many species (e.g. abalone and other benthic invertebrates) can have particular habitat requirements. Together these characteristics mean they show much more volatility and are quite sensitive to strings of stochastic events.

The short time frame for this project (both in terms of the life of the project itself, but also its focus on the more immediate future) meant that not a lot of attention was given to the potential for acclimation and evolution in either the sensitivity assessment or the modelling platforms. While Atlantis can represent such shifts, it was not done with any degree of elaboration here as it is not typically important until the middle of the century or beyond (i.e. beyond the temporal scope of this project). However, this presumes that the work of Fulton and Gorton (2014) is correct as to the potienital time frames that epigenetic shifts may occur more quickly and that has not been considered here.

It is a truism of modelling that a model is only as strong as its weakest part. In terms of ecosystem models this transforms to be that the reliability of the model result for a species is only as good as the data used to constrain (and train) the model. This is why the targeted MICE models are some of the most effective as their focus is tight and each part is closely fit to data. There is higher uncertainty for many parts of the ecosystem models as there is much less data to fit these across all species and (for Atlantis across space and time). Scientists are often accused of answering all questions with the quip “we need more data”, but the reality is that is exactly what is needed if ecosystem models are to be constrained. The logistical reality of trying to monitor Australia’s marine estate is that with current technology it is not possible to monitor everything everywhere. However, we would positively encourage any effort at broadening the spatial and taxonomic extent of any data collection exercises. We really do need information on everything everywhere, while we freely acknowledge that this is infeasible it would be highly beneficial to all if citizen science, industry collection of information (e.g. if spike samples for isotope or fatty acid analysis could be taken in addition to current ISMP collections, as a low cost means of tracking some aspects of trophic connectivity), ships of opportunity (as done for acoustics and plankton recording) and the like could be adopted and if fisheries independent surveys could be broadened (though we appreciate that there are strong logistical and implementation constraints around this suggestion). Until such broad scale data collection is available ecosystem models will always have a reasonably high level of uncertainty. A pragmatic solution maybe to use sensitivity analysis and ecosystem models (including qualitative modelling approaches such as Dambacher et al. 2009, 2010, 2015) to identify systems that then receive more targeted monitoring, modelling and statistical fitting using MICE approaches.

Table 3-2: Summary of sensitivity scores and information projected by the sensitivity assessment, and regional and global models. S = Stable; P1 = Positive damped; P2 = Positive; P3 = Positive enhanced; N1 = Negative damped; N2 = Negative; N3 = Negative enhanced. Red – highly sensitive species with sensitivity scores > 2 and positive or negative changes < or > 20%. A dark grey square indicates that the species was not considered in that model or assessment.

		Approach								
		Sensitivity assessment			Regional models					Global Species distribution
Fishery	Commercial species	Abundance	Phenology	Distribution	Atlantis_F	Atlantis_D	EwE	EwE2	MICE	
BSCZSF	Commercial Scallop	1.75	2.25	2.5	N2	P2				
SPF	Redbait	1.5	2.0	2.0	P3	P2	S	S		-20
	Blue Mackerel	1.25	2.0	1.75	P2	S				-15
	Jack Mackerel	1.75	2.0	2.0	P2	P2	S	N2		-12
	Australian Sardine	1.25	2.0	1.75			P3			+6
SESSF	Blue Grenadier	2.0	2.25	2.0	S	P2		S		-15
	Tiger Flathead	1.5	1.5	2.25	P2	P2	N3	S		
	Pink Ling	1.75	1.0	1.75	P2	P2		S		-25
	Silver/blue Warehou	1.75	1.75	1.0	P2	P3				
	Eastern Redfish	1.5	1.0	1.5	P2	P2	N3	S		-3
	Eastern Gemfish	2.0	1.0	1.75	S	N3		PD		-1
	School Shark	2.0	2.0	2.25	P2	P2				-23
	Gulper Shark	2.5	1.0	2.75	N2	N2	ND	N2		
	Jackass Morwong	1.5	1.0	1.75	N2	N2		S		-10
	Orange Roughy	2.0	3.0	1.5	P2	P2		S		-41
SBTF	Southern Bluefin Tuna	1.5	2.5	1.25			P3			-14
WTBF	Tuna (all species)	1.5	2	1.25	S	S	N3	PD		
NPF	Banana Prawn	1.25	2.38	2.25			N2			-20
	Brown Tiger Prawn	1.38	2	2.38			PD			
TSFF	Coral Trout	2.5	1.75	2.5						
TSFLF	Lobster	2	2.25	2.5	N2				N3	
TSSMF	Spanish Mackerel	2	1.75	2						-21
ETBF	Yellowfin Tuna	1.5	2	1.25	P2		N2			-6
	Bigeye Tuna	1.5	2	1.25	P3		N3			-2

Table 3-3: Comparison of relative sensitivity of species per region across the different assessment approaches.

Region 1			Region 2			Region 3			Region 4			Region 5		
Agree	Some agreement	Disagree	Agree	Some agreement	Disagree	Agree	Some agreement	Disagree	Agree	Some agreement	Disagree	Agree	Some agreement	Disagre
Blue grenadier Jack mackerel Sth bluefin tuna Sardine Anchovy Tropical tunas Aust.salmon Snapper Garfish Marlin	Sth calamari Blue mackerel Flatheads Redbait Rock lobster	Gummy shark Abalones King prawn George Whiting Yellowtail kingfish	Herring Brown tiger prawn Goldband snapper Tailor Red emperor Eightbar grouper Gloomy octopus	Dhufish Snapper King prawn	Abalone Rock lobster Pearl oyster Blue swimmer crab Scallop Mud crabs Threadfin Baldchin groper Spangled emperor Sprat Sandfish Stripey snapper Grass emperor Pilchard Spanish mackerel	King prawns Banana prawns Crimson snapper Golden snapper Red emperor Spangled emperor Mangrove jack Grass emperor Mullet Golden trevally Pikey bream Whiting	Tiger prawns Billfish Sandfish Tropical lobster Bugs Coral trout Saddletail snapper Goldband snapper Hammerhead Blacktip sharks Spanish mackerel Giant trevally Spotted mackerel	Saucer scallops Spanner crabs Mud crabs Jewfish Sardines/ Herring Threadfin Barramundi Grey mackerel Dusky flathead	Sandfish Banana prawn King prawns Tiger prawns Emperors Golden snapper Mangrove jack Garfish Grey mackerel Mullet Blacktip sharks Spot tail shark Pikey bream Whiting	Tropical lobster Billfish Goldband snapper Crimson snapper Saddle tail snapper Threadfin Jewfish Coral trout Mud crabs Spanish Mackerel Bugs Spotted mackerel	Threadfin Sardine/ Herring Barramundi Hammerhead	Tropical lobster Tiger prawns King prawns Barramundi Billfish	Banana prawns Threadfin Snappers Spanish mackerel	Sandfish Hammerhe Blacktip sharks School mackerel Coral trou Emperors Cods Grey mackerel Pikey brea Barred javelin Spotted mackerel Mangrove jack Dusky flathead

The use of a diversity of approaches does leave the way open for divergence and disagreement between the outcomes of the different methods. It is easy to agree that where the methods agree that the results can be considered more robust. However, integrating divergent results is more difficult. In the first instance the ensemble can be used to the flag potential range in outcomes and the uncertainty associated with the future of that species – the range may be constrained by weighting the contribution of the individual methods to the ensemble by the confidence in the output of that method for that species. Alternatively, disagreement may be used to flag the need for more information before acting, however that is likely to become rapidly unwieldly given the patchiness of available data. Pragmatically, at least in the short to medium term, it may be necessary to seek expert advice on whether model output should be trusted or not for species where results differ strongly across the different approaches.

While additional data can help better fit ecosystem models they will likely always remain strategic (high level) models used to triage the list of potentially sensitive species and potential broad scale management options rather than for fine scale operational management decision making. In that vein, the models highlight here that

(i) there will be a strong differential in sensitivity and response across species, but in the main demersal sub-systems appear to be more strongly effected than pelagic sub-systems (this is concerning given the reliance on demersal food webs for much of Australia's seafood production)
(ii) individuals in shallower (i.e. more effected) waters or more margin habitats for that species will be the first to respond and will show the greatest magnitude of response
(iii) invertebrates may be among the most heavily impacted species and deserve a much better representation (and greater focus) in quantitative modelling approaches
(iv) the variability in primary production rather than simply the degree of temperature change will be important for ecosystem responses – if change in primary production is low and relatively stable) then ecosystems will show little change short of the temperature regimes moving beyond the tolerance levels of many species – unfortunately as yet there is no general agreement on the future primary productivity around Australia and this remains an active area of research
(v) the mechanisms of change cannot be easily generalised across all species (e.g. look at the range of outcomes and mechanisms identify in Atlantis-AMS in Table B-6), for some species the change is due to shifts in supporting productivity and prey fields, in other species it is a shift in predation pressure (as a predator switches after the loss of alternative prey, or when a more attractive or accessible target becomes available), for many species it is a more direct response to a loss in habitat, or shifting environmental conditions that move beyond preferred ranges – so that the timing of seasonal events moves forward (or backward) in time to compensate or the species moves to more favourable conditions (or shifts in abundance if distributional shifts are not possible); as frustrating as it may be for managers, industry and researchers looking to make things more straightforward it will likely come down to a case-by-case basis (which may even vary spatially across a species' extent)
(vi) single species models (e.g. species distribution and population models) are insufficient for understanding dynamics under climate change, key interactions and dependencies must be included for a better reflection of the potentially complex response of species – this means that assessment models likely need to be extended more along the lines of MICE models so as not to miss key drivers

An aspect of climate change not necessarily well reflected in the current oceanographic models is the degree of climate variability, as the environment will not shift in smooth slowly changing trajectories as is typically the case in the current forcing files. Current climate models do not yet well capture inter-decadal variability (it is the current major focus of research bodies such as the CSIRO's Climate

Centre), but as the mass mortalities of marine habitats around Australia in the last 5-10 years and the drop in abundance of species such as abalone in response to marine heatwaves attest, short duration extreme events may pose many more problems for marine species than considered in this project. Nevertheless, for the next 10-30 years climate variability will likely dominate over climate trends and so the results here may underestimate the rapidity of any changes seen.

Conclusion

Fisheries governance is likely to face ongoing changes into the future as new shifts in ecosystems, the climate system and the broader socioecological system of Australia (including its culture) are realised. However, it is safe to say that fisher behaviour and management regimes will need to be flexible if they are to cope with anticipated shifts in environmental forcing and associated responses in species (and system) abundance, distribution and phenology. A failure to do so will bring economic (and likely social) hardship (Fulton and Gorton, 2014).

Risks of adverse outcomes are minimised with flexible, integrated and centralised management that allows for spatial shifts and appropriate shifts in targeting and relevant management reference points. As with ecosystem-based management in general, climate change issues will not be solved by simple prescriptions or single management actions (Worm et al. 2009; Fulton et al. 2014; Fulton and Gorton, 2014; Smith et al. 2017). Instead science and observation-based adaptive management processes will be required that utilise updating information sources to support continuous revision and adjustment of management levers in response to shifting system state and changes in social attitudes (Adger et al. 2009; Fulton et al. 2014; Fulton and Gorton, 2014).

Article II. Implications

The CSIRO and its collaborators have pulled together all available information on how climate may affect fished species in Australia – identifying those most sensitive to climate. This information helps highlight those species that may be at risk and those that might benefit, allowing fisheries to be better prepared.

So far this has provided management and research recommendations – both to guide future management change to allow for greater adaptation to changes and to help ensure sustainability going forward, but also to prioritise actions that can help clarify what is occurring and minimise uncertainty.

This work is significant in that it has identified highly sensitive target and protected species within the jurisdictions of all Australian fisheries. Overall 60% of target species are highly sensitive to climate drivers and potential losses if no adaptation is possible may be as high as 80% in some fisheries. Consequently, the use of the content of this report to inform ongoing work around fisheries adaptation is imperative and highly valuable. Periodic reviews of this kind will be imperative to ensure that Australian fisheries continue to have the best information possible, to allow them to mitigate undesirable outcomes and maximise new opportunities.

Article III. Recommendations

Based on previous work on barriers to adaptation in Australian fisheries – e.g. work under taken for SEAP (Fulton and Gorton, 2014; Pecl et al 2014; Caputi et al 2015; Welch et al 2014) – and the findings of this project 8 recommendations can be made as a starting point for thinking about how to modify Australian fisheries governance to make it more climate robust

1. ***Based on short term sensitivity, focal areas should be (i) northern invertebrate fisheries and (ii) finfish fisheries within areas of regime change (e.g. Tasman Sea area and species)***

While the recommendations given below apply across fisheries it makes sense to begin with those fisheries and species identified by this study as potentially most sensitive. That means any actions or consideration taken should likely be focused first on invertebrate species (so in the context of Commonwealth species this would be the sandfish/beche-de-mer and tropical prawn species) and on fisheries in areas that are already experiencing climate related shifts and restructuring (such as south east Australia, especially the Tasman Sea region, where shifts in the East Australian Current and repeated extreme events including marine heatwaves have already seen a number of range extensions into new areas (e.g. Sunday et al. 2015; Ling et al. 2009; Pitt et al. 2010), habitat losses and community shifts (Johnson et al. 2011) and changes in species productivity (Wayte, 2013).

2. ***Existing management strategies must be assessed in terms of whether they help or hinder long term ecological and resources management objectives***

The shape of extant management strategies has unavoidably been conditioned by historical contexts and as such many not automatically be delivering what is required for the long-term achievement of management objectives under climate change (and associated changes to the kinds of stressors on stocks and ecosystems). This means that a sensible first action is to step back and check that the management strategies in place really are likely to deliver as required into the future (especially for those species or fisheries that are flagged as most sensitive to climate drivers). As part of this evaluation, management strategies should be assessed in terms of their capacity to not only rebuild stocks, but also help recover (where possible given changing potential productivity) degraded marine ecosystems, as this larger system perspective will be required for maximum resilience going forward (Fulton and Gorton, 2014). If gaps are found to exist then new or variant management strategies will need to be developed.

An additional necessary part of this evaluation will be addressing whether current objectives themselves remain sensible or whether they too need updating. Objective setting is a social exercise that goes far beyond the scope of this report, however it is worth noting that there is an ongoing and rich debate with the scientific literature around how to sustainably exploit marine ecosystems and what this means for coordinating management across sectors and gears to achieve this (e.g. Garcia et al. 2012; Curtin & Prellezo 2010). As this remains an active area of research this review process will likely need iterative updating (e.g. as part of the 5-year cycles of ERAEF and harvest strategy reviews). It is already clear that as part of taking an ecosystem based management (EBM) approach management considerations must go beyond focusing on fisheries target species to think about system structure and which groups maintain system cohesiveness. This will require greater coordination between conservation and fisheries management as previous work (e.g. Fulton and Gorton, 2014; Pomeroy et al. 2001) shows that key groups include habitat forming groups and top predators such as large pelagic sharks and rays, as well as iconic mammals (seals and orcas) that are already of keen conservation interest.

A fish group with a central role in many Australian marine ecosystems that has received little management, industry, or even scientific, attention to date is mesopelagics. The key role mesopelagics play in global ecosystems is beginning to be appreciated (Kloser et al. 2009; Irigoien et al. 2014) and their potential as a large untapped protein source is also gathering consideration (e.g. in Peru where they are being proposed as an alternative fish oil source given the increasing volatility in the small pelagics, such as anchovy, there). If this resource is to be sustainably exploited without unduly disturbing ecosystem function however, more caution would be required that would typically be assumed by classical fisheries approaches given their abundance and productivity. Modelling suggests that the depletion of these species would have a disproportionately negative effect on the energy flow between trophic levels and within trophic groups for most Australian ecosystems, but particularly in temperate Australia (Fulton and Gorton, 2014).

Another potential aspect of EBM that requires more explicit consideration is the topic of ecosystem and species interventions. Research initiatives and discussions in the popular media already highlight that transplantation of species or manipulation of genomes are being considered as options for increasing the adaptive capacity of the Great Barrier Reef. Transplantation has also been trialled for other species (e.g. southern rock lobster, Gardner & Van Putton 2008). While modification of the environment to tailor it to human needs is a feature of marine ecosystem use in some Asian nations (e.g. use of artificial reefs and structures in ocean ranching in Japan and China) it has received less explicit consideration in Australia. While the topic will need to be handled with care, given its potentially controversial nature (Hobday et al. 2014), it should not be shied away from as stumbling into a decision without due consideration of the true implications (potential benefits and drawbacks for individual species and entire ecosystems as well as the financial implications) would be unwise. Even if direct life history intervention is considered too extreme, other system modifications in support of increasing adaptive capacity may be found to be acceptable (e.g. the provision of artificial nests for seabirds (Hobday et al. 2014) or protection of estuarine nursery habitats, or the modification of flow regimes to enhance fecundity or migration success (Creighton et al 2015).

3. *Fisheries management methods should be made as flexible as possible, so they can change as rapidly as need to respond to changing system state*

Traditionally the shift had to be recognised (observed), the degree quantified, the causes attributed and the responses formulated. There simply isn’t time for such linear sequential approaches any longer. The rapidity of change being seen off Eastern Australia means that more adaptive approaches are required, where no (or at least minimal) regrets approaches are taken and updated as new information comes to light (Creighton et al 2016). Moreover, given the uncertainty around climate change (e.g. energy) policy and the true magnitude of future climate change and resulting responses, managers (and the instruments they use) will need to remain flexible and adaptable. This is in line with the concepts of adaptive management (Holling, 1978; Walters, 1986; Ostrom et al. 1999; Dietz et al. 2003), which is already the premise behind Australian fisheries management processes, and governance based on resilience thinking (Lebel et al. 2006; Walker et al, 2006; Allen and Holling, 2010). Nevertheless, some management instruments will need to be further adapted in recognition of the non-stationary nature of climate drivers; the use of spatial or seasonal closures, even some reference points, will have to be done in such a way that they are not fixed. For example, recognition of regime shifts in assessments (Wayte, 2013), allowing for non-stationarity in management strategies (A’Mar et al. 2009) and the definition of fisheries closures based on water bodies rather than a fixed geographic location (Hobday et al. 2010).

The updating of reference points has been suggested as the best practice means of adapting current management strategies for changing climate conditions (A’mar et al. 2009; Brown et al. 2012). Such modifications need to navigate noise in monitoring data and follow frameworks such as those in proposed in (Klaer et al. 2015) to make sure they are responding to true regime shifts.

Individual Transferable Quotas (ITQs) are likely to remain a mainstay of fisheries management approaches, as despite their weaknesses, they are an inherently flexible management approach. However, care must be undertaken not to accidentally undermine their performance. Brown et al.

(2012) demonstrated that, if a system is under a directional driver or is transitioning to a new state, delays in governance can undermine management performance. When stocks are declining in productivity overfishing during periods with poor environmental conditions can result in a greater probability of the stock dropping to lower biomass levels (Fulton and Gorton, 2015) or even collapse (Brown et al. 2012). While industry and others has made the argument for less frequent assessments and TAC setting on the grounds of a need for stability in catches (for the purposes of investment) and a reduction in management costs, Fulton and Gorton (2014) found that such delays in the assessment cycle provided a perception of stability in the short term, but that a more responsive assessment system performed more strongly in the long-term. Moreover, Brown et al. (2012) found that harvest and returns were ultimately lower (40% lower over 50 years) with delays in the management system, as changes were often in much larger steps (to account for periods of accidental overfishing). While the use of more conservative reference points and the introduction of limits on harvest rates could reduce the risk of overfishing when using less frequent assessments for stocks with declining productivity, Brown et al. (2012) found that these came at a significant cost in foregone catch – as target reference points needed to be set to B_{80} or higher and the harvest limits saw 5-15% of harvest lost.

Spatial management has been suggested as an alternative management method that is less reliant on reference levels and assessment cycles (Steffen et al. 2009). However, dynamic approaches such as that described in (Hobday et al. 2010) and used until 2015 in the ETBF will likely need to increasingly become the standard as static forms of spatial zoning is not well suited to the more fluid nature of marine ecosystems under directional drivers (Hobday et al 2014; Lewison et al 2015; Maxwell et al 2015). Shifting system boundaries and extents make fixed zones less effective (potentially completely ineffectual). This makes defining zones around specific oceanographic features rather than only geographic coordinates an attractive and suitably flexible approach. Although care does need to be taken that some of the species that are slower to (or do not) relocate do not lose their protection.

4. ***Fisheries policy, management and assessment methods (including ERAEF) need to allow for the concept of regime shifts and extreme events and for contextual management decision making***

Just as management tools will need to allow for changed potential stock productivity, they will also need to recognize step changes in system state. Adapting management (especially underlying policy) for trending change is non-trivial, but dealing with sudden large changes is much harder. Most economic assessments of future change (e.g. Garnaut, 2008; Productivity Commission, 2012) assume gradual or smooth change. Unfortunately, nonlinear change is a feature of complex systems and is already being seen in Australian marine ecosystems (e.g. Wayte, 2013; Ling et al. 2009). Many parameterisations, of the models used in this study do suggest the potential for significant system wide shifts in key locations such as the Tasman Sea (Fulton, 2011; Fulton and Gorton, 2014); due to mechanisms including the synergistic action of distributional and phenological changes, truncation of the age structure and altered community compositions, which effect system structure, reducing interconnectedness, buffering capacity and resilience (Fulton and Gorton, 2014).

This means fundamental changes in fisheries management will likely be required. The classic fisheries concepts of B_0, virgin biomass and associated classical fishery methodologies are likely to become meaningless. New approaches to management need to be developed (these may include Bayesian or artificial intelligence-based approaches for instance). Lessons regarding how to cope with step changes in productivity (whether once off or due to the system alternating between different overall states of productivity, as hinted at in the Atlantis-AMS runs summarised in Table B-6) can be found in other systems (particularly upwelling systems) that have already faced such challenges. Frame-based approaches which adjust the level of precaution applied, as well as acceptable fishing mortality rates and survivorship, based on system status have been suggested for both the Benguela

(Smith et al. 2015) and the California Current (Punt et al. 2016). The precautionary reduction of harvest rates when the system is thought to be less productive (which also occurs in the Bering Sea) does require tracking of contextual indicators so that managers can be kept informed regarding the system state.

5. ***Non-static environmental conditions must receive increased attention in fisheries operations, but particularly in the assessment and decision making processes; fishing operations, monitoring, the level of precaution applied and the frequency of assessment should be cognizant of the level of a species' or fishery's vulnerability/sensitivity***

Given the issues identified above around the negative consequences of delays in management responses and the risks associated with step changes in system productivity, the management decision making process will either need to (i) more explicitly priorities resources and awareness around vulnerable/sensitive species and fisheries or (ii) have a discussion (and make a clear decision) on whether it is acceptable for some species to be recognised as being beyond the capacity of the management process to protect and maintain. Such hard decisions may be required regardless of ideals given that it may simply be impossible to retain all species in the ecosystem as the climate shifts.

Nonetheless, the development of nested forecasting tools – spanning time frames from days to months to years and decades – will help fortify the decision-making process and help industry and management target their investments and fishing activities wisely and efficiently (Hobday et al. 2011). At present these forecasts allow industry to identify when they need to shift timing or between neighbouring locations, but the day may come when forecasts and models are to advise on more significant transformations (e.g. a switch in target species that are not yet a major focus, such as snapper off Tasmania, or a major regional relocation). Such tools will likely require dedicated streams of data for assimilation and this will need to be considered as future monitoring programs are drawn up and technology invested in.

6. ***Cross jurisdictional management of stocks is becoming imperative***

A pressing change required in Australian fisheries management is coordination over large spatial areas, across sectors and jurisdictions. Stocks have already begun to shift between states and to straddle jurisdictional boundaries. It also possible that spawning stocks can be in one jurisdiction, while the fishable stock in another. This means fisheries management needs to be coordinated over multiple jurisdictions if the most is to be made of new opportunities while avoiding (or at least minimising) any negative effects. This will not only raise allocation issues (e.g. between jurisdictions but also sectors, including recreational and indigenous) but also social and legal challenges.

Successful management of straddling stocks has been a contentious and often unresolved issue for decades now (with the UN agreement on straddling and highly migratory fish stocks adopted in 1995). Jurisdictional and resource sharing issues are complicated further if it is not simply a matter of a range extending species, but if stages of the life history become smeared over many jurisdictions. For example, if a species comes to rely on a small number of productive "source" spawning locations, with exploited populations sitting downstream; which raises thorny questions regarding relative responsibility, benefit and compensation for restraint (e.g. if societies surrounding a source population acts not only for their own benefit but also for downstream users). Psychological research suggests that in such circumstances centralised management is most effective, as humans find that learning and acting wisely on temporally or spatially remote information is quite difficult (Kahneman, 2011). Without centralised management (or cooperation across jurisdictions) local stress for fishing communities can become significant (Fulton and Gorton, 2014).

Centralised consultation will also be required when deciding on allocation across sectors, as a bigger picture view will be required when considering whether a range extending species can be treated as a pest species in the new jurisdiction (and fished heavily by one or more sectors) or whether it needs to be allowed to establish in the new location as it is being lost from its historical locations, or because it is picking up the functional role of another species (maintaining functional diversity as the other species declines). While there will be initial disruption and overhead associated with the centralisation or coordination of management, ultimately it will be the most effective approach as the case-by-case nature of species shifts and responses means creating universally robust decision trees that can be individually applied in each jurisdiction will be impossible.

7. ***Not all fisheries and operators have equal adaptive capacity, which will compound the differential outcomes of changes seen across species and fisheries, meaning either accepting uneven social and economic consequences (and potential controversy) or implementation of differential support mechanisms and broad communication channels***

It is already known that there will be differential environmental change around Australia, west to east as well as north to south (Matear et al. 2013) meaning exploitation in some locations will need to retract while it expands in others (Brown et al. 2009; Fulton, 2011; Dutkiewicz et al. 2013; Fulton et al. 2014); equally there will be differential social flexibility contraction in ownership, and changes in employment (Fulton and Gorton, 2014). While coherent industry wide adaptation may be preferred, rather than competition between individuals, it is unlikely as smaller operators are more socially tied to specific locations and resource constrained than others – i.e. adaptive capacity is greater amongst larger fisheries operators, who have greater financial flexibility and can quickly shift behaviour via employing “captains for hire” (Baelde, 2001; Marshall et al. 2007). Consequently, regulatory bodies will need to navigate opposition from at least some sectors of society, as can already been seen in the increasing tensions over social licence around the use of some fishing and processing methods (Tracey et al. 2013). Avoiding exacerbation of such issues into the future, will require effective communication of management needs and the changing status of fisheries so that disconnects between effective management options and public perception are minimised or common ground around acceptable options identified (Hobday et al. 2014).

8. ***Integrated management needs to be central to the thinking behind fisheries management***

In the short to medium term fisheries management will focus on getting its own house in order, coordinating across sectors and jurisdictions to improve its robustness to climate change. However, in the not too distant future, it will be important for fisheries to set themselves in the context of the entire blue economy. Fisheries are now but one of many competing uses of marine and coastal systems and in many places access is becoming spatially constrained (Swartz et al. 2010). In the context of climate change and global change more broadly (which spans other changes in human use and influence of marine ecosystems) success of management approaches will ultimately be dependent on coordination across all uses of the marine environment (all industries and conservation, recreational and cultural uses) and levels of government, as actions by one user group or level of government may undermine those of another. For example, built infrastructure may provide new habitats (e.g. rigs and pipelines), or equally prevent the retreat of crucial estuarine nursery habitats (e.g. shore hardening). Extension of fisheries management to integrated management, addressing the interaction of the multiple users of the marine and coastal environments (that supplements dedicated industry specific management efforts) is consistent with the current approach of balancing performance across the multiple objectives held for marine ecosystems (Fulton et al. 2011; Fulton et al. 2014; Smith et al. 2017). However, success of such an approach is not immediately guaranteed as existing departmental structures do not facilitate it and large scale operational examples do not yet exist (though smaller regional scale pre-cursors can be found in Gladstone, NSW, Spence Gulf and in GBRMPA; Smith et al. 2017). Whatever the final form, it will (i) need to maintain an adaptive framework so that it can address the changing nature of the broader socioecological system, (ii) require a mix if management levers due to the range of species and processes to be managed and (iii) recognise the trade-offs between the objectives held for the different sectors and the system as a whole (Kinzig et al. 2006; Fulton and Gorton 2014; Smith et al. 2017).

3.2.1 Monitoring

Availability of good environmental information, transparently shared, facilitates good decision-making and is fundamental to successful fisheries management (Worm et al. 2009), especially co-management (Pomeroy et al. 2001). In an ideal world, up-to-date fisheries dependent and independent data would be collected at the finest spatial and temporal resolution possible, so as to reduce scientific uncertainty and improve assessment and ecosystem models. Given the extent of Australia's EEZ and the relative size and value of its fisheries this is not feasible with current technologies. While we wait for the next generation of sensors (and the "internet of things") to come online priority should be given to:

i. Improved understanding and prediction of shifts in primary production around Australia - this is fundamental to understanding the potential changes to rest of the ecosystem but is currently highly uncertain. This will require improved process understanding.
ii. Greater knowledge of how species are adapting to the changed conditions - this information will provide insight into whether species are robust to change (acclimating to the new conditions, or responding via evolution or changed behaviour), or whether they are simply being overwhelmed.
iii. Indicators of the physical state of the system (which is becoming increasingly available through operational oceanography, but may also be sourced through collaborative agreements with fisheries operators who often employ highly sophisticated net sensors).
iv. Indicators of primary productivity and plankton community composition, as this dictates basal productivity and can also forewarn of coming stock productivity and recruitment issues (remote sensing products and continuous plankton recorders on ships of opportunity, coordinated by IMOS, provide the best available source of such data).
v. Maintenance of the quality of fisheries dependent data, as it is the longest and most widely available data set for the target species.
vi. Independent surveys (where possible) so that the broader system structure, relative content and function can be assessed (relying on ecosystem and diet information that is in many cases decades old, speculative or based on analogous systems elsewhere puts the quantitative methods at a distinct disadvantage); this may only be possible episodically, in which case it will need to be done with extreme care to maximise the statistical value of such expeditions (Smith et al. 2011).
vii. Encouragement of non-traditional data sources, such as information sourced from citizen science initiatives such as Redmap (http://www.redmap.org.au/); while such data will also require careful interpretation and appropriate statistical handling the almost ubiquitous coverage of smart phones and other cameras and recording devices once only available to professionals makes the Australian public a potentially very valuable source of information on marine and coastal systems and how they are changing.

The next challenge is synthesising this information into a coherent message around system status and trends. Lessons can be learnt from how this is done in the EU and US, which have ecological indicator reporting in parallel with the stock assessment process and undertake periodic Integrated Ecosystem Assessments (e.g. DePiper et al. 2017). Work is also underway on operationalising ecosystem based fisheries management via identifying indicators that can be used to provide an ecosystem context to existing single species and specific fisheries oriented management processes (the SESSF is a case study location in this work being led by CSIRO and UTAS researchers Fulton and Sainsbury). Model based assessments of suites of ecological indicator for fisheries management have already highlighted that the creation of aggregate indices (combining many separate data streams) can be sensitive to the methods used and risk losing transparency, understanding and information content (Fulton et al. 2005).

Section 3.01 Further development

This work us already serving as a basis for an additional FRDC project supporting AFMA's review and revision of its management practices to make them more adaptable and robust to climate drivers. A similar process will be required across state fisheries to ensure they are not negatively impacted by climate induced ecosystem shifts. The work in here can aid that process. In addition, periodic review and updating will be required to make sure the current climate status and trends (and their implications for fisheries) are up to date and of maximal value for industry, management and society.

Article IV. References

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Article V. Extension and Adoption

The content (trends and recommendations) of the project have been discussed with the climate research community and intensively with all relevant AFMA managers. The work is being used as a launch point for the new AFMA work on making fisheries management climate robust so as to maximise adaptation options.

AFMF is also being briefed and summaries per region and state have been prepared to help State fisheries update their understanding of climate implications. To help with this and to help communicate findings to Industry and broader society a non-technical summary, fact sheet and info graphic have been created.

Section 5.01 Project coverage

As yet not articles from the media, industry or the government exist. However, the communications bodies of AFMA and CSIRO are working closely together to produce materials to help communicate some of the more sensitive content to industry, management, government departments and the broader Australian community.

Article VI. Glossary

Term	Description
Anomaly	The difference between future conditions and current (or reference conditions)
Atlantis	A whole of system modelling framework that includes oceanography (currents and environmental conditions such as temperature, salinity and oxygen), food web and habitat links, fishing, and management processes
CAAB	Codes of Australian Aquatic Biota
CMIP	Coupled Model Intercomparison Project
constant F	Models run under constant (2010) levels of fishing mortality rates
control scenario	No emission scenario (climate model run with historical drivers and without an assumed trajectory of global emissions)
DBEM	Dynamic Bioclimate Envelope Models
dynamic F	Models run under dynamic fishing effort and management simulations (applies to the Atlantis-SEA model only), this simulations include full feedback management decision processes and active effort and species targeting decisions by the modelled fishers (influenced by economic and social drivers as well as historical patterns of fishing)
Ensemble (or suite) of models	A group of models of different types, using different assumptions and formulations that are run using the same (or similar) input. The output of these models is then taken as a group to show the potential range of outcomes and thereby give some indication of uncertainty across all the structural differences in the models. While this approach is only beginning to be used in ecosystem modelling it is considered world's best practice for climate models and is now the standard approach to looking at the trajectory of global temperatures (for example).
EwE	Ecopath with Ecosim, a food web model that tracks the flow of energy through the trophic connections of an ecosystem
EEZ	Exclusive Economic Zone – the area out to 200 nautical miles from the coastline over which the nation has special rights (as prescribed by the United Nations Convention on the Law of the Sea) regarding exploration and use of marine resources (e.g. fish stocks, minerals, energy production etc).
IPCC	Intergovernmental Panel on Climate Change – the international body that draws together the scientific understanding of climate change
MICE	Models of Intermediate Complexity
OFAM	Ocean Forecasting Australia Model (the model of Australian oceanography, currents, flows, temperature and salinity)
RCP	Representative Carbon Pathway – IPCC scenarios about the level of future emissions (and resulting climate change)
RCP 8.5 scenario	High emission "business as usual" scenario (20-30 Gigatons of Carbon, or 1370 ppm of CO_2 at the end of 2100) – most severe climate change scenario currently used by the IPCC
SEAP	Southeast Australia Program – a program exploring potential influences of climate and aquaculture in SE Australia and potential adaptation options
Size-based model	A modelling approach that groups age classes and species based on size (or size-based traits such as maximum size). Reproduction adds material to the smallest size class and transition between size classes represents both growth and aging. All feeding is done based on feeding windows (i.e. the size of prey available to predators of a particular size) and preferences (so that links that are possible based on size but never seen in reality can be screen out).
Species distribution model	A model of the distribution of a species based on its observed physiological and other tolerances (e.g. if a species is seen in certain habitats and at certain temperatures today its future distribution is projected based on where those habitats and temperatures are expected to be in the future as dictated by climate model outputs).

Article VII.Project materials developed

In addition to this technical project report, a non-technical summary, a factsheet and an infographic of the results have been created for wider circulation. Additional communications materials are also under development by CSIRO and AFMA. A scientific paper is also in preparation and the findings will be presented at 4th International Symposium on the Effects of Climate Change on the World's Oceans meeting in Washington DC in June 2018.

Article VIII. Appendices

See below for all Appendices to this report.

Appendix A Sensitivity results - Scores for all species

Appendix A Table 1: Scores for region 1: South East Australia (Pecl et al. 2011 - Part 1). Taxa DC: demersal chondrichthyans; DF: demersal fish; PF: pelagic fish; I: invertebrates

Common name	Species name	Taxa	FRDC - CAAB	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Australian anchovy	*Engraulis australis*	PF	37086001	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
Australian salmon – eastern[1]	*Arripis trutta*	PF	37344002	1.00	2.00	2.00	2.00	1.75	2.00	1.00	1.00	2.00	1.50	2.00	2.00	2.00	3.00	2.25	5.50
Australian salmon – western[1]	*Arripis truttaceus*	PF	37344004	1.00	2.00	2.00	2.00	1.75	2.00	1.00	1.00	2.00	1.50	2.00	2.00	2.00	3.00	2.25	5.50
Australian sardine	*Sardinops sagax*	PF	37085002	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
Bigeye tuna	*Thunnus obesus*	PF	37441011	1.00	2.00	2.00	1.00	1.50	2.00	1.00	1.00	1.00	1.25	2.00	2.00	2.00	2.00	2.00	4.75
Black bream	*Acanthopagrus butcheri*	DF	37353003	1.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00	3.00	2.25	3.00	3.00	2.00	1.00	2.25	6.50
Blacklip abalone	*Haliotis rubra rubra*	I	24038006	1.00	2.00	2.00	2.00	1.75	3.00	3.00	2.00	3.00	2.75	3.00	3.00	2.00	1.00	2.25	6.75
Blue grenadier	*Macruronus novaezelandiae*	DF	37227001	1.00	3.00	2.00	2.00	2.00	2.00	1.00	2.00	3.00	2.00	2.00	2.00	2.00	3.00	2.25	6.25
Blue mackerel	*Scomber australasicus*	PF	37441001	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
Blue sprat	*Spratelloides robustus*	DF	37085003	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	5.75
Blue swimmer crab	*Portunus armatus*[2]	I	28911005	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	1.00	1.75	3.00	3.00	2.00	2.00	2.50	5.50
Commercial scallop	*Pecten fumatus*	I	23270007	1.00	3.00	1.00	2.00	1.75	2.00	3.00	2.00	3.00	2.50	3.00	3.00	2.00	1.00	2.25	6.50
Dusky flathead	*Platycephalus fuscus*	DF	37296004	1.00	2.00	2.00	2.00	1.75	2.00	2.00	1.00	2.00	1.75	2.00	1.00	2.00	2.00	1.75	5.25
Eastern king prawn	*Melicertus plebejus*	I	28711052	1.00	2.00	2.00	2.00	1.75	2.00	1.00	1.00	2.00	1.50	3.00	3.00	2.00	3.00	2.75	6.00

Common name	Species name	Taxa	FRDC - CAAB	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Greenlip abalone	*Haliotis laevigata*	I	24038004	1.00	2.00	2.00	2.00	1.75	3.00	3.00	3.00	2.00	2.75	3.00	3.00	3.00	1.00	2.50	7.00
Gummy shark	*Mustelus antarcticus*	DC	37017001	3.00	1.00	2.00	2.00	2.00	3.00	1.00	2.00	3.00	2.25	1.00	1.00	2.00	3.00	1.75	6.00
Jack mackerel	*Trachurus declivis*	PF	37337002	1.00	2.00	2.00	2.00	1.75	1.00	2.00	2.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00	5.75
King George whiting	*Sillaginodes punctatus*	DF	37330001	1.00	2.00	2.00	2.00	1.75	1.00	2.00	2.00	2.00	1.75	3.00	3.00	2.00	3.00	2.75	6.25
Redbait	*Emmelichthys nitidus*	PF	37345001	1.00	2.00	2.00	1.00	1.50	1.00	2.00	2.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00	5.50
Rock flathead	*Platycephalus laevigatus*	DF	37296006	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	3.00	2.25	2.00	1.00	2.00	1.00	1.50	5.50
Sandy sprat	*Hyperlophus vittatus*	DF	37085005	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	5.75
School prawn	*Metapenaeus macleayi*	I	28711029	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	3.00	3.00	2.00	3.00	2.75	6.50
Snapper	*Chrysophrys auratus*	DF	37353001	1.00	2.00	2.00	2.00	1.75	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.50
Southern bluefin tuna	*Thunnus maccoyii*	PF	37441004	1.00	1.00	3.00	1.00	1.50	2.00	1.00	1.00	1.00	1.25	3.00	2.00	2.00	3.00	2.50	5.25
Southern bluespot flathead	*Platycephalus speculator*	DF	37296037	1.00	2.00	1.00	1.00	1.25	2.00	2.00	2.00	2.00	2.00	2.00	1.00	2.00	2.00	1.75	5.00
Southern calamari	*Sepioteuthis australis*	I	23617005	2.00	1.00	1.00	2.00	1.50	3.00	2.00	1.00	3.00	2.25	2.00	2.00	2.00	3.00	2.25	6.00
Southern garfish	*Hyporhamphus melanochir*	DF	37234001	2.00	1.00	1.00	2.00	1.50	2.00	2.00	2.00	3.00	2.25	2.00	2.00	2.00	1.00	1.75	5.50
Southern rock lobster	*Jasus edwardsii*	I	28820001	1.00	2.00	2.00	2.00	1.75	1.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	1.00	2.50	6.75
Southern sand flathead	*Platycephalus bassensis*	DF	37296003	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	3.00	2.25	3.00	2.00	2.00	1.00	2.00	5.75
Spanner crab	*Ranina ranina*	I	28865001	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	1.00	1.75	2.00	2.00	1.00	2.00	1.75	5.25
Striped marlin	*Tetrapturus audax*	PF	37444002	1.00	1.00	2.00	2.00	1.50	2.00	2.00	1.00	1.00	1.50	2.00	2.00	2.00	3.00	2.25	5.25
Tiger flathead	*Platycephalus richardsoni*	DF	37296001	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	3.00	2.25	2.00	1.00	2.00	1.00	1.50	5.25
Western	*Melicertus*	I	28711047	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	1.00	1.75	3.00	3.00	2.00	2.00	2.50	5.50

Common name	Species name	Taxa	FRDC - CAAB	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
king prawn	*latisulcatus*																		
Yellowfin tuna	*Thunnus albacares*	PF	37441002	1.00	2.00	2.00	1.00	1.50	2.00	1.00	1.00	1.00	1.25	2.00	2.00	2.00	2.00	2.00	4.75
Yellowtail kingfish	*Seriola lalandi*	PF	37337006	2.00	2.00	2.00	1.00	1.75	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.50
Yellowtail scad	*Trachurus novaezelandiae*	PF	37337003	1.00	2.00	2.00	1.00	1.50	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.25

[1] Two species Australian salmon (eastern and western) were assessed together in Pecl et al. 2011. We separated them (*Arripis trutta* and *A. truttaceus)* and used the same score values for both.

[2] In Pecl et al. 2011, the scientific name used for the blue swimmer crab was *Portunus pelagicus*. Current accepted scientific name is *Portunus armatus*.

Appendix A Table 2: Scores for region 2: Western Australia (Caputi et al. 2015). Taxa DC: demersal chondrichthyans; DF: demersal fish; PF: pelagic fish; I: invertebrates

Common name	Species name	Taxa	FRDC - CAAB	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Australian herring	*Arripis georgianus*	DF	37344001	1.00	2.00	2.00	2.00	1.75	2.00	1.00	2.00	2.00	1.75	3.00	2.00	3.00	3.00	2.75	6.25
Baldchin groper	*Choerodon rubescens*	DF	37384039	1.00	2.00	2.00	2.00	1.75	2.00	3.00	2.00	2.00	2.25	3.00	1.00	2.00	1.00	1.75	5.75
Ballot's saucer scallop[3]	*Ylistrum balloti*[3]	I	23270001	1.00	2.00	1.00	2.00	1.50	2.00	3.00	2.00	2.00	2.25	3.00	2.00	2.00	1.00	2.00	5.75
Bight redfish	*Centroberyx gerrardi*	DF	37258004	1.00	2.00	2.00	1.00	1.50	2.00	2.00	3.00	2.00	2.25	2.00	3.00	2.00	2.00	2.25	6.00
Black bream	*Acanthopagrus butcheri* [4]	DF	37353003	1.00	3.00	2.00	1.00	1.75	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	1.00	2.00	6.75
Blue swimmer crab	*Portunus armatus*	I	28911005	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	5.75
Blue threadfin	*Eleutheronema tetradactylum*	DF	37383004	1.00	2.00	1.00	2.00	1.50	2.00	3.00	3.00	2.00	2.50	2.00	2.00	2.00	1.00	1.75	5.75
Bluespotted	*Lethrinus*	DF	#N/A	1.00	2.00	2.00	1.00	1.50	2.00	2.00	3.00	2.00	2.25	2.00	2.00	2.00	1.00	1.75	5.50

Common name	Species name	Taxa	FRDC - CAAB	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
emperor	*punctulatus*																		
Brown tiger prawn	*Penaeus esculentus*	I	28711044	1.00	2.00	1.00	2.00	1.50	2.00	2.00	3.00	2.00	2.25	3.00	3.00	2.00	3.00	2.75	6.50
Brownlip abalone	*Haliotis rubra conicopora*	I	24038002	1.00	2.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	1.75	6.75
Eightbar grouper	*Epinephelus octofasciatus*	DF	37311152	1.00	2.00	2.00	1.00	1.50	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	1.00	1.75	5.00
Gloomy octopus	*Octopus tetricus*	I	23659006	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	1.00	1.50	3.00	3.00	2.00	1.00	2.25	4.75
Goldband snapper	*Pristipomoides multidens*	DF	37346002	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.75	5.50
Grass emperor	*Lethrinus laticaudis*	DF	37351006	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.75	5.50
Greenlip abalone	*Haliotis laevigata*	I	24038004	1.00	1.00	2.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	1.75	6.50
King threadfin	*Polydactylus macrochir*	DF	37383005	1.00	2.00	2.00	2.00	1.75	2.00	2.00	3.00	2.00	2.25	2.00	2.00	2.00	1.00	1.75	5.75
Mud crab[5]	*Scylla serrata*	I	28911008	1.00	1.00	1.00	2.00	1.25	2.00	3.00	2.00	2.00	2.25	3.00	3.00	1.00	2.00	2.25	5.75
Orange mud crab[5]	*Scylla olivacea*[5]	I	28911007	1.00	1.00	1.00	2.00	1.25	2.00	3.00	2.00	2.00	2.25	3.00	3.00	1.00	2.00	2.25	5.75
Perth herring	*Nematalosa vlaminghi*	DF	37085017	1.00	2.00	2.00	2.00	1.75	3.00	2.00	3.00	3.00	2.75	3.00	2.00	3.00	3.00	2.75	7.25
Pilchard	*Sardinops sagax*	PF	37085002	1.00	1.00	1.00	1.00	1.00	2.00	2.00	3.00	2.00	2.25	3.00	2.00	2.00	2.00	2.25	5.50
Red emperor	*Lutjanus sebae*	DF	37346004	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.75	5.25
Roe's abalone	*Haliotis roei*	I	24038005	1.00	2.00	2.00	3.00	2.00	3.00	3.00	2.00	3.00	2.75	2.00	2.00	2.00	1.00	1.75	6.50
Sandfish (Beche-de-mer)	*Holothuria scabra*	I	25416004	1.00	2.00	1.00	2.00	1.50	2.00	3.00	2.00	2.00	2.25	2.00	2.00	2.00	1.00	1.75	5.50
Sandy sprat	*Hyperlophus vittatus*	DF	37085005	1.00	2.00	1.00	2.00	1.50	3.00	2.00	3.00	2.00	2.50	2.00	2.00	1.00	1.00	1.50	5.50
Silver lipped pearl oyster	*Pinctada maxima*	I	23236003	1.00	2.00	2.00	2.00	1.75	2.00	3.00	2.00	2.00	2.25	3.00	3.00	2.00	1.00	2.25	6.25
Snapper[6]	*Chrysophrys auratus*	DF	37353001	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	6.00
Spangled emperor	*Lethrinus nebulosus*	DF	37351008	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	5.75
Spanish	*Scomberomorus*	PF	37441007	1.00	2.00	1.00	2.00	1.50	2.00	2.00	2.00	1.00	1.75	2.00	2.00	2.00	2.00	2.00	5.25

Common name	Species name	Taxa	FRDC - CAAB	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
mackerel	*commerson*																		
Stripey snapper	*Lutjanus carponotatus*	DF	37346011	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.75	5.50
Tailor	*Pomatomus saltatrix*	DF	37334002	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	1.00	1.75	3.00	2.00	1.00	3.00	2.25	5.50
Sandbar shark	*Carcharhinus plumbeus*	DC	37018007	3.00	1.00	3.00	1.00	2.00	3.00	1.00	2.00	1.00	1.75	2.00	2.00	2.00	3.00	2.25	6.00
WA Dhudish	*Glaucosoma hebraicum*	DF	37320004	1.00	2.00	2.00	2.00	1.75	2.00	2.00	3.00	2.00	2.25	3.00	3.00	2.00	1.00	2.25	6.25
Western blue groper	*Achoerodus gouldii*	DF	37384002	1.00	2.00	3.00	1.00	1.75	2.00	3.00	3.00	1.00	2.25	3.00	1.00	1.00	1.00	1.50	5.50
Western king prawn	*Melicertus latisulcatus*[7]	I	28711047	1.00	2.00	1.00	2.00	1.50	2.00	2.00	2.00	2.00	2.00	2.00	3.00	1.00	3.00	2.25	5.75
Western rock lobster	*Panulirus cygnus*	I	28820005	1.00	2.00	2.00	2.00	1.75	1.00	2.00	2.00	2.00	1.75	3.00	3.00	2.00	3.00	2.75	6.25
Whiskery shark	*Furgaleus macki*	DC	37017003	3.00	1.00	2.00	3.00	2.25	3.00	2.00	3.00	2.00	2.50	1.00	1.00	2.00	2.00	1.50	6.25

[3] Named as Southern Saucer scallop *Amusium balloti* in Caputi et al. 2015. We used the name Ballot's Saucer Scallop *Ylistrum balloti* as in FRDC database.

[4] Black bream scientific name was spelt as *A. butcherii* in Caputi et al. 2015

[5] Two species of mud crab were assessed together (*S. serrata* and *S. olivacea*) in Caputi et al. 2015. We separated them in mud crab (*Scylla serrata*) and orange mud crab (*Scylla olivacea*), and used same score values for both.

[6] Listed as Pink snapper in Caputi et al. 2015.

[7] Western king prawn scientific name used in Caputti et al. 2015 was *Penaeus latisulcatus*

Appendix A Table 3: Scores for region 3: North-Western Australia (Welch et al. 2014, raw data from species prioritisation). Taxa DC: demersal chondrichthyans; DF: demersal fish; PC: pelagic chondrichthyans, PF: pelagic fish; I: invertebrates.

Common name	Species name	Taxa	FRDC - CAAB	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Banana prawn	*Penaeus merguiensis*	I	28711050	1.50	2.00	1.00	1.50	1.50	2.00	2.50	2.00	2.50	2.25	2.50	2.00	3.00	1.50	2.25	6.00
Barramundi	*Lates calcarifer*	DF	37310006	1.50	2.00	2.00	1.50	1.75	2.50	2.50	1.50	2.00	2.13	2.00	1.00	2.00	2.00	1.75	5.63
Barred javelin	*Pomadasys kaakan*	DF	37350011	1.50	1.50	1.00	1.00	1.25	1.50	1.50	1.50	2.00	1.63	1.50	1.50	1.50	1.00	1.38	4.25
Billfish (sailfish)	*Istiophorus platypterus*	PF	37444005	3.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00	1.00	2.25	2.00	2.00	2.00	3.00	2.25	7.50
Black jewfish	*Protonibea diacanthus*	DF	37354003	1.50	2.00	2.00	1.50	1.75	2.00	2.50	2.00	3.00	2.38	2.00	2.00	2.00	2.00	2.00	6.13
Blacktip shark 1[8]	*Carcharhinus tilstoni*[8]	DC	37018014	2.00	2.00	2.00	1.00	1.75	2.00	1.50	1.00	1.50	1.50	2.00	1.00	2.00	2.00	1.75	5.00
Blacktip shark 2[8]	*Carcharhinus limbatus*[8]	DC	37018901[10]	2.00	2.00	2.00	1.00	1.75	2.00	1.50	1.00	1.50	1.50	2.00	1.00	2.00	2.00	1.75	5.00
Blue threadfin	*Eleutheronema tetradactylum*	DF	37383004	1.00	1.50	2.00	1.00	1.38	2.50	2.50	1.50	2.50	2.25	2.00	2.50	1.50	2.00	2.00	5.63
Brown Tiger prawn[9]	*Penaeus esculentus*[9]	I	28711044	1.50	2.00	1.00	1.50	1.50	2.00	2.50	2.00	2.50	2.25	2.50	2.00	3.00	1.50	2.25	6.00
Bug	*Thenus orientalis*	I	#N/A	2.00	2.00	2.00	1.00	1.75	2.00	3.00	2.00	2.00	2.25	3.00	2.00	3.00	1.00	2.25	6.25
Coral trout	*Plectropomus spp. & Variola spp.*	DF	37311905	2.00	2.00	2.50	2.00	2.13	2.00	2.50	2.50	3.00	2.50	1.50	2.00	2.00	1.00	1.63	6.25
Crimson snapper	*Lutjanus erythropterus*	DF	37346005	3.00	2.00	3.00	2.00	2.50	2.00	2.00	3.00	3.00	2.50	2.00	2.00	2.00	2.00	2.00	7.00
Dusky flathead	*Platycephalus fuscus*	DF	37296004	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	3.00	2.25	2.00	2.00	1.00	1.00	1.50	5.25
Eastern king prawn	*Melicertus plebejus*	I	28711052	1.50	2.00	1.00	1.50	1.50	2.00	2.50	2.00	2.50	2.25	2.50	2.00	3.00	1.50	2.25	6.00
Garfish	*Hyporamphus spp*	DF	#N/A	1.00	2.00	1.00	2.00	1.50	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.25
Giant trevally	*Caranx ignobilis*	PF	37337027	1.00	2.00	2.00	1.00	1.50	2.00	1.00	2.00	1.00	1.50	2.00	2.00	2.00	1.00	1.75	4.75
Goldband snapper	*Pristipomoides multidens*	DF	37346002	2.00	2.00	2.50	1.50	2.00	2.00	2.00	2.50	2.50	2.25	2.00	1.50	1.50	1.50	1.63	5.88
Golden snapper	*Lutjanus johnii*	DF	37346030	2.00	2.50	2.50	1.50	2.13	2.00	2.50	2.50	3.00	2.50	2.00	2.00	2.00	2.00	2.00	6.63

Common name	Species name	Taxa	FRDC - CAAB	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Golden trevally	*Gnathanodon speciosus*	DF	37337012	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	1.00	1.75	2.00	2.00	2.00	1.00	1.75	5.00
Grass emperor	*Lethrinus laticaudis*	DF	37351006	2.00	2.50	2.50	1.50	2.13	2.00	2.50	2.50	2.00	2.25	2.00	2.00	2.00	2.00	2.00	6.38
Grey mackerel	*Scomberomorus semifasciatus*	PF	37441018	1.00	2.00	1.00	2.00	1.50	2.00	2.00	2.50	1.50	2.00	2.00	1.50	2.50	2.00	2.00	5.50
Grooved tiger prawn[9]	*Penaeus semisulcatus*[9]	I	28711053	1.50	2.00	1.00	1.50	1.50	2.00	2.50	2.00	2.50	2.25	2.50	2.00	3.00	1.50	2.25	6.00
King threadfin	*Polydactylus macrochir*	DF	37383005	1.50	1.50	2.00	1.00	1.50	2.50	2.50	1.50	2.50	2.25	2.00	2.50	2.00	2.50	2.25	6.00
Mangrove jack	*Lutjanus argentimaculatus*	DF	37346015	2.00	2.50	2.50	1.50	2.13	2.00	2.00	2.00	2.50	2.13	2.00	2.00	2.50	2.50	2.25	6.50
Mud crab	*Scylla serrata*	I	28911008	2.50	2.50	2.00	1.50	2.13	1.50	2.50	2.00	2.50	2.13	2.50	2.00	2.00	1.00	1.88	6.13
Mullet	*Liza vaigiensis*	DF	37381008	1.00	2.00	1.00	2.00	1.50	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.25
Pigeye shark	*Carcharhinus amboinensis*	DC	37018026	3.00	2.00	3.00	1.00	2.25	2.00	1.50	1.50	1.50	1.63	2.00	1.00	2.00	1.50	1.63	5.50
Pikey bream	*Acanthopagrus pacificus*	DF	37353011	1.50	1.50	1.00	1.00	1.25	1.50	1.50	1.50	2.00	1.63	1.50	1.50	1.50	1.00	1.38	4.25
Red emperor	*Lutjanus sebae*	DF	37346004	2.00	2.50	2.50	1.50	2.13	2.00	2.50	2.50	2.50	2.38	2.00	2.00	2.00	2.00	2.00	6.50
Red spot king prawn	*Melicertus longistylus*	I	28711048	1.50	2.00	1.00	1.50	1.50	2.00	2.50	2.00	2.50	2.25	2.50	2.00	3.00	1.50	2.25	6.00
Saddle tail snapper	*Lutjanus malabaricus*	DF	37346007	2.00	2.00	2.50	1.50	2.00	2.00	2.00	2.50	2.50	2.25	2.00	1.50	2.00	1.50	1.75	6.00
Sandfish (Beche-de-mer)	*Holothuria scabra*	I	25416004	1.50	2.00	2.00	2.00	1.88	2.50	3.00	2.50	3.00	2.75	2.50	2.50	3.00	2.00	2.50	7.13
Sardines/Herring	*Clupeidae: Clupeinae - undifferentiated*	PF	37085904	1.00	2.00	1.00	2.00	1.50	2.00	3.00	2.00	1.00	2.00	2.00	2.00	2.00	3.00	2.25	5.75
Saucer scallops	*Amusium japonicum*	I	#N/A	2.00	2.00	1.00	1.00	1.50	2.00	3.00	2.00	3.00	2.50	3.00	2.00	3.00	1.00	2.25	6.25
Scalloped hammerhead	*Sphyrna lewini*	PC	37019001	3.00	2.00	3.00	1.00	2.25	2.00	1.50	1.00	1.50	1.50	2.00	1.00	2.00	2.00	1.75	5.50
Spangled emperor	*Lethrinus nebulosus*	DF	37351008	2.00	2.50	2.50	1.50	2.13	2.00	2.50	2.50	2.50	2.38	2.00	2.00	2.00	2.00	2.00	6.50
Spanish mackerel	*Scomberomorus commerson*	PF	37441007	1.50	2.00	1.00	1.50	1.50	2.00	1.50	2.00	1.50	1.75	1.50	1.50	2.00	1.50	1.63	4.88
Spanner crab	*Ranina ranina*	I	28865001	2.00	2.00	2.00	1.00	1.75	2.00	3.00	3.00	1.00	2.25	3.00	2.00	3.00	1.00	2.25	6.25
Spot tail shark	*Carcharhinus sorrah*	PC	37018013	2.00	2.00	2.00	1.00	1.75	2.00	1.50	1.50	1.50	1.63	2.00	1.00	2.00	1.50	1.63	5.00

Common name	Species name	Taxa	FRDC - CAAB	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Spotted mackerel	*Scomberomorus munroi*	PF	37441015	1.00	1.50	1.00	1.50	1.25	2.00	1.50	1.50	1.50	1.63	1.50	1.50	2.00	2.00	1.75	4.63
Tropical lobster	*Panulirus ornatus*	I	28820006	1.50	2.50	2.00	2.00	2.00	2.00	2.00	2.50	2.00	2.13	2.50	2.50	3.00	2.50	2.63	6.75
Whiting	Sillago ciliata	DF	37330010	1.00	1.50	1.00	1.00	1.13	1.50	1.50	1.50	2.00	1.63	1.50	1.50	1.50	1.00	1.38	4.13

[8] Two species of black tip sharks (*Carcharhinus tilstoni* and *C. limbatus*) were assessed together in Welsh et al. 2014. We separated them and assigned score same values.

[9] Tiger prawn species were assessed together in Welsh et al.2014. We separated them in brown tiger prawn (*Penaeus esculentus*) and Grooved tiger prawn (*Penaeus semisulcatus*), and used same score values for both.

[10] We assigned CAAB 37018901 from FRDC database. This CAAB id includes species Carcharhinus, Loxodon and Rhizoprionodon (Blacktip sharks).

Appendix A Table 4: Scores for region 4: Gulf of Carpentaria (Welch et al. 2014, raw data from species prioritisation). Taxa DC: demersal chondrichthyans; DF: demersal fish; PC: pelagic chondrichthyans, PF: pelagic fish; I: invertebrates.

Common name	Species name	Taxa	FRDC - CAAB	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Banana prawn	*Penaeus merguiensis*	I	28711050	1.00	1.50	1.00	1.50	1.25	2.00	2.00	2.00	3.00	2.25	2.00	2.00	3.00	2.50	2.38	5.88
Barramundi	*Lates calcarifer*	DF	37310006	1.50	1.00	2.00	1.50	1.50	2.50	2.50	1.50	2.00	2.13	1.50	1.50	1.50	2.50	1.75	5.38
Barred javelin	*Pomadasys kaakan*	DF	37350011	2.00	1.00	1.00	1.00	1.25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.25
Billfish (sailfish)	*Istiophorus platypterus*	PF	37444005	3.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00	1.00	2.25	2.00	2.00	2.00	3.00	2.25	7.50
Black jewfish	*Protonibea diacanthus*	DF	37354003	2.00	2.00	2.00	2.00	2.00	2.00	3.00	2.00	3.00	2.50	2.00	2.00	2.00	3.00	2.25	6.75
Blacktip shark 1[8]	*Carcharhinus tilstoni*[8]	DC	37018014	1.00	2.00	2.00	1.00	1.50	1.00	2.00	1.00	1.00	1.25	2.00	1.00	1.00	2.00	1.50	4.25
Blacktip shark 2[8]	*Carcharhinus limbatus*[8]	DC	37018901[10]	1.00	2.00	2.00	1.00	1.50	1.00	2.00	1.00	1.00	1.25	2.00	1.00	1.00	2.00	1.50	4.25
Blue threadfin	*Eleutheronema tetradactylum*	DF	37383004	1.00	1.00	2.00	1.00	1.25	3.00	3.00	1.00	2.00	2.25	2.00	3.00	2.00	3.00	2.50	6.00
Brown tiger prawn[9]	*Penaeus esculentus*[9]	I	28711044	1.00	1.50	1.00	2.00	1.38	2.00	2.50	2.00	3.00	2.38	1.50	2.00	2.50	2.00	2.00	5.75

Common name	Species name	Taxa	FRDC - CAAB	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Bug	*Thenus orientalis*	I	#N/A	1.00	2.00	2.00	1.00	1.50	2.00	2.00	1.00	3.00	2.00	1.00	1.00	2.00	1.00	1.25	4.75
Coral trout	*Plectropomus spp. & Variola spp.*	DF	37311905	3.00	2.00	3.00	2.00	2.50	2.00	2.00	3.00	3.00	2.50	2.00	2.00	2.00	1.00	1.75	6.75
Crimson snapper	*Lutjanus erythropterus*	DF	37346005	3.00	2.00	3.00	2.00	2.50	2.00	2.00	3.00	3.00	2.50	2.00	2.00	2.00	2.00	2.00	7.00
Dusky flathead[11]	*Platycephalus fuscus*	DF	37296004	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	4.75
Eastern king prawn	*Melicertus plebejus*	I	28711052	1.00	2.00	1.00	1.00	1.25	2.00	2.00	2.00	3.00	2.25	2.00	2.00	3.00	2.00	2.25	5.75
Garfish	*Hyporamphus spp*	DF	#N/A	1.00	2.00	1.00	2.00	1.50	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.25
Goldband snapper	*Pristipomoides multidens*	DF	37346002	3.00	2.00	3.00	2.00	2.50	2.00	2.00	3.00	3.00	2.50	2.00	2.00	2.00	2.00	2.00	7.00
Golden snapper	*Lutjanus johnii*	DF	37346030	3.00	3.00	3.00	2.00	2.75	2.00	3.00	3.00	3.00	2.75	2.00	2.00	2.00	3.00	2.25	7.75
Grass emperor	*Lethrinus laticaudis*	DF	37351006	3.00	3.00	3.00	2.00	2.75	2.00	3.00	3.00	3.00	2.75	2.00	2.00	2.00	3.00	2.25	7.75
Grey mackerel	*Scomberomorus semifasciatus*	PF	37441018	1.00	2.00	1.00	2.00	1.50	2.00	2.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00	1.75	5.25
Grooved tiger prawn[9]	*Penaeus semisulcatus*	I	28711053	1.00	1.50	1.00	2.00	1.38	2.00	2.50	2.00	3.00	2.38	1.50	2.00	2.50	2.00	2.00	5.75
King threadfin	*Polydactylus macrochir*	DF	37383005	3.00	1.00	3.00	1.00	2.00	3.00	3.00	1.00	2.00	2.25	2.00	3.00	2.00	3.00	2.50	6.75
Longtail tuna[11]	*Thunnus tonggol*	PF	37441013	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	4
Mangrove jack	*Lutjanus argentimaculatus*	DF	37346015	3.00	3.00	3.00	2.00	2.75	2.00	3.00	3.00	3.00	2.75	2.00	2.00	2.00	3.00	2.25	7.75
Mud crab	*Scylla serrata*	I	28911008	2.00	1.50	1.50	1.50	1.63	2.00	2.00	1.50	2.50	2.00	2.00	2.00	2.00	1.50	1.88	5.50
Mullet	*Liza vaigiensis*	DF	37381008	1.00	2.00	1.00	2.00	1.50	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.25
Pigeye shark	*Carcharhinus amboinensis*	DC	37018026	3.00	2.00	3.00	1.00	2.25	1.00	2.00	1.00	1.00	1.25	2.00	1.00	1.00	2.00	1.50	5.00
Pikey bream	*Acanthopagrus pacificus*	DF	37353011	2.00	1.00	1.00	1.00	1.25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.25
Red emperor	*Lutjanus sebae*	DF	37346004	3.00	3.00	3.00	2.00	2.75	2.00	3.00	3.00	3.00	2.75	2.00	2.00	2.00	3.00	2.25	7.75
Red spot king prawn	*Melicertus longistylus*	I	28711048	1.00	1.50	1.00	2.00	1.38	2.00	2.50	2.00	3.00	2.38	1.50	1.50	2.50	1.50	1.75	5.50
Saddle tail snapper	*Lutjanus malabaricus*	DF	37346007	3.00	2.00	3.00	2.00	2.50	2.00	2.00	3.00	3.00	2.50	2.00	2.00	2.00	2.00	2.00	7.00
Sandfish (Beche-	*Holothuria*	I	25416004	2.00	2.00	2.00	3.00	2.25	3.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00	3.00	2.75	8.00

Common name	Species name	Taxa	FRDC - CAAB	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
de-mer)	*scabra*																		
Sardines/Herring	*Clupeidae: Clupeinae - undifferentiated*	PF	37085904	1.00	2.00	1.00	2.00	1.50	2.00	3.00	2.00	1.00	2.00	2.00	2.00	2.00	3.00	2.25	5.75
Saucer scallops[11]	*Amusium japonicum*	I	#N/A	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	5.75
Scalloped hammerhead	*Sphyrna lewini*	PC	37019001	3.00	2.00	3.00	1.00	2.25	1.00	2.00	1.00	1.00	1.25	2.00	1.00	1.00	2.00	1.50	5.00
Spangled emperor	*Lethrinus nebulosus*	DF	37351008	3.00	3.00	3.00	2.00	2.75	2.00	3.00	3.00	3.00	2.75	2.00	2.00	2.00	3.00	2.25	7.75
Spanish mackerel	*Scomberomorus commerson*	PF	37441007	2.00	2.00	1.00	2.00	1.75	2.00	2.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00	1.75	5.50
Spot tail shark	*Carcharhinus sorrah*	PC	37018013	1.00	2.00	2.00	1.00	1.50	1.00	2.00	1.00	1.00	1.25	2.00	1.00	1.00	2.00	1.50	4.25
Spotted mackerel	*Scomberomorus munroi*	PF	37441015	1.00	1.00	1.00	2.00	1.25	2.00	2.00	2.00	1.00	1.75	1.00	2.00	2.00	2.00	1.75	4.75
Tropical lobster	*Panulirus ornatus*	I	28820006	1.00	3.00	2.00	2.00	2.00	3.00	2.00	3.00	2.00	2.50	2.00	2.00	3.00	2.00	2.25	6.75
Whiting	*Sillago ciliata*	DF	37330010	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.00

[8] Two species of black tip sharks (*Carcharhinus tilstoni* and *C. limbatus*) were assessed together in Welsh et al. 2014. We separated them and assigned score same values.

[9] Tiger prawn species were assessed together in Welsh et al.2014. We separated them in brown tiger prawn (*Penaeus esculentus*) and Grooved tiger prawn (*Penaeus semisulcatus*), and used same score values for both.

[10] We assigned CAAB 37018901 from FRDC database. This CAAB id includes species Carcharhinus, Loxodon and Rhizoprionodon (Blacktip sharks).

[11] No raw data available, only total risk ranking score for the species.

Appendix A Table 5: Scores for region 5: Queensland East Coast (Welch et al. 2014, raw data from species prioritisation). Taxa DC: demersal chondrichthyans; DF: demersal fish; PC: pelagic chondrichthyans, PF: pelagic fish; I: invertebrates

Common name	Species name	Taxa	FRDC - CAAB	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Banana prawn	*Penaeus merguiensis*	I	28711050	1.33	1.67	1.00	2.00	1.50	2.33	2.33	2.00	2.00	2.17	2.67	2.33	3.00	2.33	2.58	6.25
Barramundi	*Lates calcarifer*	DF	37310006	1.00	2.25	1.75	2.00	1.75	2.50	1.75	1.50	1.75	1.88	2.75	2.25	2.25	2.00	2.31	5.94
Barred javelin	*Pomadasys kaakan*	DF	37350011	1.33	2.00	1.33	1.67	1.58	2.50	1.67	1.67	2.00	1.96	2.33	2.33	2.33	2.00	2.25	5.79
Billfish (Sailfish)	*Istiophorus platypterus*	PF	37444005	1.00	1.50	2.00	2.00	1.63	2.00	1.00	1.00	1.00	1.25	3.00	2.00	2.00	2.00	2.25	5.13
Black jewfish	*Protonibea diacanthus*	DF	37354003	1.00	2.00	2.00	1.67	1.67	2.50	1.67	1.67	2.00	1.96	2.67	2.33	2.00	2.00	2.25	5.88
Black spot cod	*Epinephelus coiodes*	DF	#N/A	1.00	1.50	2.00	2.00	1.63	2.50	1.50	1.50	1.50	1.75	2.50	2.50	2.50	2.50	2.50	5.88
Blacktip shark 1[8]	*Carcharhinus tilstoni*[8]	DC	37018014	3.00	1.50	2.00	2.00	2.13	2.50	2.00	1.50	2.00	2.00	2.50	2.00	2.50	2.50	2.38	6.50
Blacktip shark 2[8]	*Carcharhinus limbatus*[8]	DC	37018901[10]	3.00	1.50	2.00	2.00	2.13	2.50	2.00	1.50	2.00	2.00	2.50	2.00	2.50	2.50	2.38	6.50
Blue swimmer crab[11]	*Portunus armatus*	I	28911005	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	5
Blue threadfin	*Eleutheronema tetradactylum*	DF	37383004	1.33	2.33	1.67	1.67	1.75	2.67	1.67	1.67	2.00	2.00	2.67	2.67	2.00	2.00	2.33	6.08
Brown Tiger prawn[9]	*Penaeus esculentus*[9]	I	28711044	1.33	1.67	1.00	2.33	1.58	2.33	2.67	2.00	2.00	2.25	2.33	2.33	2.67	2.00	2.33	6.17
Bug[12]	*Thenus orientalis*	I	#N/A	1.33	1.67	1.67	1.67	1.58	2.33	2.33	1.67	2.33	2.17	2.33	2.00	2.67	1.67	2.17	5.92
Coral trout	*Plectropomus spp. & Variola spp.*	DF	37311905	1.00	1.50	2.00	2.00	1.63	2.50	2.50	2.00	2.50	2.38	2.00	2.50	2.00	2.00	2.13	6.13
Crimson snapper	*Lutjanus erythropterus*	DF	37346005	1.00	1.50	2.00	1.50	1.50	2.50	2.00	2.00	2.00	2.13	2.50	2.00	2.00	2.00	2.13	5.75
Dusky flathead	*Platycephalus fuscus*	DF	37296004	1.33	1.67	2.00	1.67	1.67	2.00	1.67	1.33	2.00	1.75	2.67	2.33	2.00	2.00	2.25	5.67
Eastern king prawn	*Melicertus plebejus*	I	28711052	1.33	1.67	1.00	2.00	1.50	2.33	2.00	1.67	2.00	2.00	2.33	2.33	3.00	2.33	2.50	6.00
Gold spot cod	*Epinephelus pelagicus*	DF	#N/A	1.00	1.50	2.00	2.00	1.63	2.50	1.50	1.50	1.50	1.75	2.50	2.50	2.50	2.50	2.50	5.88
Goldband snapper	*Pristipomoides multidens*	DF	37346002	1.00	1.50	2.00	1.50	1.50	2.50	2.00	2.00	2.00	2.13	2.50	2.00	1.50	2.00	2.00	5.63

Common name	Species name	Taxa	FRDC - CAAB	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Golden snapper	*Lutjanus johnii*	DF	37346030	1.00	1.50	2.00	1.50	1.50	2.50	2.00	2.00	2.00	2.13	2.50	2.00	2.00	2.00	2.13	5.75
Grass emperor	*Lethrinus laticaudis*	DF	37351006	1.33	1.67	2.00	1.67	1.67	2.00	2.33	2.00	2.00	2.08	2.33	2.33	2.00	2.00	2.17	5.92
Grey mackerel	*Scomberomorus semifasciatus*	PF	37441018	1.00	1.67	1.67	1.67	1.50	2.33	2.00	1.67	2.00	2.00	2.33	2.00	2.67	2.67	2.42	5.92
Grooved tiger prawn[9]	*Penaeus semisulcatus*[9]	I	28711053	1.33	1.67	1.00	2.33	1.58	2.33	2.67	2.00	2.00	2.25	2.33	2.33	2.67	2.00	2.33	6.17
King threadfin	*Polydactylus macrochir*	DF	37383005	1.33	2.00	2.00	1.67	1.75	2.67	1.67	1.67	2.00	2.00	2.67	2.67	2.33	2.33	2.50	6.25
Mangrove jack	*Lutjanus argentimaculatus*	DF	37346015	1.33	1.67	2.00	1.33	1.58	2.50	1.33	1.00	2.00	1.71	2.33	2.33	2.33	2.67	2.42	5.71
Mud crab	*Scylla serrata*	I	28911008	1.33	2.00	1.33	2.00	1.67	2.00	2.33	1.67	2.00	2.00	2.67	2.33	2.33	2.00	2.33	6.00
Pigeye shark	*Carcharhinus amboinensis*	DC	37018026	3.00	1.50	2.50	2.00	2.25	2.50	2.00	2.00	2.00	2.13	2.50	2.00	2.50	2.00	2.25	6.63
Pikey bream	*Acanthopagrus pacificus*	DF	37353011	1.33	2.00	1.33	1.67	1.58	2.33	2.00	1.67	2.00	2.00	2.67	2.33	2.33	1.67	2.25	5.83
Red emperor	*Lutjanus sebae*	DF	37346004	1.33	1.67	2.00	1.67	1.67	2.00	2.33	2.00	2.00	2.08	2.33	2.33	2.00	2.00	2.17	5.92
Red spot king prawn	*Melicertus longistylus*	I	28711048	1.33	1.67	1.00	2.33	1.58	2.33	2.67	2.00	2.67	2.42	2.33	2.00	2.67	1.67	2.17	6.17
Red throat emperor	*Lethrinus miniatus*	DF	37351009	1.00	1.50	2.00	1.50	1.50	2.00	2.50	2.50	2.50	2.38	3.00	2.50	2.00	2.50	2.50	6.38
Saddle tail snapper	*Lutjanus malabaricus*	DF	37346007	1.00	1.50	2.00	1.50	1.50	2.50	2.00	2.00	2.00	2.13	2.50	2.00	2.00	2.00	2.13	5.75
Sandfish (Beche-de-mer)	*Holothuria scabra*	I	25416004	2.00	2.50	2.00	2.00	2.13	2.50	3.00	2.50	2.50	2.63	3.00	2.50	3.00	2.00	2.63	7.38
Saucer scallops	*Amusium japonicum*	I	#N/A	1.33	1.67	1.33	1.67	1.50	2.33	2.67	2.00	2.00	2.25	2.33	2.00	2.67	1.67	2.17	5.92
Scalloped hammerhead	*Sphyrna lewini*	PC	37019001	3.00	1.50	2.50	2.00	2.25	2.50	2.00	1.50	2.00	2.00	2.50	2.00	2.50	2.50	2.38	6.63
School mackerel	*Scomberomorus queenslandicus*	PF	37441014	1.00	1.50	1.50	2.00	1.50	2.50	2.00	2.00	2.00	2.13	3.00	2.50	2.50	2.50	2.63	6.25
Spangled emperor	*Lethrinus nebulosus*	DF	37351008	1.33	1.67	2.00	1.67	1.67	2.00	2.33	2.00	2.00	2.08	2.33	2.33	2.00	2.00	2.17	5.92
Spanish mackerel	*Scomberomorus commerson*	PF	37441007	1.00	1.67	1.67	1.33	1.42	2.33	1.33	1.33	2.00	1.75	2.00	2.00	2.33	2.33	2.17	5.33
Spanner crab	*Ranina ranina*	I	28865001	1.33	1.33	1.33	1.67	1.42	2.33	2.33	2.33	2.00	2.25	2.33	2.00	2.67	2.00	2.25	5.92

Common name	Species name	Taxa	FRDC - CAAB	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Spot tail shark	*Carcharhinus sorrah*	PC	37018013	3.00	1.50	2.00	2.00	2.13	2.50	2.00	2.00	2.00	2.13	2.50	2.00	2.50	2.00	2.25	6.50
Spotted mackerel	*Scomberomorus munroi*	PF	37441015	1.00	2.00	1.67	1.67	1.58	2.50	1.33	1.33	2.00	1.79	2.67	2.00	2.33	2.67	2.42	5.79
Tropical lobster	*Panulirus ornatus*	I	28820006	2.50	2.50	1.50	2.50	2.25	2.00	2.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	3.00	7.25
Whiting	*Sillago ciliata*	DF	37330010	1.00	2.00	1.00	1.50	1.38	2.50	1.50	1.50	1.50	1.75	2.50	2.50	2.50	2.00	2.38	5.50

[8] Two species of black tip sharks (*Carcharhinus tilstoni* and *C. limbatus*) were assessed together in Welsh et al. 2014. We separated them and assigned score same values.

[9] Tiger prawn species were assessed together in Welsh et al.2014. We separated them in brown tiger prawn (*Penaeus esculentus*) and Grooved tiger prawn (*Penaeus semisulcatus*), and used same score values for both.

[10] We assigned CAAB 37018901 from FRDC database. This CAAB id includes species Carcharhinus, Loxodon and Rhizoprionodon (Blacktip sharks)

[11] No raw data available, only total risk ranking score for the species.

[12] Common name for this species in Welch et al. 2014 is Moreton bay bug.

Appendix A Table 6: Scores per gear types and fisheries for region 1: South East Australia.

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Australian salmon - eastern	*Arripis trutta*	37344002	Ocean Hauling	NSW	Purse Seine	1.00	2.00	2.00	2.00	1.75	2.00	1.00	1.00	2.00	1.50	2.00	2.00	2.00	3.00	2.25	5.50
Australian salmon - western	*Arripis truttaceus*	37344004	Lakes and Coorong Fishery	SA	Gillnet	1.00	2.00	2.00	2.00	1.75	2.00	1.00	1.00	2.00	1.50	2.00	2.00	2.00	3.00	2.25	5.50
			Marine Scalefish Fishery	SA	Gillnet	1.00	2.00	2.00	2.00	1.75	2.00	1.00	1.00	2.00	1.50	2.00	2.00	2.00	3.00	2.25	5.50
			Northern Zone Rock Lobster Fishery	SA	Trap	1.00	2.00	2.00	2.00	1.75	2.00	1.00	1.00	2.00	1.50	2.00	2.00	2.00	3.00	2.25	5.50

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
			Southern Zone Rock Lobster Fishery	SA	Trap	1.00	2.00	2.00	2.00	1.75	2.00	1.00	1.00	2.00	1.50	2.00	2.00	2.00	3.00	2.25	5.50
Australian sardine	*Sardinops sagax*	37085002	Ocean Hauling	NSW	Purse Seine	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
			Ocean Purse Seine Fishery	VIC	Purse Seine	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
			Port Phillip Bay Purse Seine Fishery	VIC	Purse Seine	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
			South Australian Sardine Fishery	SA	Purse Seine	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
Blacklip abalone	*Haliotis rubra rubra*	24038006	New South Wales Abalone Fishery	NSW	Dive	1.00	2.00	2.00	2.00	1.75	3.00	3.00	2.00	3.00	2.75	3.00	3.00	2.00	1.00	2.25	6.75
			Tasmanian Western Zone Fishery	TAS	Trap	1.00	2.00	2.00	2.00	1.75	3.00	3.00	2.00	3.00	2.75	3.00	3.00	2.00	1.00	2.25	6.75
Blue mackerel	*Scomber australasicus*	37441001	Ocean Hauling	NSW	Purse Seine	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
			Ocean Trawl Fishery	NSW	Trawl	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
			Ocean Trap and Line	NSW	Trap	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
			South Coast Trawl Fishery (Condition), South West Trawl Managed Fishery, Open access in the South Coast & West Coast	WA	Trawl	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
			Scalefish Fishery	TAS	Gillnet	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
			Victorian Inshore Trawl Fishery	VIC	Trawl	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
Blue swimmer crab	*Portunus armatus*	28911005	Blue Crab Fishery	SA	Trap	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	1.00	1.75	3.00	3.00	2.00	2.00	2.50	5.50
			Marine Scalefish Fishery	SA	Gillnet	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	1.00	1.75	3.00	3.00	2.00	2.00	2.50	5.50
			Ocean Trawl Fishery	NSW	Trawl	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	1.00	1.75	3.00	3.00	2.00	2.00	2.50	5.50

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Commercial scallop	*Pecten fumatus*	23270007	Ocean Scallop Fishery	VIC	Dredge	1.00	3.00	1.00	2.00	1.75	2.00	3.00	2.00	3.00	2.50	3.00	3.00	2.00	1.00	2.25	6.50
			Port Phillip Bay Dive Scallop Fishery	VIC	Dive	1.00	3.00	1.00	2.00	1.75	2.00	3.00	2.00	3.00	2.50	3.00	3.00	2.00	1.00	2.25	6.50
			Tasmanian Scallop Fishery	TAS	Dredge	1.00	3.00	1.00	2.00	1.75	2.00	3.00	2.00	3.00	2.50	3.00	3.00	2.00	1.00	2.25	6.50
Dusky flathead	*Platycephalus fuscus*	37296004	Gippsland Lakes Fishery	VIC	Gillnet	1.00	2.00	2.00	2.00	1.75	2.00	2.00	1.00	2.00	1.75	2.00	1.00	2.00	2.00	1.75	5.25
Eastern king prawn	*Melicertus plebejus*	28711052	Estuary Prawn Trawl Fishery	NSW	Trawl	1.00	2.00	2.00	2.00	1.75	2.00	1.00	1.00	2.00	1.50	3.00	3.00	2.00	3.00	2.75	6.00
			Ocean Trawl Fishery	NSW	Trawl	1.00	2.00	2.00	2.00	1.75	2.00	1.00	1.00	2.00	1.50	3.00	3.00	2.00	3.00	2.75	6.00
Greenlip abalone	*Haliotis laevigata*	24038004	Tasmanian Greenlip Abalone Fishery	TAS	Dive	1.00	2.00	2.00	2.00	1.75	3.00	3.00	3.00	2.00	2.75	3.00	3.00	3.00	1.00	2.50	7.00
Gummy shark	*Mustelus antarcticus*	37017001	Corner Inlet Fishery	VIC	Gillnet	3.00	1.00	2.00	2.00	2.00	3.00	1.00	2.00	3.00	2.25	1.00	1.00	2.00	3.00	1.75	6.00
			Estuary Prawn Trawl Fishery	NSW	Trawl	3.00	1.00	2.00	2.00	2.00	3.00	1.00	2.00	3.00	2.25	1.00	1.00	2.00	3.00	1.75	6.00
			Giant Crab Fishery	TAS, VIC	Trap	3.00	1.00	2.00	2.00	2.00	3.00	1.00	2.00	3.00	2.25	1.00	1.00	2.00	3.00	1.75	6.00
			Inshore Trawl Fishery	VIC	Trawl	3.00	1.00	2.00	2.00	2.00	3.00	1.00	2.00	3.00	2.25	1.00	1.00	2.00	3.00	1.75	6.00
			Lakes and Coorong Fishery	SA	Gillnet	3.00	1.00	2.00	2.00	2.00	3.00	1.00	2.00	3.00	2.25	1.00	1.00	2.00	3.00	1.75	6.00
			Marine Scalefish Fishery	SA	Gillnet	3.00	1.00	2.00	2.00	2.00	3.00	1.00	2.00	3.00	2.25	1.00	1.00	2.00	3.00	1.75	6.00
			Ocean Fishery	VIC	Line	3.00	1.00	2.00	2.00	2.00	3.00	1.00	2.00	3.00	2.25	1.00	1.00	2.00	3.00	1.75	6.00
			Ocean Trawl Fishery	NSW	Trawl	3.00	1.00	2.00	2.00	2.00	3.00	1.00	2.00	3.00	2.25	1.00	1.00	2.00	3.00	1.75	6.00
			Ocean Trap and Line	NSW	Trap	3.00	1.00	2.00	2.00	2.00	3.00	1.00	2.00	3.00	2.25	1.00	1.00	2.00	3.00	1.75	6.00
			Port Phillip Bay Fishery	VIC	Gillnet	3.00	1.00	2.00	2.00	2.00	3.00	1.00	2.00	3.00	2.25	1.00	1.00	2.00	3.00	1.75	6.00
			Scalefish Fishery	TAS	Gillnet	3.00	1.00	2.00	2.00	2.00	3.00	1.00	2.00	3.00	2.25	1.00	1.00	2.00	3.00	1.75	6.00
			Victorian Rock	VIC	Trap	3.00	1.0	2.0	2.00	2.00	3.0	1.00	2.0	3.00	2.2	1.0	1.00	2.0	3.0	1.75	6.0

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
			Lobster Fishery				0	0			0		0		5	0		0	0		0
			Western Port Bay Fishery	VIC	Gillnet	3.00	1.00	2.00	2.00	2.00	3.00	1.00	2.00	3.00	2.25	1.00	1.00	2.00	3.00	1.75	6.00
Jack mackerel	*Trachurus declivis*	37337002	Ocean Trawl Fishery	NSW	Trawl	1.00	2.00	2.00	2.00	1.75	1.00	2.00	2.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00	5.75
			Scalefish Fishery	TAS	Gillnet	1.00	2.00	2.00	2.00	1.75	1.00	2.00	2.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00	5.75
			Victorian Inshore Trawl Fishery	VIC	Trawl	1.00	2.00	2.00	2.00	1.75	1.00	2.00	2.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00	5.75
King George whiting	*Sillaginodes punctatus*	37330001	Corner Inlet Fishery	VIC	Gillnet	1.00	2.00	2.00	2.00	1.75	1.00	2.00	2.00	2.00	1.75	3.00	3.00	2.00	3.00	2.75	6.25
			Gippsland Lakes Fishery	VIC	Gillnet	1.00	2.00	2.00	2.00	1.75	1.00	2.00	2.00	2.00	1.75	3.00	3.00	2.00	3.00	2.75	6.25
			Marine Scalefish Fishery	SA	Gillnet	1.00	2.00	2.00	2.00	1.75	1.00	2.00	2.00	2.00	1.75	3.00	3.00	2.00	3.00	2.75	6.25
			Northern Zone Rock Lobster Fishery	SA	Trap	1.00	2.00	2.00	2.00	1.75	1.00	2.00	2.00	2.00	1.75	3.00	3.00	2.00	3.00	2.75	6.25
			Ocean Fishery	VIC	Line	1.00	2.00	2.00	2.00	1.75	1.00	2.00	2.00	2.00	1.75	3.00	3.00	2.00	3.00	2.75	6.25
			Port Phillip Bay Fishery	VIC	Gillnet	1.00	2.00	2.00	2.00	1.75	1.00	2.00	2.00	2.00	1.75	3.00	3.00	2.00	3.00	2.75	6.25
School prawn	*Metapenaeus macleayi*	28711029	Estuary Prawn Trawl Fishery	NSW	Trawl	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	3.00	3.00	2.00	3.00	2.75	6.50
			Inshore Trawl Fishery	VIC	Trawl	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	3.00	3.00	2.00	3.00	2.75	6.50
			Ocean Trawl Fishery	NSW	Trawl	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	3.00	3.00	2.00	3.00	2.75	6.50
Snapper	*Chrysophrys auratus*	37353001	Corner Inlet Fishery	VIC	Gillnet	1.00	2.00	2.00	2.00	1.75	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.50
			Marine Scalefish Fishery	SA	Gillnet	1.00	2.00	2.00	2.00	1.75	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.50
			Ocean Fishery	VIC	Line	1.00	2.00	2.00	2.00	1.75	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.50
			Ocean Trap and Line	NSW	Trap	1.00	2.00	2.00	2.00	1.75	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.50
			Port Phillip Bay and Western Port Bay	VIC	Gillnet	1.00	2.00	2.00	2.00	1.75	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.50

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
			Fishery																		
			Rocky Reef Fin Fish Fishery	Queensland	Line	1.00	2.00	2.00	2.00	1.75	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.50
Southern calamari	*Sepioteuthis australis*	23617005	Corner Inlet Fishery	VIC	Gillnet	2.00	1.00	1.00	2.00	1.50	3.00	2.00	1.00	3.00	2.25	2.00	2.00	2.00	3.00	2.25	6.00
			Inshore Trawl Fishery	VIC	Trawl	2.00	1.00	1.00	2.00	1.50	3.00	2.00	1.00	3.00	2.25	2.00	2.00	2.00	3.00	2.25	6.00
			Marine Scalefish Fishery	SA	Gillnet	2.00	1.00	1.00	2.00	1.50	3.00	2.00	1.00	3.00	2.25	2.00	2.00	2.00	3.00	2.25	6.00
			Northern Zone Rock Lobster Fishery	SA	Trap	2.00	1.00	1.00	2.00	1.50	3.00	2.00	1.00	3.00	2.25	2.00	2.00	2.00	3.00	2.25	6.00
			Ocean Trawl Fishery	NSW	Trawl	2.00	1.00	1.00	2.00	1.50	3.00	2.00	1.00	3.00	2.25	2.00	2.00	2.00	3.00	2.25	6.00
			Ocean Trap and Line	NSW	Trap	2.00	1.00	1.00	2.00	1.50	3.00	2.00	1.00	3.00	2.25	2.00	2.00	2.00	3.00	2.25	6.00
			Port Phillip Bay Fishery	VIC	Gillnet	2.00	1.00	1.00	2.00	1.50	3.00	2.00	1.00	3.00	2.25	2.00	2.00	2.00	3.00	2.25	6.00
			South Australian Prawn Fishery	SA	Trawl	2.00	1.00	1.00	2.00	1.50	3.00	2.00	1.00	3.00	2.25	2.00	2.00	2.00	3.00	2.25	6.00
			Scalefish Fishery	TAS	Gillnet	2.00	1.00	1.00	2.00	1.50	3.00	2.00	1.00	3.00	2.25	2.00	2.00	2.00	3.00	2.25	6.00
			Southern Zone Rock Lobster Fishery	SA	Trap	2.00	1.00	1.00	2.00	1.50	3.00	2.00	1.00	3.00	2.25	2.00	2.00	2.00	3.00	2.25	6.00
Southern garfish	*Hyporhamphus melanochir*	37234001	Corner Inlet Fishery	VIC	Gillnet	2.00	1.00	1.00	2.00	1.50	2.00	2.00	2.00	3.00	2.25	2.00	2.00	2.00	1.00	1.75	5.50
			Marine Scalefish Fishery	SA	Gillnet	2.00	1.00	1.00	2.00	1.50	2.00	2.00	2.00	3.00	2.25	2.00	2.00	2.00	1.00	1.75	5.50
			Port Phillip Bay Fishery	VIC	Gillnet	2.00	1.00	1.00	2.00	1.50	2.00	2.00	2.00	3.00	2.25	2.00	2.00	2.00	1.00	1.75	5.50
			Scalefish Fishery	TAS	Gillnet	2.00	1.00	1.00	2.00	1.50	2.00	2.00	2.00	3.00	2.25	2.00	2.00	2.00	1.00	1.75	5.50
			Southern Zone Rock Lobster Fishery	SA	Trap	2.00	1.00	1.00	2.00	1.50	2.00	2.00	2.00	3.00	2.25	2.00	2.00	2.00	1.00	1.75	5.50
Southern rock lobster	*Jasus edwardsii*	28820001	South Australian Southern Rock Lobster Fishery	SA	Trap	1.00	2.00	2.00	2.00	1.75	1.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	1.00	2.50	6.75
			Tasmanian Rock	TAS	Trap	1.00	2.0	2.0	2.00	1.75	1.0	3.00	3.0	3.00	2.5	3.0	3.00	3.0	1.0	2.50	6.7

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
			Lobster Fishery				0	0			0		0		0	0		0	0		5
			Victorian Rock Lobster Fishery	VIC	Trap	1.00	2.00	2.00	2.00	1.75	1.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	1.00	2.50	6.75
Southern sand flathead	*Platycephalus bassensis*	37296003	Corner Inlet Fishery	VIC	Gillnet	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	3.00	2.25	3.00	2.00	2.00	1.00	2.00	5.75
			Inshore Trawl Fishery	VIC	Trawl	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	3.00	2.25	3.00	2.00	2.00	1.00	2.00	5.75
			Ocean Fishery	VIC	Line	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	3.00	2.25	3.00	2.00	2.00	1.00	2.00	5.75
			Port Phillip Bay Fishery	VIC	Gillnet	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	3.00	2.25	3.00	2.00	2.00	1.00	2.00	5.75
			Scalefish Fishery	TAS	Gillnet	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	3.00	2.25	3.00	2.00	2.00	1.00	2.00	5.75
Spanner crab	*Ranina ranina*	28865001	Ocean Trap and Line	NSW	Trap	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	1.00	1.75	2.00	2.00	1.00	2.00	1.75	5.25
Tiger flathead	*Platycephalus richardsoni*	37296001	Inshore Trawl Fishery	VIC	Trawl	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	3.00	2.25	2.00	1.00	2.00	1.00	1.50	5.25
			Ocean Trawl Fishery	NSW	Trawl	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	3.00	2.25	2.00	1.00	2.00	1.00	1.50	5.25
			Scalefish Fishery	TAS	Gillnet	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	3.00	2.25	2.00	1.00	2.00	1.00	1.50	5.25
Western king prawn	*Melicertus latisulcatus*	28711047	Gulf St Vincent Prawn Fishery	SA	Trawl	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	1.00	1.75	3.00	3.00	2.00	2.00	2.50	5.50
			Spencer Gulf Prawn Fishery	SA	Trawl	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	1.00	1.75	3.00	3.00	2.00	2.00	2.50	5.50
			West Coast Prawn Fishery	SA	Trawl	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	1.00	1.75	3.00	3.00	2.00	2.00	2.50	5.50
Yellowtail kingfish	*Seriola lalandi*	37337006	Ocean Trap and Line	NSW	Trap	2.00	2.00	2.00	1.00	1.75	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.50

Appendix A Table 7: Scores per gear types and fisheries for region 2: Western Australia.

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Ballot's Saucer Scallop	*Ylistrum balloti*	23270001	Abrolhos Islands and Mid West Trawl Managed Fishery	WA	Trawl	1.00	2.00	1.00	2.00	1.50	2.00	3.00	2.00	2.00	2.25	3.00	2.00	2.00	1.00	2.00	5.75
			Shark Bay Scallop Managed Fishery	WA	Dredge	1.00	2.00	1.00	2.00	1.50	2.00	3.00	2.00	2.00	2.25	3.00	2.00	2.00	1.00	2.00	5.75
			South Coast Trawl Fishery (Condition)	WA	Trawl	1.00	2.00	1.00	2.00	1.50	2.00	3.00	2.00	2.00	2.25	3.00	2.00	2.00	1.00	2.00	5.75
			South West Trawl Managed Fishery	WA	Trawl	1.00	2.00	1.00	2.00	1.50	2.00	3.00	2.00	2.00	2.25	3.00	2.00	2.00	1.00	2.00	5.75
Blue swimmer crab	*Portunus armatus*	28911005	Cockburn Sound Crab Managed Fishery	WA	Trap	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	5.75
			Exmouth Gulf Developing Crab Fishery, Pilbara Developmental Crab Fishery, Kimberley Developing Mud Crab Fishery	WA	Trap	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	5.75
			Exmouth Gulf Prawn Managed Fishery	WA	Trawl	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	5.75
			Joint Authority Southern Demersal Gillnet and Demersal Longline Managed Fishery (Zone 1 & Zone 2)	WA	Gillnet	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	5.75
			Mandurah to Bunbury Developing Crab Fishery, Swan and Canning Rivers Crab Fishery (Area 1 of West Coast Estuarine	WA	Trap	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	5.75

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
			Managed Fishery), South West Trawl Managed Fishery, Warnbro Sound Crab Managed Fishery, Open access in the South Coast																		
			Nickol Bay Prawn Managed Fishery	WA	Trawl	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	5.75
			Peel–Harvey Estuary Crab Fishery (Area II of West Coast Estuarine Managed Fishery)	WA	Trap	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	5.75
			Shark Bay Crab Managed Fishery	WA	Trap	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	5.75
			South Coast Estuarine Managed Fishery	WA	Gillnet	1.00	1.00	1.00	2.00	1.25	2.00	3.00	1.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	5.75
Brown tiger prawn	*Penaeus esculentus*	28711044	Exmouth Gulf Prawn Managed Fishery	WA	Trawl	1.00	2.00	1.00	2.00	1.50	2.00	2.00	3.00	2.00	2.25	3.00	3.00	2.00	3.00	2.75	6.50
			Nickol Bay Prawn Managed Fishery	WA	Trawl	1.00	2.00	1.00	2.00	1.50	2.00	2.00	3.00	2.00	2.25	3.00	3.00	2.00	3.00	2.75	6.50
			Onslow Prawn Managed Fishery	WA	Trawl	1.00	2.00	1.00	2.00	1.50	2.00	2.00	3.00	2.00	2.25	3.00	3.00	2.00	3.00	2.75	6.50
			Shark Bay Prawn Managed Fishery	WA	Trawl	1.00	2.00	1.00	2.00	1.50	2.00	2.00	3.00	2.00	2.25	3.00	3.00	2.00	3.00	2.75	6.50
Goldband snapper	*Pristipomoides multidens*	37346002	Gascoyne Demersal Scalefish Managed Fishery	WA	Line	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.75	5.50
			Nickol Bay Prawn Managed Fishery	WA	Trawl	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.75	5.50
			Pilbara Line Fishery	WA	Line	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.75	5.50
			Pilbara Trap Managed Fishery, Pilbara Fish Trawl (Interim) Managed Fishery	WA	Trap	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.75	5.50
			West Coast Demersal Scalefish (Interim)	WA	Gillnet	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.75	5.50

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
			Managed Fishery																		
Red emperor	*Lutjanus sebae*	37346004	Gascoyne Demersal Scalefish Managed Fishery	WA	Line	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.75	5.25
			Nickol Bay Prawn Managed Fishery	WA	Trawl	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.75	5.25
			Pilbara Trap Managed Fishery, Pilbara Fish Trawl (Interim) Managed Fishery	WA	Trap	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.75	5.25
			West Coast Demersal Scalefish (Interim) Managed Fishery	WA	Gillnet	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.75	5.25
Silver lipped pearl oyster	*Pinctada maxima*	23236003	Pearl Oyster Managed Fishery	WA	Dive	1.00	2.00	2.00	2.00	1.75	2.00	3.00	2.00	2.00	2.25	3.00	3.00	2.00	1.00	2.25	6.25
Snapper	*Chrysophrys auratus*	37353001	Boat Based Recreational Fishery	WA	Line	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	6.00
			Gascoyne Demersal Scalefish Managed Fishery	WA	Line	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	6.00
			Joint Authority Southern Demersal Gillnet and Demersal Longline Managed Fishery (Zone 1 & Zone 2)	WA	Gillnet	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	6.00
			Shark Bay Beach Seine and Mesh Net Managed Fishery	WA	Purse Seine	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	6.00
			South Coast Estuarine Managed Fishery	WA	Gillnet	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	6.00
			South Coast Trawl Managed Fishery, Windy Harbour Rock Lobster Fishery, Open access in the South Coast	WA	Trawl	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	6.00

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
			South West Trawl Managed Fishery, West Coast Demersal Gillnet and Demersal Longline (Interim) Managed Fishery, Open access in the West Coast	WA	Trawl	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	6.00
			West Coast Demersal Scalefish (Interim) Managed Fishery	WA	Gillnet	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	6.00
Spanish mackerel	*Scomberomorus commerson*	37441007	Mackerel Managed Fishery	WA	Line	1.00	2.00	1.00	2.00	1.50	2.00	2.00	2.00	1.00	1.75	2.00	2.00	2.00	2.00	2.00	5.25
Tailor	*Pomatomus saltatrix*	37334002	Cockburn Sound Crab Managed Fishery, South West Trawl Managed Fishery, West Coast (Beach Bait Fish Net) Managed Fishery, Open access in the West Coast	WA	Trap	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	1.00	1.75	3.00	2.00	1.00	3.00	2.25	5.50
			Gascoyne Demersal Scalefish Managed Fishery	WA	Line	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	1.00	1.75	3.00	2.00	1.00	3.00	2.25	5.50
			Shark Bay Beach Seine and Mesh Net Managed Fishery	WA	Purse Seine	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	1.00	1.75	3.00	2.00	1.00	3.00	2.25	5.50
			South Coast Estuarine Managed Fishery	WA	Gillnet	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	1.00	1.75	3.00	2.00	1.00	3.00	2.25	5.50
			South West Coast Beach Net Fishery (Order)	WA	Purse Seine	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	1.00	1.75	3.00	2.00	1.00	3.00	2.25	5.50
			West Coast Demersal Gillnet and Demersal Longline (Interim) Managed Fishery	WA	Gillnet	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	1.00	1.75	3.00	2.00	1.00	3.00	2.25	5.50
			West Coast Demersal Scalefish (Interim) Managed Fishery	WA	Gillnet	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	1.00	1.75	3.00	2.00	1.00	3.00	2.25	5.50
			West Coast Estuarine	WA	Gillnet	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	1.00	1.75	3.00	2.00	1.00	3.00	2.25	5.50

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
			Managed Fishery																		
Sandbar shark	*Carcharhinus plumbeus*	37018007	Joint Authority Southern Demersal Gillnet and Demersal Longline Managed Fishery (Zone 1 & Zone 2)	WA	Gillnet	3.00	1.00	3.00	1.00	2.00	3.00	1.00	2.00	1.00	1.75	2.00	2.00	2.00	3.00	2.25	6.00
			West Coast Demersal Gillnet and Demersal Longline (Interim) Managed Fishery	WA	Gillnet	3.00	1.00	3.00	1.00	2.00	3.00	1.00	2.00	1.00	1.75	2.00	2.00	2.00	3.00	2.25	6.00
WA Dhudish	*Glaucosoma hebraicum*	37320004	Gascoyne Demersal Scalefish Managed Fishery	WA	Line	1.00	2.00	2.00	2.00	1.75	2.00	2.00	3.00	2.00	2.25	3.00	3.00	2.00	1.00	2.25	6.25
			Joint Authority Southern Demersal Gillnet and Demersal Longline Managed Fishery (Zone 1 & Zone 2)	WA	Gillnet	1.00	2.00	2.00	2.00	1.75	2.00	2.00	3.00	2.00	2.25	3.00	3.00	2.00	1.00	2.25	6.25
			West Coast Demersal Gillnet and Demersal Longline (Interim) Managed Fishery	WA	Gillnet	1.00	2.00	2.00	2.00	1.75	2.00	2.00	3.00	2.00	2.25	3.00	3.00	2.00	1.00	2.25	6.25
			West Coast Demersal Scalefish (Interim) Managed Fishery	WA	Gillnet	1.00	2.00	2.00	2.00	1.75	2.00	2.00	3.00	2.00	2.25	3.00	3.00	2.00	1.00	2.25	6.25
Western king prawn	*Melicertus latisulcatus*	28711047	Broome Prawn Managed Fishery	WA	Trawl	1.00	2.00	1.00	2.00	1.50	2.00	2.00	2.00	2.00	2.00	2.00	3.00	1.00	3.00	2.25	5.75
			Exmouth Gulf Prawn Managed Fishery	WA	Trawl	1.00	2.00	1.00	2.00	1.50	2.00	2.00	2.00	2.00	2.00	2.00	3.00	1.00	3.00	2.25	5.75
			Nickol Bay Prawn Managed Fishery	WA	Trawl	1.00	2.00	1.00	2.00	1.50	2.00	2.00	2.00	2.00	2.00	2.00	3.00	1.00	3.00	2.25	5.75
			Onslow Prawn Managed Fishery	WA	Trawl	1.00	2.00	1.00	2.00	1.50	2.00	2.00	2.00	2.00	2.00	2.00	3.00	1.00	3.00	2.25	5.75
			Shark Bay Prawn Managed Fishery	WA	Trawl	1.00	2.00	1.00	2.00	1.50	2.00	2.00	2.00	2.00	2.00	2.00	3.00	1.00	3.00	2.25	5.75
			South West Trawl Managed Fishery	WA	Trawl	1.00	2.00	1.00	2.00	1.50	2.00	2.00	2.00	2.00	2.00	2.00	3.00	1.00	3.00	2.25	5.75

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Western rock lobster	*Panulirus cygnus*	28820005	West Coast Rock Lobster Managed Fishery	WA	Trap	1.00	2.00	2.00	2.00	1.75	1.00	2.00	2.00	2.00	1.75	3.00	3.00	2.00	3.00	2.75	6.25

Table A-1: Scores per gear types and fisheries for region 3: North Western Australia.

Common name	Species name	FRDC – CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis	Life-cycle events	Migration	Mean Phenology	Score
Barramundi	*Lates calcarifer*	37310006	Kimberley Prawn Managed Fishery	WA	Trawl	1.50	2.00	1.00	1.50	1.50	2.00	2.50	2.00	2.50	2.25	2.50	2.00	3.00	1.50	2.25	6.00
			Barramundi Fishery	NT	Gillnet	1.50	2.00	2.00	1.50	1.75	2.50	2.50	1.50	2.00	2.13	2.00	1.00	2.00	2.00	1.75	5.63
		37310006	Kimberley Gillnet and Barramundi ManagedFishery	WA	Gillnet	1.50	2.00	2.00	1.50	1.75	2.50	2.50	1.50	2.00	2.13	2.00	1.00	2.00	2.00	1.75	5.63
Black jewfish	*Protonibea diacanthus*	37354003	Coastal Line Fishery	NT	Line	1.50	2.00	2.00	1.50	1.75	2.00	2.50	2.00	3.00	2.38	2.00	2.00	2.00	2.00	2.00	6.13
			Demersal Fishery	NT	Line	1.50	2.00	2.00	1.50	1.75	2.00	2.50	2.00	3.00	2.38	2.00	2.00	2.00	2.00	2.00	6.13
			Fishery Tour Operator	NT	Line	1.50	2.00	2.00	1.50	1.75	2.00	2.50	2.00	3.00	2.38	2.00	2.00	2.00	2.00	2.00	6.13
			Kimberley Gillnet and Barramundi	WA	Gillnet	1.50	2.00	2.00	1.50	1.75	2.00	2.50	2.00	3.00	2.38	2.00	2.00	2.00	2.00	2.00	6.13

Common name	Species name	FRDC – CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis	Life-cycle events	Migration	Mean Phenology	Score
			ManagedFishery																		
			Off Net and Line Fishery	NT	Gillnet	1.50	2.00	2.00	1.50	1.75	2.00	2.50	2.00	3.00	2.38	2.00	2.00	2.00	2.00	2.00	6.13
			Timor Reef Fishery	NT	Line	1.50	2.00	2.00	1.50	1.75	2.00	2.50	2.00	3.00	2.38	2.00	2.00	2.00	2.00	2.00	6.13
			WA North Coast Shark Fishery, Pilbara Trap Managed Fishery, Pilbara Fish Trawl (Interim) Managed Fishery	WA	Gillnet	1.50	2.00	2.00	1.50	1.75	2.00	2.50	2.00	3.00	2.38	2.00	2.00	2.00	2.00	2.00	6.13
Blacktip shark 1	*Carcharhinus tilstoni*	37018014	Off Net and Line Fishery	NT	Gillnet	2.00	2.00	2.00	1.00	1.75	2.00	1.50	1.00	1.50	1.50	2.00	1.00	2.00	2.00	1.75	5.00
Brown tiger prawn	*Penaeus esculentus*	28711044	Kimberley Prawn Managed Fishery	WA	Trawl	1.50	2.00	1.00	1.50	1.50	2.00	2.50	2.00	2.50	2.25	2.50	2.00	3.00	1.50	2.25	6.00
Coral trout	*Plectropomus spp. & Variola spp.*	37311905	Coastal Line Fishery	NT	Line	2.00	2.00	2.50	2.00	2.13	2.00	2.50	2.50	3.00	2.50	1.50	2.00	2.00	1.00	1.63	6.25
			Fishery Tour Operator	NT	Line	2.00	2.00	2.50	2.00	2.13	2.00	2.50	2.50	3.00	2.50	1.50	2.00	2.00	1.00	1.63	6.25
Crimson snapper	*Lutjanus erythropterus*	37346005	Demersal Fishery, Coastal Line Fishery, Timor Reef Fishery	NT	Line	3.00	2.00	3.00	2.00	2.50	2.00	2.00	3.00	3.00	2.50	2.00	2.00	2.00	2.00	2.00	7.00
Goldband snapper	*Pristipomoides multidens*	37346002	Demersal Fishery, Coastal Line Fishery, Timor Reef Fishery	NT	Line	2.00	2.00	2.50	1.50	2.00	2.00	2.00	2.50	2.50	2.25	2.00	1.50	1.50	1.50	1.63	5.88

Common name	Species name	FRDC – CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis	Life-cycle events	Migration	Mean Phenology	Score
Golden snapper	*Lutjanus johnii*	37346030	Coastal Line Fishery	NT	Line	2.00	2.50	2.50	1.50	2.13	2.00	2.50	2.50	3.00	2.50	2.00	2.00	2.00	2.00	2.00	6.63
			Demersal Fishery	NT	Line	2.00	2.50	2.50	1.50	2.13	2.00	2.50	2.50	3.00	2.50	2.00	2.00	2.00	2.00	2.00	6.63
			Fishery Tour Operator	NT	Line	2.00	2.50	2.50	1.50	2.13	2.00	2.50	2.50	3.00	2.50	2.00	2.00	2.00	2.00	2.00	6.63
			Timor Reef Fishery	NT	Line	2.00	2.50	2.50	1.50	2.13	2.00	2.50	2.50	3.00	2.50	2.00	2.00	2.00	2.00	2.00	6.63
Grey mackerel	*Scomberomorus semifasciatus*	37441018	Mackerel Managed Fishery	WA	Line	1.00	2.00	1.00	2.00	1.50	2.00	2.00	2.50	1.50	2.00	2.00	1.50	2.50	2.00	2.00	5.50
			Off Net and Line Fishery	NT	Gillnet	1.00	2.00	1.00	2.00	1.50	2.00	2.00	2.50	1.50	2.00	2.00	1.50	2.50	2.00	2.00	5.50
King threadfin	*Polydactylus macrochir*	37383005	Kimberley Gillnet and Barramundi ManagedFishery	WA	Gillnet	1.50	1.50	2.00	1.00	1.50	2.50	2.50	1.50	2.50	2.25	2.00	2.50	2.00	2.50	2.25	6.00
Red emperor	*Lutjanus sebae*	37346004	Demersal Fishery, Coastal Line Fishery, Timor Reef Fishery	NT	Line	2.00	2.50	2.50	1.50	2.13	2.00	2.50	2.50	2.50	2.38	2.00	2.00	2.00	2.00	2.00	6.50
Saddle tail snapper	*Lutjanus malabaricus*	37346007	Demersal Fishery, Coastal Line Fishery, Timor Reef Fishery	NT	Line	2.00	2.00	2.50	1.50	2.00	2.00	2.00	2.50	2.50	2.25	2.00	1.50	2.00	1.50	1.75	6.00
Spanish mackerel	*Scomberomorus commerson*	37441007	Demersal Fishery	NT	Line	1.50	2.00	1.00	1.50	1.50	2.00	1.50	2.00	1.50	1.75	1.50	1.50	2.00	1.50	1.63	4.88
			Mackerel Managed Fishery	WA	Line	1.50	2.00	1.00	1.50	1.50	2.00	1.50	2.00	1.50	1.75	1.50	1.50	2.00	1.50	1.63	4.88
			Off Net and Line Fishery	NT	Gillnet	1.50	2.00	1.00	1.50	1.50	2.00	1.50	2.00	1.50	1.75	1.50	1.50	2.00	1.50	1.63	4.88

Common name	Species name	FRDC – CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis	Life-cycle events	Migration	Mean Phenology	Score
			Spanish Mackerel Fishery	NT	Line	1.50	2.00	1.00	1.50	1.50	2.00	1.50	2.00	1.50	1.75	1.50	1.50	2.00	1.50	1.63	4.88
Spot tail shark	*Carcharhinus sorrah*	37018013	WA North Coast Shark Fishery, Joint Authority Northern Shark Fishery, Exmouth Gulf Beach Seine and Mesh Net Managed Fishery, Kimberley Gillnet and Barramundi Managed Fishery	WA	Gillnet	2.00	2.00	2.00	1.00	1.75	2.00	1.50	1.50	1.50	1.63	2.00	1.00	2.00	1.50	1.63	5.00
Spotted mackerel	*Scomberomorus munroi*	37441015	Off Net and Line Fishery	NT	Gillnet	1.00	1.50	1.00	1.50	1.25	2.00	1.50	1.50	1.50	1.63	1.50	1.50	2.00	2.00	1.75	4.63
Tropical lobster	*Panulirus ornatus*	28820006	Tropical Rock Lobster Developmental Fishery	NT	Dive	1.50	2.50	2.00	2.00	2.00	2.00	2.00	2.50	2.00	2.13	2.50	2.50	3.00	2.50	2.63	6.75

Appendix A Table 8: Scores per gear types and fisheries for region 4: Gulf of Carpentaria.

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Barramundi	*Lates calcarifer*	37310006	Gulf of Carpentaria Inshore Fin Fish	QLD	Gillnet	1.50	1.00	2.00	1.50	1.50	2.50	2.50	1.50	2.00	2.13	1.50	1.50	1.50	2.50	1.75	5.38

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
			Fishery																		
Black jewfish	*Protonibea diacanthus*	37354003	Gulf of Carpentaria Inshore Fin Fish Fishery	QLD	Gillnet	2.00	2.00	2.00	2.00	2.00	2.00	3.00	2.00	3.00	2.50	2.00	2.00	2.00	3.00	2.25	6.75
Blacktip shark 1	*Carcharhinus tilstoni*	37018901	Gulf of Carpentaria Inshore Fin Fish Fishery	QLD	Gillnet	1.00	2.00	2.00	1.00	1.50	1.00	2.00	1.00	1.00	1.25	2.00	1.00	1.00	2.00	1.50	4.25
Blacktip shark 2	*Carcharhinus limbatus*	37018901	Gulf of Carpentaria Inshore Fin Fish Fishery	QLD	Gillnet	1.00	2.00	2.00	1.00	1.50	1.00	2.00	1.00	1.00	1.25	2.00	1.00	1.00	2.00	1.50	4.25
Coral trout	*Plectropomus spp. & Variola spp.*	37311905	Developmental Fin Fish Trawl Fishery	QLD	Trawl	3.00	2.00	3.00	2.00	2.50	2.00	2.00	3.00	3.00	2.50	2.00	2.00	2.00	1.00	1.75	6.75
			Gulf of Carpentaria Line Fishery	QLD	Line	3.00	2.00	3.00	2.00	2.50	2.00	2.00	3.00	3.00	2.50	2.00	2.00	2.00	1.00	1.75	6.75
Crimson snapper	*Lutjanus erythropterus*	37346005	Gulf of Carpentaria Developmental Fin Fish Trawl Fishery	QLD	Trawl	3.00	2.00	3.00	2.00	2.50	2.00	2.00	3.00	3.00	2.50	2.00	2.00	2.00	2.00	2.00	7.00
			Gulf of Carpentaria Line Fishery	QLD	Line	3.00	2.00	3.00	2.00	2.50	2.00	2.00	3.00	3.00	2.50	2.00	2.00	2.00	2.00	2.00	7.00
Goldband snapper	*Pristipomoides multidens*	37346002	Gulf of Carpentaria Developmental Fin Fish Trawl Fishery	QLD	Trawl	3.00	2.00	3.00	2.00	2.50	2.00	2.00	3.00	3.00	2.50	2.00	2.00	2.00	2.00	2.00	7.00
Golden snapper	*Lutjanus johnii*	37346030	Gulf of Carpentaria Developmental Fin Fish Trawl Fishery	QLD	Trawl	3.00	3.00	3.00	2.00	2.75	2.00	3.00	3.00	3.00	2.75	2.00	2.00	2.00	3.00	2.25	7.75

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
			Gulf of Carpentaria Line Fishery	QLD	Line	3.00	3.00	3.00	2.00	2.75	2.00	3.00	3.00	3.00	2.75	2.00	2.00	2.00	3.00	2.25	7.75
Grey mackerel	*Scomberomorus semifasciatus*	37441018	Gulf of Carpentaria Inshore Fin Fish Fishery	QLD	Gillnet	1.00	2.00	1.00	2.00	1.50	2.00	2.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00	1.75	5.25
King threadfin	*Polydactylus macrochir*	37383005	Gulf of Carpentaria Inshore Fin Fish Fishery	QLD	Gillnet	3.00	1.00	3.00	1.00	2.00	3.00	3.00	1.00	2.00	2.25	2.00	3.00	2.00	3.00	2.50	6.75
Red emperor	*Lutjanus sebae*	37346004	Gulf of Carpentaria Developmental Fin Fish Trawl Fishery	QLD	Trawl	3.00	3.00	3.00	2.00	2.75	2.00	3.00	3.00	3.00	2.75	2.00	2.00	2.00	3.00	2.25	7.75
			Gulf of Carpentaria Line Fishery	QLD	Line	3.00	3.00	3.00	2.00	2.75	2.00	3.00	3.00	3.00	2.75	2.00	2.00	2.00	3.00	2.25	7.75
Saddle tail snapper	*Lutjanus malabaricus*	37346007	Gulf of Carpentaria Developmental Fin Fish Trawl Fishery	QLD	Trawl	3.00	2.00	3.00	2.00	2.50	2.00	2.00	3.00	3.00	2.50	2.00	2.00	2.00	2.00	2.00	7.00
			Gulf of Carpentaria Line Fishery	QLD	Line	3.00	2.00	3.00	2.00	2.50	2.00	2.00	3.00	3.00	2.50	2.00	2.00	2.00	2.00	2.00	7.00
Spanish mackerel	*Scomberomorus commerson*	37441007	Gulf of Carpentaria Inshore Fin Fish Fishery	QLD	Gillnet	2.00	2.00	1.00	2.00	1.75	2.00	2.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00	1.75	5.50
			Gulf of Carpentaria Line Fishery	QLD	Line	2.00	2.00	1.00	2.00	1.75	2.00	2.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00	1.75	5.50
Spotted mackerel	*Scomberomorus munroi*	37441015	Gulf of Carpentaria Inshore Fin Fish Fishery	QLD	Gillnet	1.00	1.00	1.00	2.00	1.25	2.00	2.00	2.00	1.00	1.75	1.00	2.00	2.00	2.00	1.75	4.75

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Tropical lobster	*Panulirus ornatus*	28820006	Crayfish and Rock Lobster Fishery	QLD	Dive	1.00	3.00	2.00	2.00	2.00	3.00	2.00	3.00	2.00	2.50	2.00	2.00	3.00	2.00	2.25	6.75

Appendix A Table 9: Scores per gear types and fisheries for region 5: Queensland East Coast.

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Banana prawn	*Penaeus merguiensis*	28711050	East Coast Inshore Fin Fish Fishery	QLD	Gillnet	1.33	1.67	1.00	2.00	1.50	2.33	2.33	2.00	2.00	2.17	2.67	2.33	3.00	2.33	2.58	6.25
			East Coast Otter Trawl Fishery	QLD	Trawl	1.33	1.67	1.00	2.00	1.50	2.33	2.33	2.00	2.00	2.17	2.67	2.33	3.00	2.33	2.58	6.25
			River and Inshore Beam Trawl Fishery	QLD	Trawl	1.33	1.67	1.00	2.00	1.50	2.33	2.33	2.00	2.00	2.17	2.67	2.33	3.00	2.33	2.58	6.25
Barramundi	*Lates calcarifer*	37310006	East Coast Inshore Fin Fish Fishery	QLD	Gillnet	1.00	2.25	1.75	2.00	1.75	2.50	1.75	1.50	1.75	1.88	2.75	2.25	2.25	2.00	2.31	5.94
Black jewfish	*Protonibea diacanthus*	37354003	East Coast Inshore Fin Fish Fishery	QLD	Gillnet	1.00	2.00	2.00	1.67	1.67	2.50	1.67	1.67	2.00	1.96	2.67	2.33	2.00	2.00	2.25	5.88
Blacktip shark 1	*Carcharhinus tilstoni*	37018901	East Coast Inshore Fin Fish Fishery	QLD	Gillnet	3.00	1.50	2.00	2.00	2.13	2.50	2.00	1.50	2.00	2.00	2.50	2.00	2.50	2.50	2.38	6.50
Blacktip shark 2	*Carcharhinus limbatus*	37018901	East Coast Inshore Fin Fish Fishery	QLD	Gillnet	3.00	1.50	2.00	2.00	2.13	2.50	2.00	1.50	2.00	2.00	2.50	2.00	2.50	2.50	2.38	6.50
Blue swimmer crab	*Portunus armatus*	28911005	Blue Swimmer Crab Fishery	QLD	Trap	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	5.00
			East Coast Otter Trawl Fishery	QLD	Trawl	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	5.00
			Estuary General Fishery	QLD	Dive	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	5.00
Brown tiger prawn	*Penaeus esculentus*	28711044	Estuary General Fishery	QLD	Dive	1.33	1.67	1.00	2.33	1.58	2.33	2.67	2.00	2.00	2.25	2.33	2.33	2.67	2.00	2.33	6.17
Coral trout	*Plectropomus spp. & Variola spp.*	37311905	Coral Reef Fin Fish Fishery	QLD	Line	1.00	1.50	2.00	2.00	1.63	2.50	2.50	2.00	2.50	2.38	2.00	2.50	2.00	2.00	2.13	6.13

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Crimson snapper	*Lutjanus erythropterus*	37346005	Coral Reef Fin Fish Fishery	QLD	Line	1.00	1.50	2.00	1.50	1.50	2.50	2.00	2.00	2.00	2.13	2.50	2.00	2.00	2.00	2.13	5.75
Dusky flathead	*Platycephalus fuscus*	37296004	East Coast Inshore Fin Fish Fishery	QLD	Gillnet	1.33	1.67	2.00	1.67	1.67	2.00	1.67	1.33	2.00	1.75	2.67	2.33	2.00	2.00	2.25	5.67
			Estuary General Fishery	QLD	Dive	1.33	1.67	2.00	1.67	1.67	2.00	1.67	1.33	2.00	1.75	2.67	2.33	2.00	2.00	2.25	5.67
Eastern king prawn	*Melicertus plebejus*	28711052	East Coast Otter Trawl Fishery	QLD	Trawl	1.33	1.67	1.00	2.00	1.50	2.33	2.00	1.67	2.00	2.00	2.33	2.33	3.00	2.33	2.50	6.00
Goldband snapper	*Pristipomoides multidens*	37346002	Coral Reef Fin Fish Fishery	QLD	Line	1.00	1.50	2.00	1.50	1.50	2.50	2.00	2.00	2.00	2.13	2.50	2.00	1.50	2.00	2.00	5.63
Golden snapper	*Lutjanus johnii*	37346030	East Coast Inshore Fin Fish Fishery	QLD	Gillnet	1.00	1.50	2.00	1.50	1.50	2.50	2.00	2.00	2.00	2.13	2.50	2.00	2.00	2.00	2.13	5.75
Grey mackerel	*Scomberomorus semifasciatus*	37441018	East Coast Inshore Fin Fish Fishery	QLD	Gillnet	1.00	1.67	1.67	1.67	1.50	2.33	2.00	1.67	2.00	2.00	2.33	2.00	2.67	2.67	2.42	5.92
King threadfin	*Polydactylus macrochir*	37383005	East Coast Inshore Fin Fish Fishery	QLD	Gillnet	1.33	2.00	2.00	1.67	1.75	2.67	1.67	1.67	2.00	2.00	2.67	2.67	2.33	2.33	2.50	6.25
Red emperor	*Lutjanus sebae*	37346004	Coral Reef Fin Fish Fishery	QLD	Line	1.33	1.67	2.00	1.67	1.67	2.00	2.33	2.00	2.00	2.08	2.33	2.33	2.00	2.00	2.17	5.92
Red throat emperor	*Lethrinus miniatus*	37351009	Coral Reef Fin Fish Fishery	QLD	Line	1.00	1.50	2.00	1.50	1.50	2.00	2.50	2.50	2.50	2.38	3.00	2.50	2.00	2.50	2.50	6.38
Saddle tail snapper	*Lutjanus malabaricus*	37346007	Coral Reef Fin Fish Fishery	QLD	Line	1.00	1.50	2.00	1.50	1.50	2.50	2.00	2.00	2.00	2.13	2.50	2.00	2.00	2.00	2.13	5.75
Spanish mackerel	*Scomberomorus commerson*	37441007	East Coast Spanish Mackerel Fishery	QLD	Line	1.00	1.67	1.67	1.33	1.42	2.33	1.33	1.33	2.00	1.75	2.00	2.00	2.33	2.33	2.17	5.33
Spanner crab	*Ranina ranina*	28865001	Spanner Crab Fishery	QLD	Trap	1.33	1.33	1.33	1.67	1.42	2.33	2.33	2.33	2.00	2.25	2.33	2.00	2.67	2.00	2.25	5.92
Spotted mackerel	*Scomberomorus munroi*	37441015	East Coast Inshore Fin Fish Fishery	QLD	Gillnet	1.00	2.00	1.67	1.67	1.58	2.50	1.33	1.33	2.00	1.79	2.67	2.00	2.33	2.67	2.42	5.79

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Tropical lobster	*Panulirus ornatus*	28820006	Crayfish and Rock Lobster Fishery	QLD	Dive	2.50	2.50	1.50	2.50	2.25	2.00	2.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	3.00	7.25
Whiting	*Sillago ciliata*	37330010	East Coast Inshore Fin Fish Fishery	QLD	Gillnet	1.00	2.00	1.00	1.50	1.38	2.50	1.50	1.50	1.50	1.75	2.50	2.50	2.50	2.00	2.38	5.50
			Estuary General Fishery	QLD	Dive	1.00	2.00	1.00	1.50	1.38	2.50	1.50	1.50	1.50	1.75	2.50	2.50	2.50	2.00	2.38	5.50

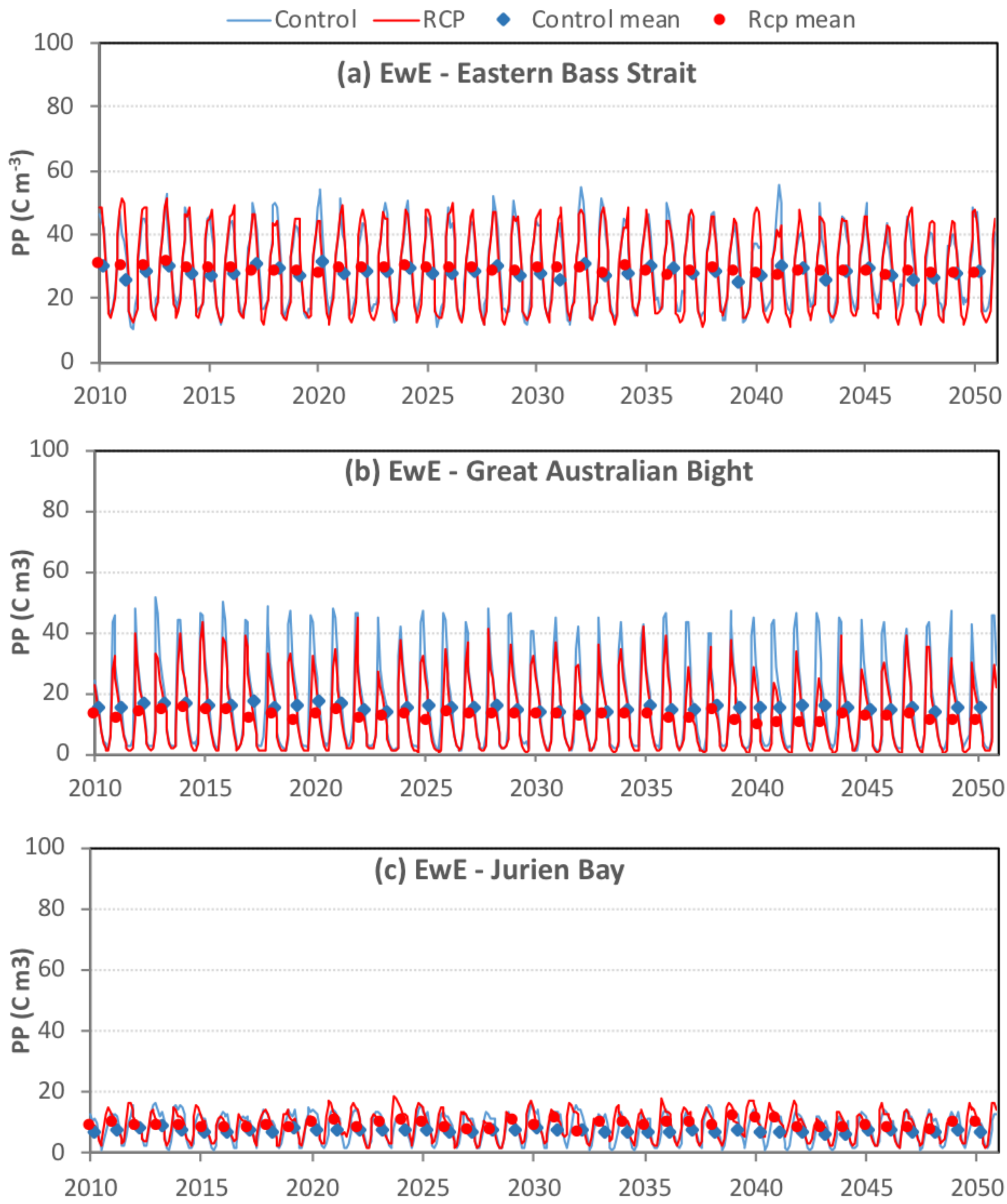
Appendix A Table 10: Scores per gear types and fisheries for Commonwealth fisheries

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Australian sardine	*Sardinops sagax*	37085002	Southern and Eastern Scalefish and Shark Fishery (Commonwealth Trawl Sector)	Commonwealth	Trawl	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
			Small Pelagic Fishery	Commonwealth	Midwater Trawl	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
Banana prawn	*Penaeus merguiensis*	28711050	Northern Prawn Fishery	Commonwealth	Trawl	1.50	2.00	1.00	1.50	1.50	2.00	2.50	2.00	2.50	2.25	2.50	2.00	3.00	1.50	2.25	6.00
Bigeye tuna	*Thunnus obesus*	37441011	Eastern Tuna and Billfish Fishery	Commonwealth	Longline	1.00	2.00	2.00	1.00	1.50	2.00	1.00	1.00	1.00	1.25	2.00	2.00	2.00	2.00	2.00	4.75
			Western Tuna	Commonwealth	Longline	1.00	2.00	2.00	1.00	1.50	2.00	1.00	1.00	1.00	1.25	2.00	2.00	2.00	2.00	2.00	4.75

Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
			Billfish Fishery																		
Blue grenadier	*Macruronus novaezelandiae*	37227001	Southern and Eastern Scalefish and Shark Fishery (Commonwealth Trawl Sector)	Commonwealth	Trawl	1.00	3.00	2.00	2.00	2.00	2.00	1.00	2.00	3.00	2.00	2.00	2.00	2.00	3.00	2.25	6.25
			Southern and Eastern Scalefish and Shark Fishery (Great Australian Bight Trawl Sector)	Commonwealth	Trawl	1.00	3.00	2.00	2.00	2.00	2.00	1.00	2.00	3.00	2.00	2.00	2.00	2.00	3.00	2.25	6.25
Blue mackerel	*Scomber australasicus*	37441001	Southern and Eastern Scalefish and Shark Fishery (Commonwealth Trawl Sector)	Commonwealth	Trawl	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
			Southern and Eastern Scalefish and Shark Fishery (Great Australian Bight Trawl Sector)	Commonwealth	Trawl	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
			Small Pelagic Fishery	Commonwealth	Midwater Trawl	1.00	2.00	1.00	1.00	1.25	1.00	2.00	2.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.00
Brown tiger prawn	*Penaeus esculentus*	28711044	Northern Prawn Fishery	Commonwealth	Trawl	1.50	2.00	1.00	1.50	1.50	2.00	2.50	2.00	2.50	2.25	2.50	2.00	3.00	1.50	2.25	6.00
Commercial scallop	*Pecten fumatus*	23270007	Bass Strait Central Zone Scallop Fishery	Commonwealth	Dredge	1.00	3.00	1.00	2.00	1.75	2.00	3.00	2.00	3.00	2.50	3.00	3.00	2.00	1.00	2.25	6.50
Coral trout	*Plectropomus spp. & Variola spp.*	37311905	Torres Strait Finfish Fishery	Commonwealth	Line	1.00	1.50	2.00	2.00	1.63	2.50	2.50	2.00	2.50	2.38	2.00	2.50	2.00	2.00	2.13	6.13
Grooved tiger prawn	*Penaeus semisulcatus*	28711053	Northern Prawn Fishery	Commonwealth	Trawl	1.50	2.00	1.00	1.50	1.50	2.00	2.50	2.00	2.50	2.25	2.50	2.00	3.00	1.50	2.25	6.00

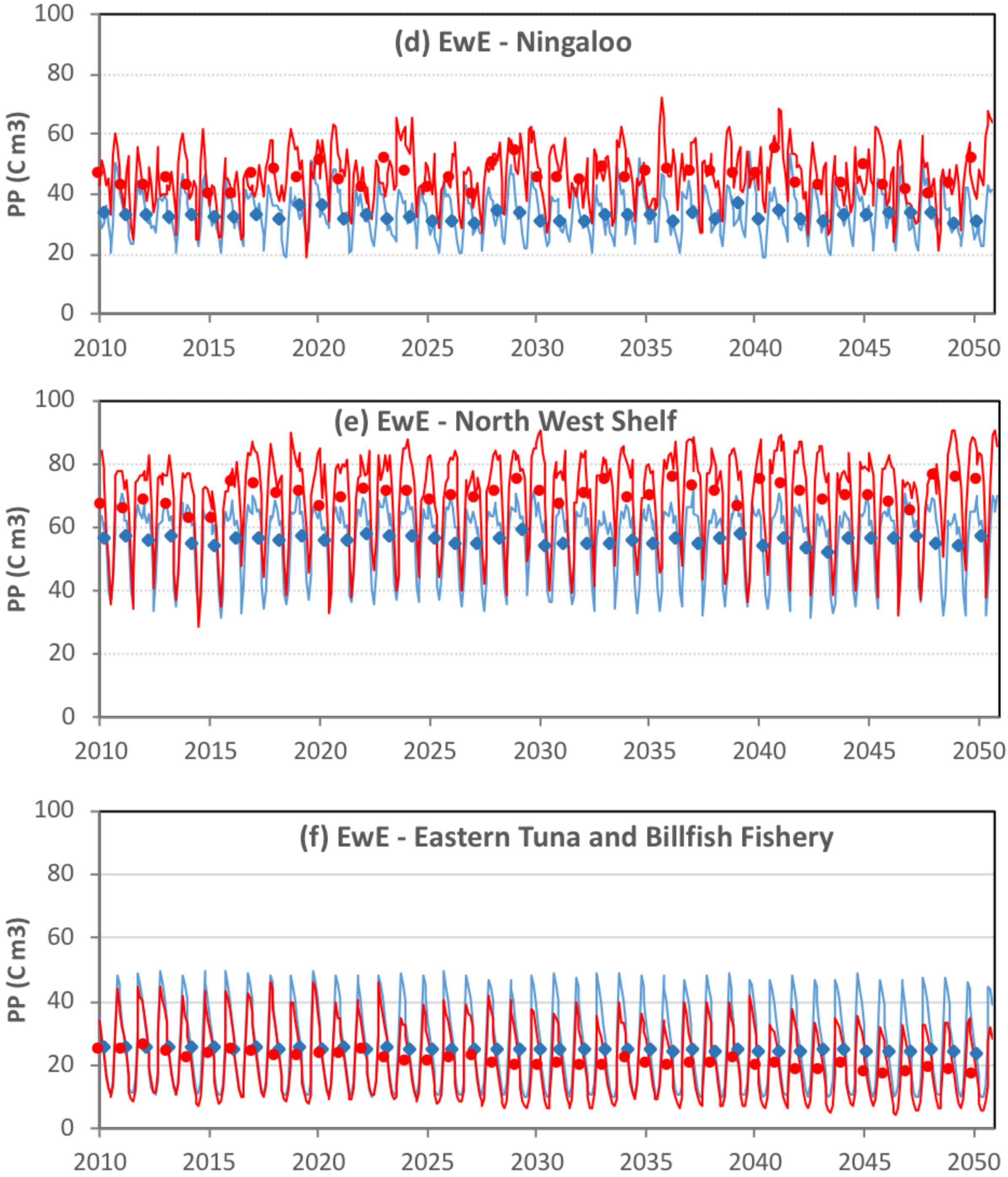
Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
Gummy shark	*Mustelus antarcticus*	37017001	Southern and Eastern Scalefish and Shark Fishery (Gillnet Hook and Trap Sector)	Commonwealth	Gillnet	3.00	1.00	2.00	2.00	2.00	3.00	1.00	2.00	3.00	2.25	1.00	1.00	2.00	3.00	1.75	6.00
Jack mackerel	*Trachurus declivis*	37337002	Southern and Eastern Scalefish and Shark Fishery (Commonwealth Trawl Sector)	Commonwealth	Trawl	1.00	2.00	2.00	2.00	1.75	1.00	2.00	2.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00	5.75
			Southern and Eastern Scalefish and Shark Fishery (Great Australian Bight Trawl Sector)	Commonwealth	Trawl	1.00	2.00	2.00	2.00	1.75	1.00	2.00	2.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00	5.75
			Small Pelagic Fishery	Commonwealth	Midwater Trawl	1.00	2.00	2.00	2.00	1.75	1.00	2.00	2.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00	5.75
Southern bluefin tuna	*Thunnus maccoyii*	37441004	Southern Bluefin Tuna Fishery	Commonwealth	Purse Seine	1.00	1.00	3.00	1.00	1.50	2.00	1.00	1.00	1.00	1.25	3.00	2.00	2.00	3.00	2.50	5.25
Southern calamari	*Sepioteuthis australis*	23617005	Southern and Eastern Scalefish and Shark Fishery (Commonwealth Trawl Sector)	Commonwealth	Trawl	2.00	1.00	1.00	2.00	1.50	3.00	2.00	1.00	3.00	2.25	2.00	2.00	2.00	3.00	2.25	6.00
Spanish mackerel	*Scomberomorus commerson*	37441007	Torres Strait Spanish Mackerel Fishery	Commonwealth	Line	1.00	1.67	1.67	1.33	1.42	2.33	1.33	1.33	2.00	1.75	2.00	2.00	2.33	2.33	2.17	5.33
Tiger flathead	*Platycephalus richardsoni*	37296001	Southern and Eastern Scalefish and Shark Fishery	Commonwealth	Trawl	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	3.00	2.25	2.00	1.00	2.00	1.00	1.50	5.25

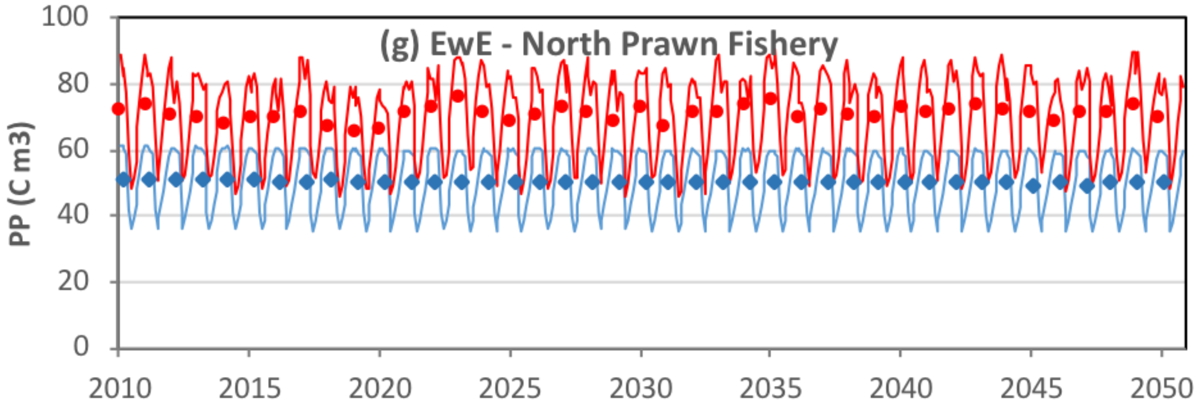
Common name	Species name	FRDC - CAAB	Fishery	Jurisdiction	Gear	Fecundity	Recruitment	Maturity	Generalist vs. specialist	Mean Abundance	Larval duration	Adult/juvenile range	Physiological tolerance	Spatial availability of habitat	Mean Distribution	Spawning cue	Settlement/ metamorphosis cue	Life-cycle events	Migration	Mean Phenology	Score
			(Commonwealth Trawl Sector)																		
			Southern and Eastern Scalefish and Shark Fishery (Gillnet Hook and Trap Sector)	Commonwealth	Gillnet	1.00	2.00	2.00	1.00	1.50	2.00	2.00	2.00	3.00	2.25	2.00	1.00	2.00	1.00	1.50	5.25
Tropical lobster	*Panulirus ornatus*	28820006	Torres Strait Rock Lobster Fishery	Commonwealth	Trap	2.50	2.50	1.50	2.50	2.25	2.00	2.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	3.00	7.25
Yellowfin tuna	*Thunnus albacares*	37441002	Eastern Tuna and Billfish Fishery	Commonwealth	Longline	1.00	2.00	2.00	1.00	1.50	2.00	1.00	1.00	1.00	1.25	2.00	2.00	2.00	2.00	2.00	4.75
			Western Tuna Billfish Fishery	Commonwealth	Longline	1.00	2.00	2.00	1.00	1.50	2.00	1.00	1.00	1.00	1.25	2.00	2.00	2.00	2.00	2.00	4.75
			Southern and Eastern Scalefish and Shark Fishery (Commonwealth Trawl Sector)	Commonwealth	Trawl	2.00	2.00	2.00	1.00	1.75	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.50
			Southern and Eastern Scalefish and Shark Fishery (Gillnet Hook and Trap Sector)	Commonwealth	Gillnet	2.00	2.00	2.00	1.00	1.75	2.00	2.00	1.00	2.00	1.75	2.00	2.00	2.00	2.00	2.00	5.50



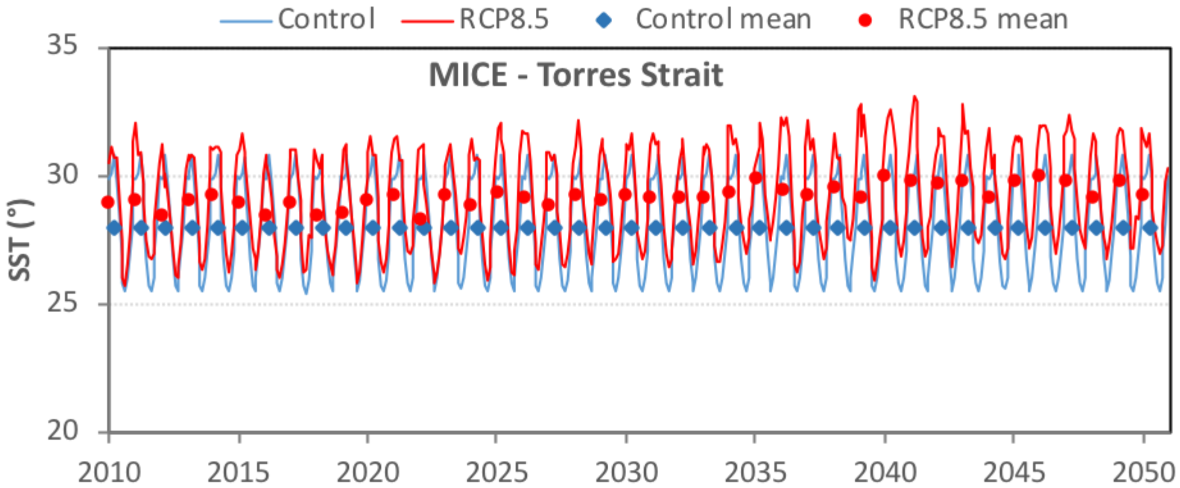
Control
RCP
Control mean
Rcp mean
(a) EwE - Eastern Bass Strait
PP (C m-3)
(b) EwE - Great Australian Bight
PP (C m3)
(c) EwE - Jurien Bay
PP (C m3)
0
20
40
60
80
100
2010
2015
2020
2025
2030
2035
2040
2045
2050

Appendix B Figure 1: Time-series, and annual means of the climate projections of primary productivity used as input forcing for EwE regional models. Continued on the next page

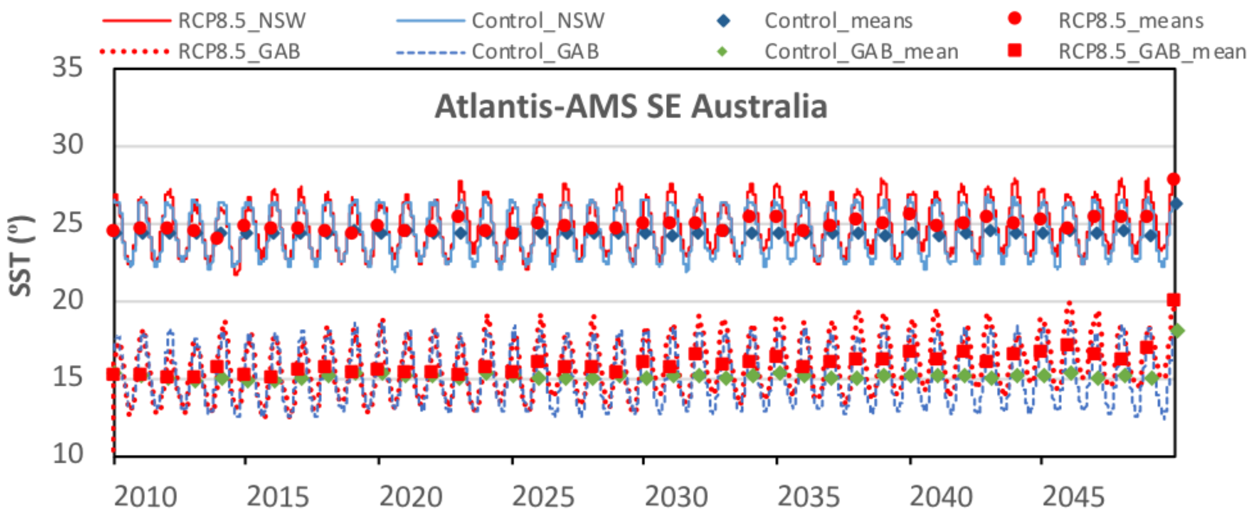




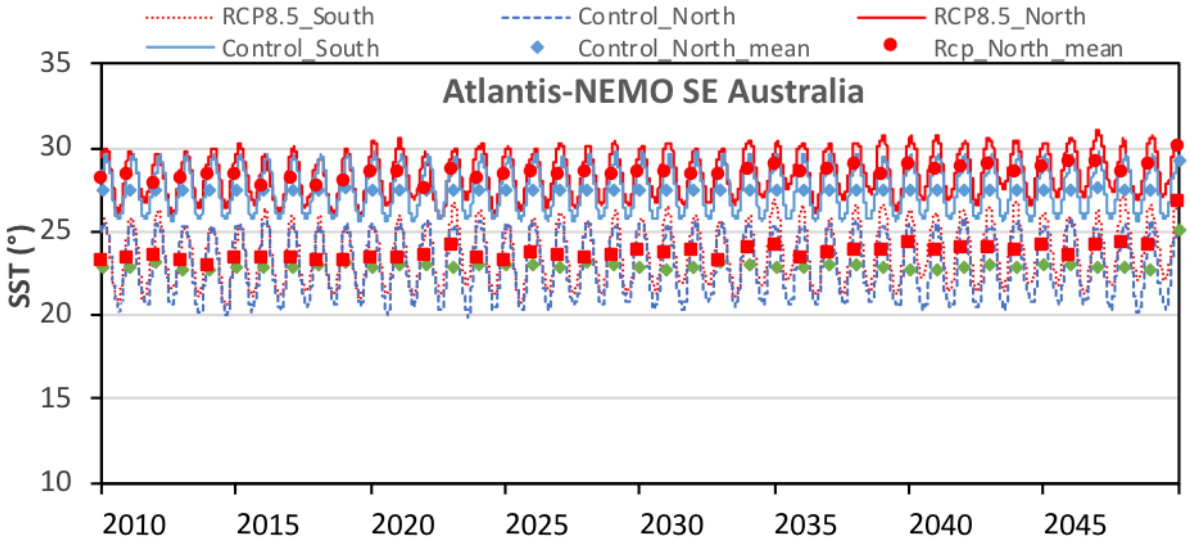
(g) EwE - North Prawn Fishery
PP (C m3)
100
80
60
40
20
0
2010
2015
2020
2025
2030
2035
2040
2045
2050



Control
RCP8.5
Control mean
RCP8.5 mean
MICE - Torres Strait
SST (°)
35
30
25
20
2010
2015
2020
2025
2030
2035
2040
2045
2050



RCP8.5_NSW
Control_NSW
Control_means
RCP8.5_means
RCP8.5_GAB
Control_GAB
Control_GAB_mean
RCP8.5_GAB_mean
Atlantis-AMS SE Australia
SST (°)
35
30
25
20
15
10
2010
2015
2020
2025
2030
2035
2040
2045



Appendix B Figure 2: Time-series, and annual means of sea surface temperature projections of the Australian climate model used as input forcing of regional MICE and Atlantis models.

Appendix B Table 1: Responses of harvested and TEP (*) functional groups in the Atlantis-AMS ecosystem model (Assessment region 1). S = Stable; P1 = Positive damped; P2 = Positive; P3 = Positive enhanced; PD = Positive divergent, N1 = Negative damped; N2 = Negative; N3 = Negative enhanced, ND = Negative divergent. C – level of confidence judged by the model developer, based on how well projected biomass of group or species fit to data.

		Constant fishing				Dynamic fishing	
Functional group	C	2020-25	2045-50	Functional group	C	2020-25	2045-50
Grenadier	M	N2	S	Grenadier	M	S	P2
Filter_Other	L	N2	N2	Filter_Other	L	S	N2
Demersal_S_Fish	M	PD	P2	Demersal_S_Fish	M	N2	N2
Morwong	H	PD	N2	Morwong	H	S	N2
Lobster	L	PD	S	Lobster	L/M	S	N2
Flathead	H	P1	P2	Flathead	H	S	P2
BlueMackerel	M	P2	P2	BlueMackerel	M	P3	S
Whiting	M	P2	P2	Whiting	M	P2	P2
Redfish	M/H	P2	P2	Redfish	M/H	P2	P2
Ribaldo	M	P2	P1	Ribaldo	M	P2	P2
PinkLing	M	P2	P2	PinkLing	H	N2	P2
Trevalla	M	P2	P2	Trevalla	M	P2	P2
Warehou	M/H	P2	P2	Warehou	M/H	P1	P3
Pinniped *	M	P2	P2	Pinniped *	M	P2	P3
Whale_Small *	L	P2	P2	Whale_Small *	L	P2	P1
Whale_Tooth *	L	P2	P2	Whale_Tooth *	L	P2	P1
Sealion *	L/M	P2	P2	Sealion *	L/M	S	P2
RedBait	M/L	P3	P3	RedBait	M/L	S	P2
Anchovy	M	S	P3	Anchovy	M	S	P3
JackMackerel	M	S	P2	JackMackerel	M	P2	P2
SmallPelagic	M	S	ND	SmallPelagic	M	S	ND
Cardinalfish	L	S	S	Cardinalfish	L	S	S
Gemfish	M	S	S	Gemfish	M	S	S
Pisciv_S_Fish	L	S	N3	Pisciv_S_Fish	L	S	N3
SpottedWarehou	M	S	P2	SpottedWarehou	M	P2	P2
Tuna	L/M	S	S	Tuna	L/M	S	S
DoriesOreos	M	S	S	DoriesOreos	M	S	S
Roughy	M/H	S	P2	Roughy	M/H	S	P2
GummyShark	H	S	S	GummyShark	H	S	S
Shark_D	M	S	S	Shark_D	M	S	S
Dogfish	M	S	N2	Dogfish	M	N2	N2
Shark_P	M	S	ND	Shark_P	M	S	S
GulperShark	H	S	N2	GulperShark	H	N2	N2

		Constant fishing				Dynamic fishing	
Functional group	C	2020-25	2045-50	Functional group	C	2020-25	2045-50
SchoolShark	H	S	P2	SchoolShark	H	P2	P2
SkateRay	L/M	S	S	SkateRay	M	P2	P2
Macrobenth_Shallow	L	S	N2	Macrobenth_Shallow	L	P3	P2
Scallop	L	S	N2	Scallop	L	S	P2
Benthic_grazer	L	S	N2	Benthic_grazer	L	P3	P2
Seabird *	L/M	S	S	Seabird *	L/M	S	S
Penguin *	L/M	S	S	Penguin *	L/M	S	S
Whale_Baleen *	M	S	S	Whale_Baleen *	M	S	S

Appendix B Table 2: Responses of harvested and TEP (*) functional groups in the EwE- GAB and EwE-EBS ecosystem model (Assessment region 1). S = Stable; P1 = Positive damped; P2 = Positive; P3 = Positive enhanced; PD = Positive divergent, N1 = Negative damped; N2 = Negative; N3 = Negative enhanced, ND = Negative divergent. C – level of confidence judged by the model developer, based on how well projected biomass of group or species fit to data.

EwE-GAB				EwE-EBS			
Functional group	C	2020	2050	Functional group	C	2020	2050
Rock.lobster	L/M	ND	ND	Jack.mackerel	M	N2	N2
Shelf.large.demersal.omnivores	M	N3	N3	Whiting	M	PD	N2
Garfish	M	N3	N1	Gemfish	H	P3	P2
Slope.large.demersal.piscivores	L/M	N3	N2	Toothed.whale *	L	S	S
Squid...cuttlefish.shelf	L/M	N3	N2	Baleen.whale *	L	S	S
Crabs...bugs	L/M	N3	ND	Seal *	H	S	S
Gannets *	L	N2	N1	Seabirds *	L	S	S
Shelf.large.pelagic.piscivores	M	N2	N1	Penguins *	L/M	S	S
Snapper	L/M	N2	N3	Tuna.billfish	L/M	S	PD
Shelf.demersal.sharks	M	P2	N2	Pelagic.sharks	L/M	S	S
Southern.Bluefin.Tuna	M	P2	P3	Demersal.sharks	L/M	S	N2
Slope.large.demersal.invertivores	L/M	P2	P1	Rays	L/M	S	S
Baleen.whales *	L	S	S	Warehous	H	S	S
Toothed.whales *	L	S	S	Redbait	L/M	S	S
Bottlenose.dolphins *	L	S	S	Redfish	M	S	S
Common.dolphins *	L	S	S	Ling	H	S	S
Long.nosed.fur.seal *	H	S	S	Dories	M	S	S
Australian.fur.seal *	M	S	S	Jackass.morwong	H	S	S
Australian.sea.lion *	M	S	S	Flathead	H	S	S
Albatross *	L	S	N3	ShOceanPerch	L	S	S
Shearwaters *	L	S	S	Chinaman.leatherjacket	L	S	S
Small.petrels *	L	S	N3	Cucumberfish	L	S	S
Terns *	L	S	S	Cardinal	M	S	S

EwE-GAB				EwE-EBS			
Functional group	C	2020	2050	Functional group	C	2020	2050
Shags.and.cormorants *	L	S	N3	ShSmInvertFeeder	L/M	S	S
Gulls *	L	S	N3	ShSmPredator	M	S	S
Little.Penguins *	M	S	P3	ShMedInvertFeeder	L/M	S	S
Shelf.pelagic.sharks	M	S	S	ShMedPredator	M	S	S
Offshore.pelagic.sharks	L/M	S	N2	ShLInvertFeeder	L/M	S	S
Shelf.demersal.piscivorous.shark	M	S	S	ShLPredator	L/M	S	S
Deep.demersal.sharks	L/M	S	ND	Blue.eye.trevalla	L/M	S	S
Skates.and.rays	M	S	S	Blue.grenadier	L/M	S	S
Tunas.and.billfish	L/M	S	N3	SlopeOceanPerch	L	S	S
Offshore.pelagic.piscivores	L/M	S	S	Deepsea.Cod	L	S	N2
Offshore.pelagic.invertivore.large	M	S	S	Oreos	L	S	S
Sardine	M	S	P3	SlopeSmInvertFeeder	L/M	S	S
Shelf.pelagic.planktivore.small	M	S	P3	SlopeSmPredator	M	S	S
Mackerels	M	S	S	SlopeMInverFeeder	L/M	S	S
Redbait	L	S	S	SlopeMPredator	M	S	S
Shelf.small.demersal.piscivores	M	S	P2	SlopeLInvertFeeder	L	S	S
Shelf.small.demersal.omnivores	M	S	S	SlopeLPredator	L/M	S	S
Shelf.large.demersal.piscivores	L/M	S	S	PelSmInvertFeeder	L/M	S	S
King.George.whiting	L/M	S	S	PelMInvertFeeder	L/M	S	S
Deepwater.flathead	L/M	S	N3	PelMPredator	L/M	S	S
Bight.redfish	L/M	S	N3	PelLInvertFeeder	L	S	S
Migratory.mesopelagics	L	S	S	PelLPredator	M	S	S
Non.migrating.mesopelagics	L	S	P2	Mesopelagics	L/M	S	S
Slope.small.demersal.invertivores	L/M	S	N3	Squid	L/M	S	S
Slope.small.demersal.piscivores	L/M	S	P1	PelagicPrawns	L/M	S	S
Benthic.grazers	L/M	S	S	Macrobenthos	L/M	S	S
Abalone	L/M	S	S	Megabenthos	L/M	S	S
Benthic.detritivore	L/M	S	S				
Benthic.carnivores..infauna.	L	S	N3				
Meiobenthos	L	S	S				
Shelf.filter.feeders	L/M	S	S				
Deep.filter.feeders	L	S	N3				
Shelf.macrozoobenthos	L/M	S	P3				
Octopus.shelf	L/M	S	S				
Western.king.prawn	L/M	S	S				

Appendix B Table 3: Responses of harvested and TEP (*) functional groups in the EwE-Ningaloo and EwE-JB ecosystem models (Assessment region 2). S = Stable; P1 = Positive damped; P2 = Positive; P3 = Positive enhanced; PD = Positive divergent, N1 = Negative damped; N2 = Negative; N3 = Negative enhanced, ND = Negative divergent. C – level of confidence judged by the model developer, based on how well projected biomass of group or species fit to data.

EwE-Ningaloo				EwE-JB			
Functional group	**C**	**2020**	**2050**	**Functional group**	**C**	**2020**	**2050**
Ospreys *	M	PD	PD	NDR.reef.aa..zooplankton.feed	M	ND	S
Coastal.seabird *	L	PD	PD	Dolphins *	M	N2	N3
Shallow.demersal.fish	L/M	PD	P3	Large.coastal.sharks	M	N2	N2
Trevallies	L/M	PD	P3	Small.coastal.sharks	M	N2	N2
Mackerels	L/M	PD	S	Inshore.reef.ass..omnivore	M	N2	N2
Queenfish	L/M	PD	S	Inshore.reef.ass..zoobenthos.feed.	M	N2	ND
Demersal.sharks	M	PD	PD	NDR.reef.ass..zoobenthos.feed.	M	N2	S
Pelagic.sharks *	M	PD	S	NDR.seagrass.ass..carnivore	M	N2	S
Lethrinids.adults	M/H	PD	PD	Rays	M	N3	N3
Lethrinids.juv	M/H	PD	PD	Dhufish	H	N3	N3
L.nebulosus.adult	M/H	PD	PD	NDR.reef.ass..carnivore	M	PD	N1
L.nebulosus.juv	M/H	PD	PD	Rabbit.fish	M	P2	S
Small.lutjanids	M/H	PD	PD	Inshore.pelagic.zooplankton.feed	M	P2	N2
Serranids	M/H	PD	PD	NDR.reef.ass..herbivore	M	P2	P1
Tuskfish	M	PD	PD	Inshore.seagrass.ass..zoob..feed.	M	P3	P2
Saurids	M	PD	PD	Sea.lions *	H	S	S
Nemipterids	M	PD	S	Intertidal.birds *	L	S	S
Small.reef.fish	L/M	PD	PD	Surface.diving.birds *	L	S	S
Tuna.and.billfish	L/M	PD	PD	Pink.snapper	H	S	ND
Reef.Associated.Pelagics	L/M	PD	PD	Baldchin.grouper	M	S	S
Small.pelagics	L/M	PD	PD	King.wrasse	H	S	S
Squid	L	PD	PD	Western.foxfish	M	S	ND
Octopus	L	PD	PD	Breaksea.cod	H	S	PD
Kingprawn	M/L	PD	PD	Inshore.reef.ass..herbivore	M	S	N3
Bananaprawn	M/L	PD	PD	Inshore.ass..carnivore	M	S	S
Lobster	L	PD	PD	Inshore.sand.ass..omnivore	M	S	P3
Crabs	L	PD	PD	Inshore.seagrass.ass..omnivore	M	S	S
Shells	L	PD	PD	Inshore.benthopelagic.carnivore	M	S	PD
Benthos	L	PD	PD	NDR.reef.ass..omnivore	M	S	S

EwE-Ningaloo				EwE-JB			
Functional group	C	2020	2050	Functional group	C	2020	2050
Dolphins *	L/M	S	S	NDR.sand.ass..omnivore	M	S	S
Whales *	M	S	S	NDR.sand.ass..carnivore	M	S	S
Whale.sharks *	M	S	PD	NDR.sand.ass..zoobenthos.feed.	M	S	S
Manta.Rays *	M	S	PD	NDR.seagrass.ass..omnivore	M	S	P3
Adult.Turtles *	L/M	S	PD				
Dugongs *	L/M	S	PD				
Herbivores	L	S	PD				
Urchins	L	S	PD				

Appendix B Table 4: Responses of harvested and TEP (*) functional groups in the EwE-NWS and EwE-NPF ecosystem models (Assessment regions 3 and 4). S = Stable; P1 = Positive damped; P2 = Positive; P3 = Positive enhanced; PD = Positive divergent, N1 = Negative damped; N2 = Negative; N3 = Negative enhanced, ND = Negative divergent. C – level of confidence judged by the model developer, based on how well projected biomass of group or species fit to data.

EwE-NWS				EwE-NPF			
Functional group	C	2020	2050	Functional group	C	2020	2050
ShLutjanids	L	ND	ND	Small.sharks	L	N1	N2
DpPonyfish	L	ND	N1	Banana.prawn.juv (and adults)	H	N2	N2
FryPBream	M/L	N1	S	Other.non.commercial.prawns	H	N2	PD
Rays	L	PD	PD	Sand.crab.and.other.large.crabs	M	N2	PD
SmTunas	M/L	PD	PD	Dolphins *	L	PD	PD
DpNemipterids	L	PD	PD	Sea.snakes *	L	PD	PD
ShSerranids	M/L	PD	ND	Sawfishes	L	PD	PD
ShLizard	M	PD	S	Rays	L	PD	PD
ShSweetlip	M/L	PD	PD	Pelagic.carnivores.Fish	L/M	PD	PD
ShMedFish	M/L	PD	S	Benthopelagic.carnivores.Fish	L/M	PD	PD
ShLgFish	L	PD	S	Benthopelagic.invert.feeders.Fish	L/M	PD	PD
DpLgFish	L	PD	S	Benthic.carnivores.Fish	L/M	PD	PD
ShNemipterirds	L	P1	P2	Benthic.invert.feeders.Fish	L/M	PD	PD
ShLethrinids	L	P3	PD	Red.snappers.Fish	M	PD	PD
RedEmperor	L/M	P3	PD	Reef.assoc..invert.feeders.Fish	L/M	PD	PD
DpMedFish	L	P3	S	Reef.assoc..herbivores.Fish	L/M	PD	PD
Coastal.sharks	L/M	S	S	Detritivores.Fish	L	PD	P3
JuvCarangids	L	S	PD	Cephalopods	L/M	PD	PD
AdCarangids	M/L	S	PD	Thallasinid.prawns	M	PD	PD
SmallPelagics	M/L	S	S	Mud.crab	H	PD	PD

EwE-NWS				EwE-NPF			
Functional group	C	2020	2050	Functional group	C	2020	2050
DpLizard	M	S	S	Large.gastropod.carnivore	L/M	PD	PD
ShMullidae	M/L	S	S	Holothurians	L/M	PD	PD
DpMullidae	L	S	PD	Spatangoids	L	PD	PD
ShSmFish	L	S	S	Echinoids	L	PD	PD
DpSmFish	L	S	S	Ophiuroids	L	PD	S
ShTriggerFish	L	S	PD	Asteriods	L	PD	S
				Small.crustaceans	L	PD	PD
				Tiger.prawn.adult	H	P3	PD
				Dugongs *	M	S	ND
				Turtles *	M	S	S
				Sea.birds *	M	S	N2
				Large.sharks	M	S	PD
				Pelagic.invert.feeders.Fish	L/M	S	S
				Reef.assoc..carnivores.Fish	L/M	S	S
				Other.commercial.prawns	H	S	N2
				Lobsters	M	S	N2
				Sessile.epibenthos	L	S	PD
				Bivalves	L	S	PD

Appendix B Table 5: Responses of harvested and TEP (*) functional groups in the Atlantis-NEMO and the EwE-EBTF ecosystem models (Assessment region 5). S = Stable; P1 = Positive damped; P2 = Positive; P3 = Positive enhanced; PD = Positive divergent, N1 = Negative damped; N2 = Negative; N3 = Negative enhanced, ND = Negative divergent. C – level of confidence judged by the model developer (L- low, M-medium, H- high), based on how well projected biomass of group or species fit to data.

Atlantis-NEMO				**EwE-ETBF**			
Functional group	**C**	**2020**	**2050**	**Functional group**	**C**	**2020**	**2050**
Mako.and.great.whites	L	N2	N3	Green.sea.turtles *	L	N3	N3
Benthic.grazer..urchins.	L	N2	N2	Leatherback.turtles *	M	N3	N3
Lobsters..tropical.	L	N3	N2	Seabirds *	L	N3	N3
Epipelagic.squid	L	PD	N3	Large.sharks	L	N3	N3
Mesopelagic.squid	L	PD	PD	Hammerhead.sharks	L	N3	N3
Sauries.and.scads	M	P2	P2	Blue.shark	L	N3	N3
Large.planktivorous.fish	L	P2	P2	Black.marlin	M	N3	N3
Oceanic.piscivorous.fish	M	P2	P2	Striped.marlin	M	N3	N3
Prawns	L	P2	P2	Spearfish.and.Sailfish	L	N3	N3
Planktivor.chondrichthyans *	L	P2	P2	Swordfish.adult	L/M	N3	N3
Large.mesopelagics	M	P3	P2	Swordfish.juvenile	L/M	N3	N3
Marlin	M	P3	P3	Bigeye.tuna.adult	M	N3	N3
Shallow.macrozoobenthos	L	P3	PD	Bigeye.tuna.juvenile	M	N3	N3
Yellowfin	M	S	P2	Large.mesopelagic.fishes	L	N3	N3
Albacore	H	S	P3	Toothed.whales *	L	S	N3
Benthopelagics	M	S	S	Pelagic.mackerel.sharks	L	S	N3
Shallow.demersal.fish	M	S	N2	Blue.marlin	M	S	N3
Small.planktivorous.fish	H	S	S	Yellowfin.tuna.adult	M	S	N3
Deep.demersal.fish	H	S	S	Yellowfin.tuna.juvenile	M	S	S
Reef.benthic.fish	L	S	N2	SBT	L	S	N3
Reef.herbivorous.fish	M	S	N3	Albacore.tuna	M	S	N3
Reef.piscivorous.fish	M	S	PD	Skipjack	L	S	N3
Skipjack.tuna	H	S	P2	Med.scombrids.dolphinfish	L	S	N3
Reef.herbivorous.scrapers	M	S	N2	Small.scombrids.and.carangids	M	S	S
Swordfish	H	S	S	Lancetfish	L	S	N3
Bigeye.tuna	M	S	P3	Medium.mesopelagic.fishes	L	S	N3
Benthic.sharks	M	S	PD	Small.mesopelagic.fishes	L	S	S
Pelagic.sharks	L	S	P2	Micronekton.fishes	L	S	N3
Shallow.benthic.filter.feeder	L	S	N2	Epipelagic.squids	L	S	N3
Deepwater.prawns	L	S	N2	Small.mesopelagic.squids	L	S	N3
Turtles *	M	S	S				

Atlantis-NEMO				EwE-ETBF			
Functional group	C	2020	2050	Functional group	C	2020	2050
Seabirds *	L	S	S				
Baleen.whales *	M	S	S				
Small.toothed.whales *	M	S	P2				

Appendix B Table 6: Summary of spatial output for all functional groups included in the Atlantis-AMS model (assessment region 1).

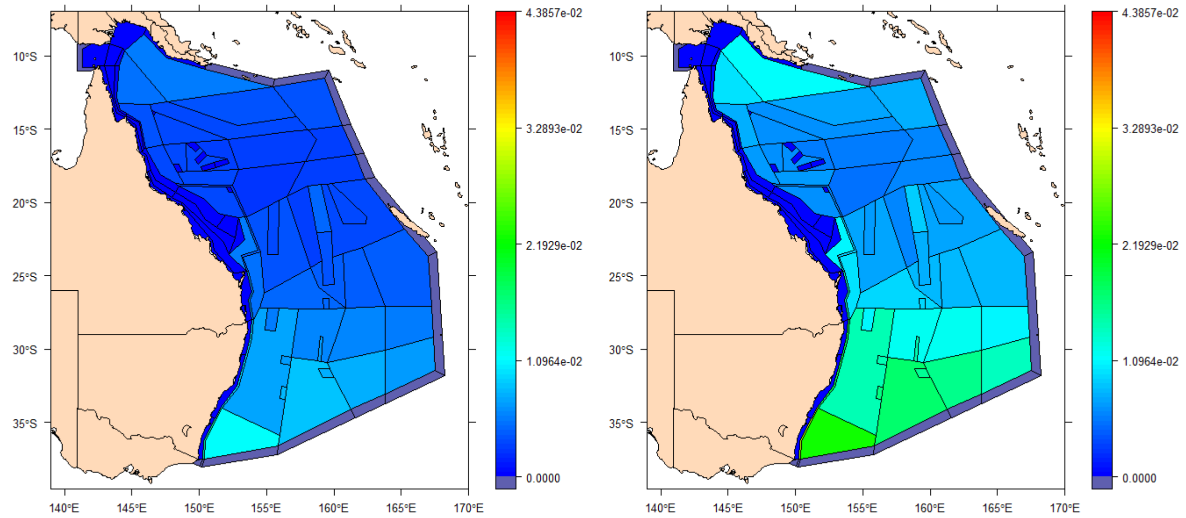
Group	Notes
Oxygen	Oxygen levels dropping in deeper and warmer waters. Becoming more variable along fronts (e.g. Tasman Sea and central GAB) and around seamounts
Phytoplankton	Production along the east coast (especially along east coast, Tasman Sea and central GAB) becomes more variable – series of very productive years interspersed by series of years with exceptionally low production. Increasing baseline contribution by small (pico) phytoplankton
Zooplankton	Influenced by phytoplankton production (so patchier), with larger zooplankton dropping away through time especially in the deeper GAB (coastal production more consistent)
Jellies	Patchy – in some locations through GAB drops, increases in other spots along east coast
Infauna	No significant difference to control run
Benthic invertebrates	Turnover in exact content but absolute abundance across all groups is smaller (by 10% or so), gross amount fairly robust for more groups until hit thermal maxima for a group (e.g. on marginal edges for benthic grazers like abalone)
Lobster	Drop in abundance by at least 10%
Macrophytes	Some turnover in composition
Anchovy	Phenology and 3D distributional shift – both along northern NSW and in GAB with juvenile fish contracting from the marginal edges of the distribution and pushing more into surface waters. Increasing inter-annual variability in numbers found in central GAB and along the NSW coast across all age classes. Individual adult fish see (<5%) increase in size.
Blue Mackerel	No significant difference to control, small change (increase) in size of individual fish
Jack Mackerel	Slightly more variable biomasses, especially along east coast when following forage fields, small change (increase) in size of individual fish
Sardines (small pelagics)	More variable across entire region (east coast and GAB), with higher highs in some years but also stretches of years with lower biomasses and recruitment
Red bait	No significant difference to control
Mesopelagics	Abundance of myctophids drops by 30%, deeper dwelling ones more constant so long as can source enough food
Cardinalfish	No significant difference to control (some small increase in fish size)
Shallow demersal fish	Some reduction (by as much as 30%) reduction in abundance
Dories and Oreos	No significant difference to control
Flathead	Deepwater flathead declines while tiger flathead down the east coast increases
Gemfish	Declining on northern edge of range, stable (but not recovering) in core eastern distribution, declining in the west; some increase in individual body size
Grenadier	Very influenced by pattern of recruitment spikes; size also shows some (small) sensitivity to forage fields

Group	Notes
Morwong	Abundance drops by 10% but individual size increases (by < 5%)
Pink ling	No significant difference to control
Shallow piscivorous fish	Highly variable along east coast, contracting from marginal edges, very large contraction
Redfish	Declining in bight, steady or small increase off east coast
Ribaldo	No significant difference to control
Roughy	Decline off northern extent, more rapid recovery than under control in southern grounds (like Cascade)
Deepwater dogfish	No significant difference to control for abundance, but small drop in individual size
School shark	Contraction of pupping grounds and more variable success
Gulper shark	Same pattern as for control, but with slightly variability in abundance levels, lower in sea mounts but slightly higher at depth so long as oxygen doesn't dip too far
Gummy shark	Adult abundance and pup levels as for control, but adult body size slightly smaller and
Shallow demersal sharks	Small drop in abundance (<10%) and more variable on marginal edges
Pelagic sharks	No significant difference to control
Skates and rays	30% drop in abundance
Spotted warehou	30% variance in abundance (patchy distribution, some increases, some decreases)
Warehou	10% drop in abundance vs control (some increase vs 2010)
Whiting	Contracting out of shallowest and warmest water and drop in overall abundance (<10%)
Trevalla	No significant difference to control
Tuna	Drop in abundance of tropical tunas (<10%), SBT response patchier (declining in west as shift east)
Sealion	Further declines in abundance (<10% difference to control though)
Fur seals	More rapid population growth
Dolphins	Decline (<10%) overall and more homogeneously dispersed along shelf areas (past hotspots through Bass Strait and off Victoria not really distinguishable from other shelf areas now)
Orcas	Decline in abundance (by as much as 50% in some locations)
Baleen whales	Increase in abundance around production hotspots and more onto shelf waters (no real change in absolute abundance more spatial redistribution)
Penguins	More influenced by on land mortality sources, though variability of small pelagics can influence chick mortality
Seabirds	Some drop in abundance (<10%) across the entire model domain

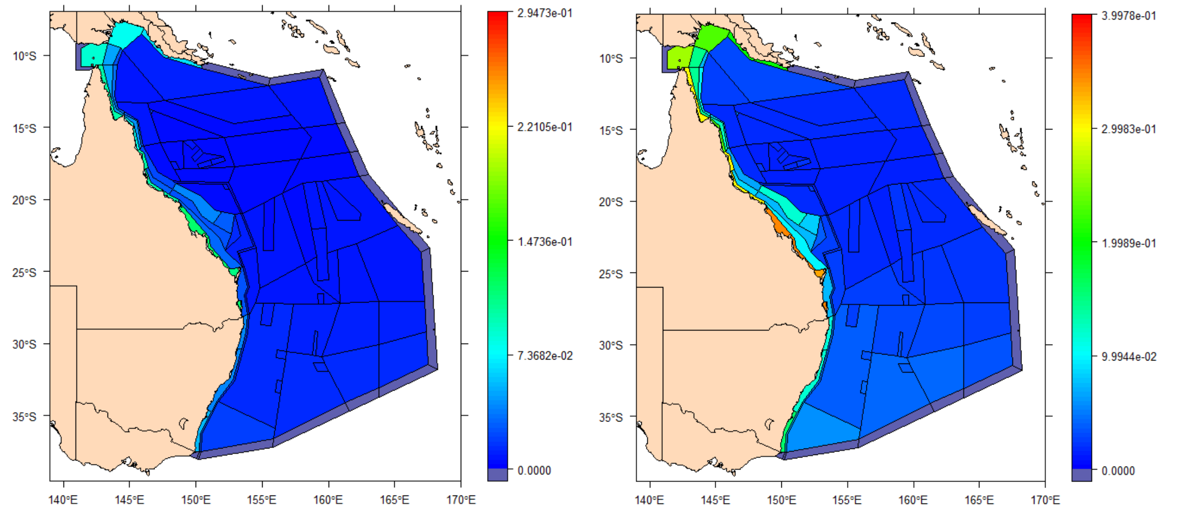
Appendix B Table 7: Summary of spatial output for all functional groups included in the Atlantis-NEMO model (assessment region 5).

Group	Notes
Oxygen	Oxygen levels dropping in deeper and warmer waters. Small noticeable spatial effect with difference in Control versus 8.5RCP in that shallower 8.5RCP waters (reefs) have lower oxygen levels.
Phytoplankton	Large phytoplankton increase by >5% with no noticeable shift in spatial distribution. Small phytoplankton also increase by same magnitude (>5%) with small noticeable shift in spatial distribution (less in shallow waters; in some Northern regions).
Zooplankton	Carnivorous zooplankton biomass increase by >7% in both Northern and Southern regions. Mesozooplankton biomass show a small decrease (<3%) with no discernible spatial effects. No overall changes in microzooplankton biomass; but small patchy changes are observed in spatial distribution.
Jellies	Small decrease in jellies (<3%) – with no clear changes in spatial distribution.
Epipelagic squid	Epipelagic squid show a medium increase in biomass (>8.5%), with no discernible spatial shifts.
Mesopelagic squid	Very large increase in mesopelagic squid (~100%) with increases in Southern and Northern regions of the model (Figure B-3).
Infauna	Very small (<2%) decreases in this group. No clear spatial effects.
Benthic invertebrates	Very mixed responses in this group; with very large increase in shallow benthic filter feeders (>12%); moderate increases in benthic grazers (>4.5%); and moderate decreases in deepwater filter feeders (>4.5% decrease).
Macrozoobenthos	Large decrease in macrozoobenthos (crabs) in the order of 16%. No clear spatial change in distribution.
Prawns	Very large increase in prawns (>150%), with increases in density in coastal waters throughout the Northern and Southern extend of the model (Figure B-4).
Lobster	Tropical rock lobster show a uniformly large magnitude increase in biomass between Control and RCP8.5 with a clear spatial changes (increase in Torres Strait). Suggest caution here with regard to interpretation of model results.
Macrophytes	Small increases in macroalgae (>2.5%) and seagrass (>3.5%) with no discernible spatial effects.
Small planktivorous fish	Increase in small planktivorous fish (>8.5%) and fish size, with very clear spatial shift in spatial distribution (decreases in the northern extent of GBR (Figure B-5).
Sauries and scads (and flying fish)	Sauries, small scads and flying fish show small increases in biomass (+/- 6.5%) but no discernible changes in spatial distribution.
Jack mackerel (+ large planktivorous fish)	Small decrease (<5%), with no spatial effects.
Dolphinfish/oceanic Piscivorous fish	Very small increase of biomass for this group (>3.5%) and a small increase in body size, with no discernible spatial effects.
Large mesopelagics (escolar)	Decrease in biomass for this group (>8.5%) with no changes observed in model predicted spatial distributions.
Medium mesopelagics (pomfret)	No changes.
Myctophids/lanternfish	Increase of biomass for this group (>7%) with no discernible spatial effects.
Driftfish	Decrease in overall biomass for this group (>9%) with a distinct southwards change in spatial distributions (Figure B-6).

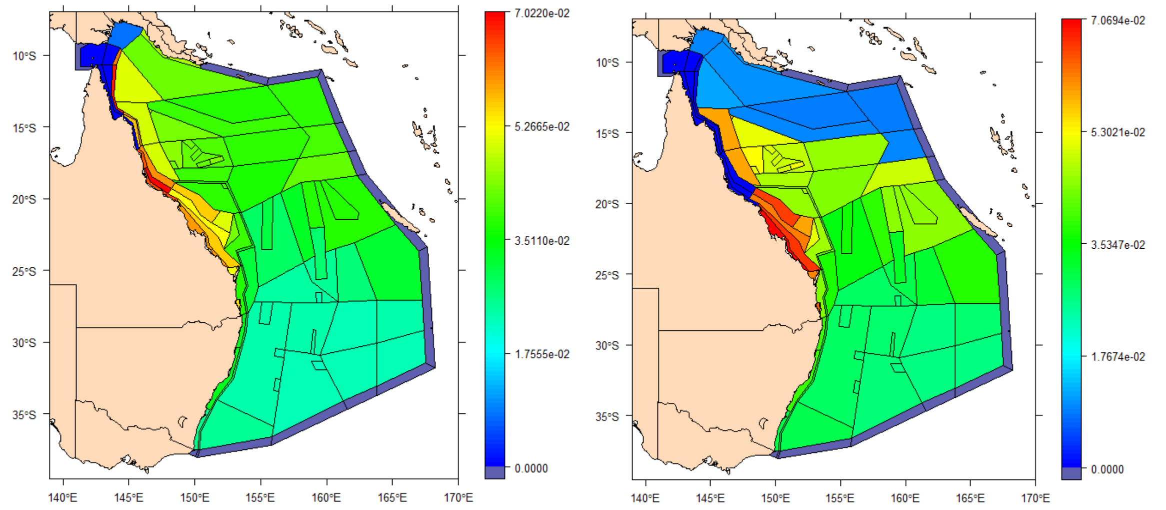
Group	Notes
Lancetfish	Increase of biomass for this group (>11%) with no discernible spatial effects.
Ocean pufferfish	Very small decrease of biomass for this group (<2.5%) with no discernible spatial effects.
Striped Marlin	Striped marlin show a large increase in predicted biomass (>14%) but with no clear spatial effect. Body size is projected to decline over time.
Yellowfin tuna	No changes.
Albacore tuna	Albacore increase in biomass by about 7% (with no discernible changes in spatial effects). Slight decline in body size projected over time.
Skipjack tuna	No overall biomass difference to control. Although observed changes in spatial distribution with large declines in the northern extent (Figure B-7).
Bigeye tuna	Very large increase in predicted biomass of Bigeye tuna (>50%) with patchy spatial distributional changes (Figure B-8).
Swordfish	Increase in biomass of Swordfish (>8%). With no clear spatial effects.
Benthopelagics (shallow seas)	Decrease in biomass of this group (>5.5%) with very clear shift from Northern regions of model domain.
Shallow demersal fish	Decrease in biomass of this group (<5%) with no clear spatial impacts of changes in climatic factors. Body size is projected to decline over time.
Deep demersal fish	Small increase (>4.5%) in biomass for deep demersal fish with no clear spatial changes in distribution. Body size is projected to decline over time.
Reef benthic fish (invertivores)	Small increase (>2.5%) of biomass in this group – no changes in spatial distribution (although fish only occur over reefs) although a slight decline in body size.
Reef herbivorous fish croppers	No changes.
Reef piscivorous fish	Increase (>7%) of biomass in this group – no changes in spatial distribution (although not clear to potentially observe given fish only occur over reefs).
Reef planktivorous fish	Small decrease (>3.5%) of biomass in this group – no changes in spatial distribution (although not clear to potentially observe given fish only occur over reefs).
Reef herbivorous scrappers	No changes.
Benthic sharks	Large increase in biomass for this group (>12%); however no clear change in spatial distribution of model predicted change in biomass due to climatic factors.
Pelagic sharks	No changes.
Mako and great whites	Large decrease in biomass for this group (>20%); however no clear change in spatial distribution of model predicted change in biomass due to climatic factors.
Whale sharks	Decrease in biomass predicted for whale sharks (>5%) with no clear spatial effects. Body size is projected to decline in adult whale sharks.
Turtles	Small increase in turtles (>4%) despite decline in jellies; however possibly due to increase in herbivorous turtles (due to increase in macrophytes). No clear spatial effects, although a clear projected decline in body size.
Seabirds	Decrease in biomass predicted for seabirds (>10%), particularly in the northern model extent (Figure B-9).
Whales	Decrease in biomass predicted for whales (>7%) with no clear spatial effects.
Dolphins	Decrease in biomass predicted for dolphins and small tooth whales (>7%) with clear southward spatial changes (Figure B-10).



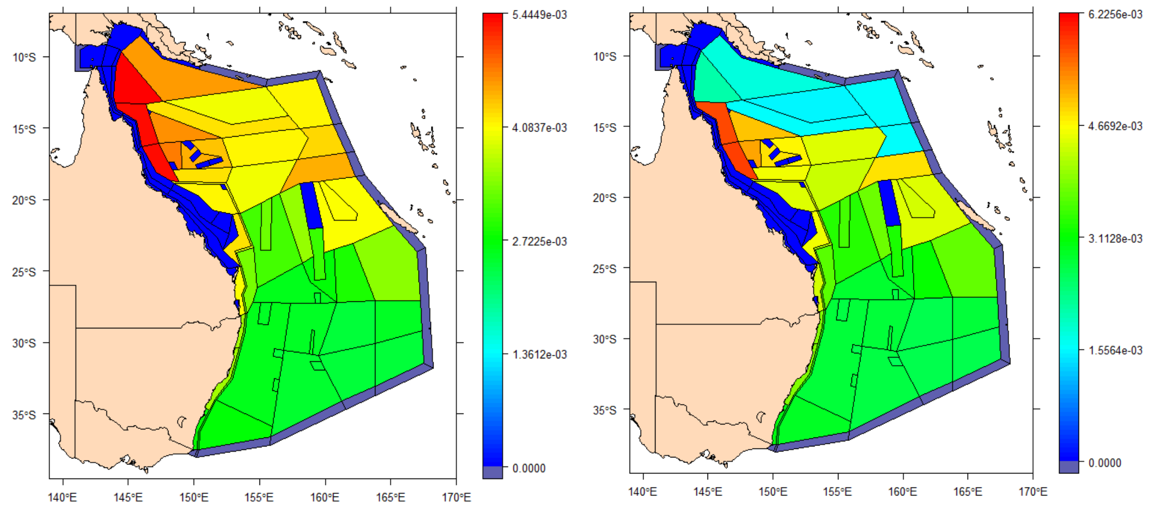
Appendix B Figure 3: The spatial distribution of mesopelagic squid (MES) for the Control (left panel) versus the RCP8.5 model run (right panel). The time period is for the end of a 40 year run (2015 forward projection 40 years – 2055).



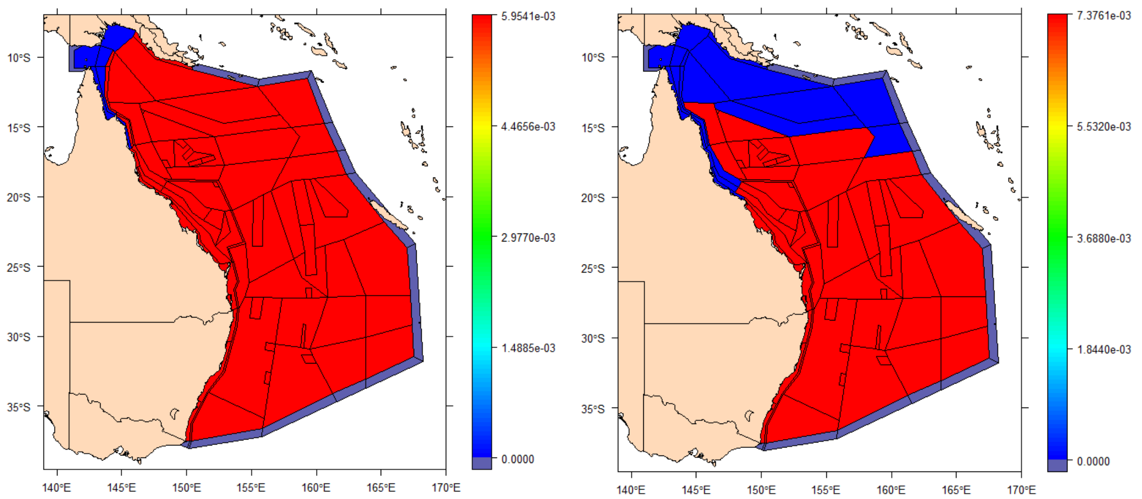
Appendix B Figure4: The spatial distribution of prawns (PWN) for the Control (left panel) versus the RCP8.5 model run (right panel). The time period is for the end of a 40 year run (2015 forward projection 40 years – 2055).



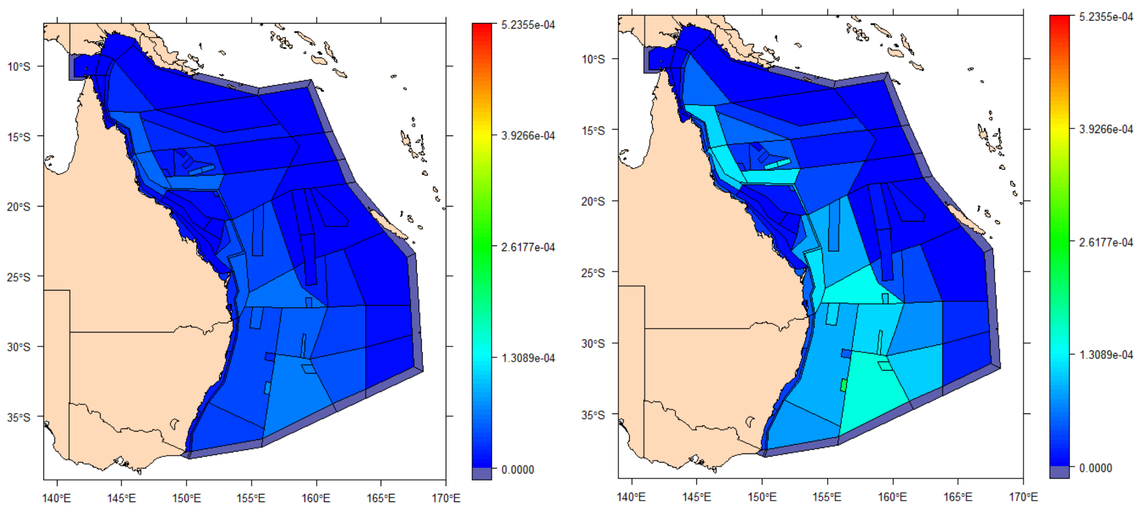
Appendix B Figure5: The spatial distribution of small planktivorous fish (FPS) for the Control (left panel) versus the RCP8.5 model run (right panel). The time period is for the end of a 40 year run (2015 forward projection 40 years – 2055).



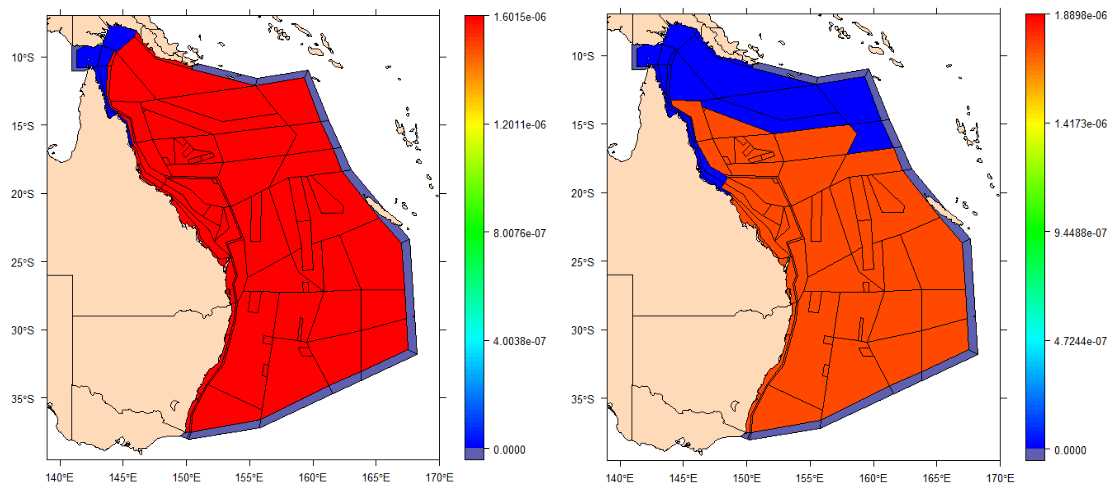
Appendix B Figure 6: The spatial distribution of driftfish (FBP) for the Control (left panel) versus the RCP8.5 model run (right panel). The time period is for the end of a 40 year run (2015 forward projection 40 years – 2055).



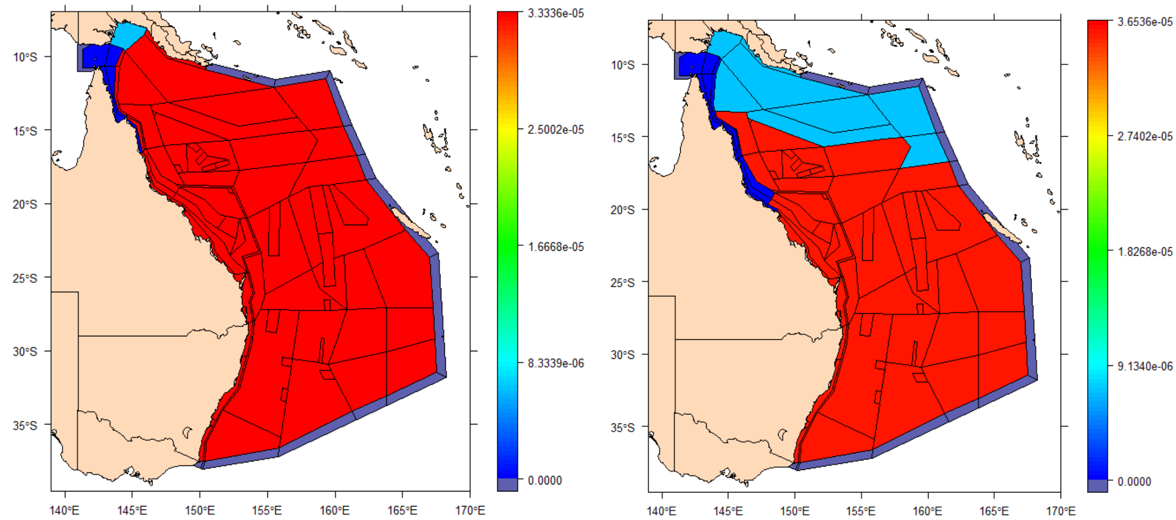
Appendix B Figure7: The spatial distribution of skipjack tuna (SKI) for the Control (left panel) versus the RCP8.5 model run (right panel). The time period is for the end of a 40 year run (2015 forward projection 40 years – 2055).



Appendix B Figure8: The spatial distribution of bigeye tuna (BIG) for the Control (left panel) versus the RCP8.5 model run (right panel). The time period is for the end of a 40 year run (2015 forward projection 40 years – 2055).



Appendix B Figure9: The spatial distribution of seabirds (SB) for the Control (left panel) versus the RCP8.5 model run (right panel). The time period is for the end of a 40 year run (2015 forward projection 40 years – 2055).



Appendix B Figure10: The spatial distribution of dolphins (WHS) for the Control (left panel) versus the RCP8.5 model run (right panel). The time period is for the end of a 40 year run (2015 forward projection 40 years – 2055).

Appendix B Table 8: Comparisons of CAAB distribution maps and map projections from the species distribution model. Blue = good, green = OK, cream/orange = wrong, clear = some discrepancies.

COMMON NAME	SPECIES	COMMENTS - distribution
Albacore tuna	*Thunnus alalunga*	OK, not in the N top section
Alfonsino	*Beryx splendens*	Overstated tropical distribution
Amberjack	*Seriola dumerili*	Incorrect, occurs on the west coast, and east coast (southern sections), potentially a better fit with *S.rivoliana* or *S. nigrofasciata* (amberjack)
Ark shell	*Tegillarca granosa*	Good, perhaps less extension on the SW and more SE
Asian blue swimmer crab	*Portunus pelagicus*	Too far south , only occurs in the gulf unless amartus and then Ok, but in the GAB and SE
Australian halibut	*Psettodes erumei*	Much further in the SW corner and half way down QLd
Australian herring	*Arripis georgianus*	Probably missing eastern extent
Australian Sardine	*Sardinops sagax*	Good
Banded bellowfish	*Centriscops humerosus*	Missing tasmania and shouldn't be in the bight - should be deepsea sp
Barracouta	*Thyrsites atun*	Good
Barramundi	*Lates calcarifer*	Good
Bartail flathead	*Platycephalus indicus*	Good, probably more further south on the east coast
Basking shark	*Cetorhinus maximus*	Good
Bigeye tuna	*Thunnus obesus*	OK, not in the N top section or in the bass strait
Bigeye trevally	*Caranx sexfasciatus*	Errors in the GAB and the west
Black deepsea cardinal fish	*Epigonus telescopus*	Should be throughout SE area, including tasmania
Black oreodory	*Allocyttus niger*	Truncated to just tasmania
Black pomfred	*Parastromateus niger*	Good
Blacklip and brownlip abalone	*Haliotis rubra*	Good, includes two sub-species
Blacktip rockcod	*Epinephelus fasciatus*	Good
Blue endeavour prawn	*Metapeeus endeavouri*	OK, extends further south on the east coast
Blue grenadier	*Macruronus novaezelandiae*	Good, up NSW a tiny bit further
Blue mackerel	*Scomber australasicus*	OK, missed the eastern coast
Blue shark	*Prioce glauca*	Not in NT area or the gulf of carpentaria, offshore species (outer reefs)
Blue Threadfin	*Eleutheronema tetradactylum*	Slightly overstates western extent

COMMON NAME	SPECIES	COMMENTS - distribution
Blue tiger prawn	*Penaeus monodon*	Broader distribution, down to exmouth and NWS
Blue warehou	*Seriolella brama*	OK, extends further west
Blueeye trevalla	*Hyperoglyphe antarctica*	Good, should go up to NSW and has gaps
Bluespot mullet	*Moolgarda seheli*	Good, should be Valamulgil seheli
Bream	*Acanthopagrus berda*	More of northern distribution
Bream	*Acanthopagrus latus*	Good, now A. morrisoni
Brier shark	*Deania calcea*	Southern deepwater - missing most of the southern extent
Bronze whaler	*Carcharhinus brachyurus*	Incorrect, got it as circum-australian when only temperate
Bullet tuna	*Auxis rochei*	Good
Camouflage Grouper	*Epinephelus polyphekadion*	Overstated in the SW areas and not in the GAB, QLD side good
Cobia, black kingfish	*Rachycentron canadum*	OK, but need to extend distribution to TAS
Comet Grouper	*Epinephelus morrhua*	Overdistributed in the western extent and guld of carpentaria
Coral rockcod	*Cephalopholis miniata*	Should only be tropical and subtropical
Ditchelee	*Pellona ditchela*	OK, not as far south on QLD
Dogtooth tuna	*Gymnosarda unicolor*	Good
Dorab wolf herring	*Chirocentrus dorab*	Good
Dusty whaler	*Carcharhinus obscurus*	Good
Eastern Australian salmon	*Arripis trutta*	OK, combined A.trutta and A.truttaceus (western Aust salmon)
Eastern Orange perch	*Lepidoperca pulchella*	OK could go a little further south
Eastern rock lobster	*Sagmariasus verreauxi*	Good, slightly further around the SW
Elephant fish	*Callorhinchus milii*	Good
Escolar	*Lepidocybium flavobrunneum*	Not in the north, but all around the south
False trevally	*Lactarius lactarius*	Good
Finny scade	*Megalaspis cordyla*	OK, externds slightly further south
Flat needlefish	*Ablennes hians*	Unlikely to be in the GAB
Flowery rockcod	*Epinephelus fuscoguttatus*	Good
Fouline striped Grunter	*Pelates quadrilineatus*	Not in the bight, further SE to sydney, not past exmouth
Frigate mackerel	*Auxis thazard*	May also be in the west
Frostfish	*Lepidopus caudatus*	Not in the north with gaps in the SE, only in the SE

COMMON NAME	SPECIES	COMMENTS - distribution
Frypan Brean	*Argyrops spinifer*	Good
Gemfish	*Rexea solandri*	Good, bit patchy
Giant mud crab	*Scylla serrata*	Not in the South or SW
Giant sea catfish	*Netuma thalassi*	Not in the south
Giant Trevally	*Caranx ignobilis*	Good, perhaps the southern extent is lobsisded
Golden trevally	*Gnathanodon speciosus*	OK, missing gaps
Golden snapper	*Lutjanus johnii*	OK, gabs in the N but not in NE coast
Green muscle	*Perna viridis*	Restricted to the NE corner cape
Greynurse shark	*Carcharias taurus*	Missing NSW coast. Should be cicrcumaustralia
Hapuku	*Polyprion oxygeneios*	Good
Imperador	*Beryx decadactylus*	Not tropical
Jack mackerel	*Trachurus declivis*	Should occur in southern half only
Jackass morwong	*Nemadactylus macropterus*	OK, but not in the NWS
John dory	*Zeus faber*	Incorrect, only southern distribution
Latchetfish	*Pterygotrigla polyommata*	OK, not that far NW
Longfin Mako	*Isurus paucus*	Not in the gulf and more on the edges - pelagic species
Longtail tuna	*Thunnus tonggol*	OK, extends slighty more to the S on the east coast
Luderick	*Girella tricuspidata*	Not as far to the west; perhaps combined with G. trucuspidata
Mackeral tuna	*Euthynnus affinis*	Good
Mahi mahi	*Coryphae hippurus*	Not in the central north and missing southern extent
Mangrove jack	*Lutjanus argentimaculatus*	OK, comes down the E coast more and not as far down the W
Morton bay bug	*Thenus orientalis*	Good
Mouth mackerel	*Rastrelliger kagurta*	Good
Northern bluefin tuna	*Thunnus orientalis*	OK, extends further south to tasmania
Oarfish	*Regalecus glesne*	Should be in all of southern areas
Oceanic whitetip	*Carcharhinus longimanus*	Not in the southern areas, shouldn't be in the GAB
Oilfish	*Ruvettus pretiosus*	Occurs in the NW and SE (including the GAB), could be erronous
Orange roughy	*Hoplostethus atlanticus*	Gaps in SE
Oxeye herring	*Megalops cyprinoides*	OK in the north, but extends further south - shallow sp (should be more

COMMON NAME	SPECIES	COMMENTS - distribution
		coastal)
Pelagic amourhead	*Pseudopentaceros richardsoni*	Not in the GAB
Pink ling	*Genypterus blacodes*	Too far NW, and needs more in the SE
Porbeagal shark	*Lamna nasus*	OK, too far north on the western and easter sides
Queenfish	*Scomberoides commersonnianus*	Good
Rankin cod	*Epinephelus multinotatus*	Missing SW and not in the gulf of carpentaria
Rays Bream	*Brama brama*	Incorrect - missing tasmania and suggesting tropical when not
Red bass	*Lutjanus bohar*	Not in the GAB or the west coast or the gulf of carpentaria - only occures on WN and SN coast
Red cod	*Pseudophycis bachus*	OK, not in western areas
Red Gurnard	*Chelidonichthys kumu*	Should only be temperate, very overstated
Redbait	*Emmelichthys nitidus nitidus*	Not in the tropics, should be a temperate species
Redspot emperor	*Lethrinus lentjan*	Good, slight gap in SN QLD
Ribaldo	*Mora moro*	Should be throughout south, not in the north
Ribbonfish	*Trichiurus lepturus*	Should occur in the south only
Rusty jobfish	*Aphareus rutilans*	Tropical but distribution might be overstatted
Sailfish	*Istiophorus platypterus*	Good, coculd come a little further south to the corners
Sardinella	*Sardinella lemuru*	Ok, not on the NWS
Scalloped hammerhead	*Sphyrna lewini*	Northern distribution
School shark	*Galeorhinus galeus*	Too far NW, and needs more in the SE
Sea mullet	*Mugil cephalus*	Not in the norther parts, including the gulf - shallow coastal species
seven gill shark	*Notorynchus cepedianus*	Should be in the SW area also
Shad	*Anodontostoma chacunda*	Good
Shortbilled spearfish	*Tetrapturus angustirostris*	Not in the N or SE (Tas) parts of Aust, occurs in the GAB and SW, n
Silver Javelin	*Pomadasys argenteus*	OK, should come around more to the south on the east coast
Silver Trevally	*Pseudocaranx dentex*	OK, not so far SN; should be P. georgianus
Silver warehou	*Seriolella punctata*	More contracted distribution, not in the western areas of the bight
Skipjack	*Katsuwonus pelamis*	Good, but should go in the gulf of carpentaria
Skipky oreodory	*Neocyttus rhomboidalis*	Good, just missing a few gaps

COMMON NAME	SPECIES	COMMENTS - distribution
Smooth hammerhead	*Sphyrna zygae*	Not northern distribution, N of 20
Smooth Oreodory	*Pseudocyttus maculatus*	OK, too far on the W coast
Snapper	*Pagrus auratus*	SW/SE temperate + S QLD; Chyroshys aurus
Southern bluefin tuna	*Thunnus maccoyii*	OK, further NW and not so on the SE
Southern rock lobster	*Jasus edwardsii*	Good, could go up a bit on the NW coast
Spanish mackerel	*Scomberomorus commerson*	OK, few gaps in the SE
Spottail shark	*Carcharhinus sorrah*	Good
Spurdog	*Squalus acanthias*	Missing GAB and gaps in SE
Striped Marlin	*Kajikia audax*	Incorrect, all around Aaust except the northern extent - pelagic , not shallow
Sunfish	*Mola mola*	Opposite - should be in the whole of the south only
Swordfish	*Xiphias gladius*	Not in the norther central areas, also off Tasmania
Tailor	*Pomatomus saltatrix*	Southern distribution (temperate species)
Teraglin	*Atractoscion aequidens*	Incorrect, should be eastern temperate
Thresher sharks	*Alopias vulpinus*	OK; combined two or more species (A. pelagicus and vulpinus in particular)
Tiger prawn	*Penaeus semisulcatus*	Good
Tiger shark	*Galeocerdo cuvier*	Not in the GAB
Toothed whiptail	*Lepidorhynchus denticulatus*	Missing bits along NSW
Turrum	*Carangoides fulvoguttatus*	Good - might be missing western subtropical extent
Violet cod	*Antimora rostrata*	Unlikely to be in the tropics
Western king prawn	*Melicertus latisulcatus*	OK, needs to extend further south
Western rock lobster	*Panulirus cygnus*	OK, little further into bight
White Banana prawn	*Fenneropeeus merguiensis*	Good, different genus - *penaeus merguiensis*
Yellow edge coronation trout	*Variola louti*	Only in E QLD and NSW and western central area
Yellowfin tuna	*Thunnus albacares*	OK, not in the gulf of carpentaria and not in the GAB
Yellowtail kingfish	*Seriola lalandi*	Incorrect, should have a southern distribution; better fit with S. rivoliana or Seriolina nigrofasciata (amberjack)
	Hilsa kelee	Not an Australian species

COMMON NAME	SPECIES	COMMENTS - distribution
	Paratrachichthys trailli	Not an Australian species; *Aulotranchicthys novazelandius* seems like a OK fit

Appendix C *Regional model output – all groups*

See separate pdf document – required due to size of the output being presented.

Appendix D *Global model output – all groups*

See separate pdf document – required due to size of the output being presented.

Appendix E *Project Staff*

The participating researchers were:

Beth Fulton (CSIRO)

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William Cheung (UBC)

Julia Blanchard (UTAS)

Gretta Pecl (UTAS)

Cecilia Villanueva (UTAS)

Primary AFMA liason: Ian Butler

Appendix F *Intellectural Property*

All models and sensitivity assessments were created prior to the project, only data updating and projections were run for this project.

Majority intellectual property owners are as follows

Sensitivity analysis – CSIRO, UTAS, FRDC as per the supporting agreement for the SEAP project, and the original principal investigators for this work (David Welch, Nick Caputi and Gretta Pecl).

Atlantis software – CSIRO

Ecoath with Ecosim software – Unversity of British Columbia

Species distribution models – Unversity of British Columbia, William Cheung

Size-based models – University of Tasmania, Julia Blanchard

FRDC FINAL REPORT CHECKLIST

Project Title:	Decadal scale projection of changes in Australian fisheries stocks under climate change.
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Project Number:	2016/139
Description:	Australia's oceans are undergoing rapid change and changes in fish distribution, abundance and phenology have been widely reported. A first step in ensuring that the fisheries of Australia adapt effectively to climate change is an understanding of the historical and projected changes in the species captured. This information will underpin development of industry and management responses and management systems that will allow negative impacts to be mitigated and opportunities that arise to be seized. This project takes two approaches to understanding climate impacts on species that are captured in Australian fisheries - species sensitivity analysis (Part 1) and ecosystem modelling based on new climate projections (Part 2). Species level responses for each of the Commonwealth fisheries are detailed in both sections, followed by a concluding synthesis and list of recommendations (Part 3). The main objectives of the study were to: 1. Update CSIRO-held Australian ecosystem models with the system status information and the latest climate impacts information. 2. Run ecosystem projections out to 2050 using the latest Ocean Forecasting Australia Models (i.e. latest physical projections), noting ecosystem and species level effects at 5 or 10 year intervals/averages. 3. Distil the fine scale (where possible species level) projections for the Australian Commonwealth fisheries. 4. Provide advice on (i) likely impacts of climate in the short, medium and long term; and (ii) information gaps and priorities for tracking climate impacts on individual fisheries.

Published Date:	20/05/2018 (if applicable)	**Year:**	2018
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Key Words:	Sensitivity analysis, Vulnerability, Ecosystem modelling, Climate change, climate variability, Adaptive management		

Please use this checklist to self-assess your report before submitting to FRDC. Checklist should accompany the report.

	Is it included (Y/N)	Comments
Foreword (optional)	N	Fact sheets instead
Acknowledgments	Y	
Abbreviations	N	

Executive Summary	Y	
− **What the report is about**		
− **Background – why project was undertaken**		
− **Aims/objectives – what you wanted to achieve at the beginning**		
− **Methodology – outline how you did the project**		
− **Results/key findings – this should outline what you found or key results**		
− **Implications for relevant stakeholders**		
− **Recommendations**		
Introduction	Y	
Objectives	Y	
Methodology	Y	
Results	Y	
Discussion	Y	
Conclusion	Y	
Implications	Y	
Recommendations	Y	
Further development	Y	
Extension and Adoption	Y	
Project coverage	Y	
Glossary	N	
Project materials developed	Y	
Appendices	Y	