Australia's National
Science Agency

Appendix: Summary of Commonwealth Fishery Climate Sensitivity

Qualitative evaluation of climate sensitivity and exposure

September 2020

Initial assessment of the biophysical climate sensitivity of fisheries managed by the Australian Fisheries Management Authority (AFMA)

This appendix summarises the exposure of AFMA managed fisheries to ecologically mediated climate change effects. The assessment was undertaken in 2020 based on best available information at the time, including:

- Expected trajectories of climate change (temperature, pH, oxygen, salinity, rainfall) as projected by (a) the modified Ocean Forecasting Australia Model version 3 (OFAM-v3) from the CSIRO Ocean Downscaling Strategic Project (and as reported in Fulton et al. 2018), which specifically focuses on fine scale ocean environment around Australia; and (b) the Australian region of the ensemble of climate model outputs available from the latest Coupled Model Intercomparison Project (CMIP6), which will inform the upcoming 2021 IPCC sixth assessment report (AR6)
- Extreme events projections made by Oliver et al. (2018)
- Biomass trajectories from species distribution models and various ecosystem models (as reported in Fulton et al. 2018); and
- Climate sensitivity assessments following the method of Pecl et al. (2014) applied to all species currently listed in the Ecological Risk Assessment (ERA) level 2 productivity-susceptibility analysis for each fishery. Where species had been previously assessed (i.e. those species reported in the appendices of Fulton et al. 2018) the extant assessments were used. Where the sensitivity of a species had not previously been assessed an automated assessment was carried out using the criteria listed in Table 1-1 of Fulton et al. (2018) and the attribute values used in the ERAs.

As many species had missing attributes an assessment wasn't possible for all species. Reporting focuses on those species with both estimated sensitivities and projections. For some fisheries (e.g. Norfolk Is) projections were not available for all/many species so only sensitivities were included. Where many species (e.g. sharks) with similar life history had matching sensitivities and projections of the same magnitude and direction these were pooled for the purposes of reporting.

Initial management/research suggestions have been made for each fishery based on the sensitivities and projections. These are by intent high level because greater elaboration of the adaptation options and what needs to be done to support that is a product of the kind of fisheries specific process (involving people from those fisheries) as outlined in the *Adaptation Handbook*. The purpose of these tables is to provide a quick summary of the exposure of the individual fisheries to help AFMA's understanding and prioritisation process. The fishery level summary of sensitivity is provided in Table A-1 and a more detailed list per fishery is given in Table A-2.

Table A-1: High level summary of climate sensitivity rating of AFMA, see Table A-2 for more details. The summary provides the breakdown per fishery of the proportion of the target, byproduct, bycatch and TEPS classified to each climate sensitivity level; the summary also indicates the proportion of groups per type of projected change.

			Sensitivity			Projected Change					
Fishery	**Species type**	**Dominant response**	**High**	**Medium**	**Low**	**Decrease**	**Steady**	**Uncert.**	**Variable**	**Increase**	**NA**
Coral Sea	Target	▼	0.46	0.31	0.33	0.92	0.04	-	-	0.04	-
	Byprod.	-	-	-	-	-	-	-	-	-	-
	Bycatch	▼	0.5	0.5	-	1	-	-	-	-	-
	TEPS	▼	0.6	0.4	-	0.6	-	-	-	0.2	0.2
Eastern Tuna and Billfish	Target	▼	0.22	0.33	0.45	0.67	0.11	-	-	0.22	-
	Byprod.	▼	0.27	0.73	-	0.82	0.09	-	-	0.09	-
	Bycatch	▼	0.15	0.62	0.23	0.54	0.08	-	0.08	0.3	-
	TEPS	▼	0.75	0.25	-	0.5	-	-	0.25	0.25	-
Heard Is., Macquarie Is.	Target	▼	-	0.5	0.5	1	-	-	-	-	-
	Byprod.	▼	-	0.75	0.25	1	-	-	-	-	0.25
	Bycatch	-	-	-	-	-	-	-	-	-	-
	TEPS	▼	0.75	0.25	-	0.63	-	-	-	0.38	-
Norfolk Is.	Target		-	1	-	-	-	-	-	-	1
	Byprod.		0.14	0.14	0.72	0.21	-	-	0.21	-	0.58
	Bycatch	▼	0.4	0.4	0.2	0.8	-	-	-	-	0.2
	TEPS		1	-	-	-	-	-	-	-	1
Northern Prawn	Target	▼	-	1	-	0.75	0.25	-	-	-	-
	Byprod.	▼	0.56	0.11	0.33	0.67	0.22	-	-	-	0.11
	Bycatch	▼	0.57	0.14	0.29	0.71	0.29	-	-	-	-
	TEPS	▼	0.72	0.14	0.14	0.72	-	-	0.14	0.14	-
Northwest Trawl	Target	Steady	-	1	-	-	1	-	-	-	-
	Byprod.	▼	0.29	0.42	0.29	0.57	-	-	-	0.14	0.29
	Bycatch	▼	1	-	-	1	-	-	-	-	-
	TEPS	▼	0.88	0.12	-	0.63	-	-	-	0.13	0.24
Southern Bluefin Tuna	Target	Uncert.	-	0.4	0.6	0.2	-	0.3	0.3	0.1	0.1
	Byprod.	▼	0.2	0.6	0.2	0.8	0.2	-	-	-	-
	Bycatch	▼	0.67	0.33	-	1	-	-	-	-	-
	TEPS	▼ ▲	1	-	-	0.5	-	-	-	0.5	-
Scallop	Target	Variable	-	1	-	-	-	-	1	-	-
	Byprod.	Uncert.	-	-	1	0.17	-	0.33	-	0.17	0.33
	Bycatch	Mixed	0.33	0.33	0.34	0.33	-	0.33	-	-	0.34
	TEPS	Mixed	1	-	-	0.4	-	-	0.4	0.2	-
SESSF	Target	Variable	0.09	0.26	0.65	0.3	-	0.05	0.35	0.17	0.13
	Byprod.	▼	0.23	0.27	0.5	0.68	0.08	0.04	0.12	0.08	-
	Bycatch	▼	0.27	0.31	0.42	0.69	0.04	-	0.12	0.15	-
	TEPS	▼	1	-	-	0.56	-	-	0.22	0.22	-
Skipjack	Target	▼	1	-	-	1	-	-	-	-	-
	Byprod.	▼	0.2	0.48	0.32	0.68	0.16	0.04	0.08	0.04	-
	Bycatch	Mixed	0.5	-	0.5	0.5	-	-	-	0.5	-
	TEPS	▲	1	-	-	0.25	-	-	0.25	0.5	-
Small Pelagics	Target		-	0.4	0.6	0.8	0.4	-	-	-	-
	Byprod.	▼	-	0.5	0.5	0.63	0.25	-	0.13	-	-
	Bycatch	▼	-	1	-	1	-	-	-	-	-
	TEPS	▼	1	-	-	0.5	0.17	-	-	0.33	-
Squid jig	Target	Uncert.	-	-	1	-	-	1	-	-	-
	Byprod.	▼	-	0.5	0.5	1	-	-	-	-	-
	Bycatch	Variable	1	-	-	-	-	-	1	-	-
	TEPS	Mixed	1	-	-	0.33	-	-	0.33	0.34	-

			Sensitivity			Projected Change					
Fishery	**Species type**	**Dominant response**	**High**	**Medium**	**Low**	**Decrease**	**Steady**	**Uncertain**	**Variable**	**Increase**	**NA**
Torres Strait	Target	Mixed	0.33	0.67	1	0.33	-	0.33	0.34	-	-
	Byprod.	Steady	-	1	-	-	1	-	-	-	-
	Bycatch	▼	0.75	0.25		0.5	0.25	-	0.25	-	-
	TEPS	Mixed	1	-	-	0.33	-	-	0.33	0.34	-
Western deepwater trawl	Target	▼	0.21	0.36	0.43	0.43	0.07	-	0.5	-	-
	Byprod.	▼	0.21	0.36	0.43	0.93	0.04	-	-	0.04	-
	Bycatch	▼	0.33	0.67	-	1	-	-	-	-	-
	TEPS	▼	1	-	-	1	-	-	-	-	-
Western tuna and billfish**	Target	Mixed	0.5	0.25	0.25	0.5	-	-	0.5	-	-
	Byprod.	▼	0.13	0.54	0.33	0.83	-	-	0.17	-	-
	Bycatch	▼	1	-	-	1	-	-	-	-	-
	TEPS	Variable	1	-	-	0.17	-	-	0.5	0.33	-

** Includes Christmas Island and Cocos Island fisheries

Table A-2: Climate sensitivity rating of AFMA managed fisheries – this shows ecological sensitivity (using Pecl et al. 2014 method), information on projections of direction of change comes from Fulton et al. (2018). Note that the key for the colour coding is:

Sensitivity	Low	Medium	High		**Confidence**	Low	Low-Med	Medium	High	Not Available

Fishery	**Species**	**Sensitivity**	**Preliminary projection**	**Confidence in projection**	**Comments on projection**	**Recommendations**
Coral Sea	Redfish, Blackfish, Stonefish, Teatfish, Sandfish, Lollyfish (all Holothurians)		▼ 10-20%		Food web interactions may see some increases (depending on changes in predator and competitor abundance locally). Deeper water species potentially more sensitive.	Respond as abundance impacted (monitoring required). Check rotational approach is still working.
	Tropical Rock Lobster		▼ 20-40%		Food web interactions can allow for increases in some circumstances. SST can amplify sensitivity.	Climate aware assessments and quota management system, targeted research to reduce uncertainty.
	Coral Trout(s)		▼ 10-25%		Food web interactions will complicate responses. Reduced catchability possible due to storms. Spawning may shift temporally. Declines likely strongest in shallower waters.	Require climate aware assessments and quota management system.
	Alfonsino		▼ 20%		Decline uniform spatially.	
	Giant Trevally		▼ 15%		Decline most in shallow waters around islands.	
	Bigeye Trevally		▲ 20%		Increase uniform spatially.	
	Golden Trevally		▼ 20%		Decline more to the margins of the region.	
	Surgeonfish		▼ 5- 40%			
	Damsels		▼ 5- 40%			
	Anemonefish		▼ 5- 40%			
	Angelfish		▼ 5- 40%			
	Butterflyfish		▼ 5- 40%			
	Wrasse and Pigfish		▼ 5- 20%			
	Gobies		▼ 5- 20%			
	Goatfish and Rabbitfish		▼ 5- 20%			
	Parrotfish		▼ 5- 25%			
	Ray's Bream		▼ 10%			

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
	Blacktip Rockcod		▼ 40%		Decline more in the north and around islands.	
	Flowery Rockcod		Steady		Relatively uniform, but stronger decline in shallows around islands.	
Coral Sea	Coral Rockcod		▼ 15%		Decline uniform spatially.	Reference points and catch limits may need to be adjusted if climate impacts stock. Use trigger points (make these more conservative when shallow water and habitat dependent).
	Camouflage Grouper		▼ 10%		Decline uniform spatially.	
	Emperor and Snapper		▼ 20- 60%			
	Moray Eels		▼ 5- 40%			
	Pipefish		▼ 20- 40%			
	Seasnakes		NA			
	Seabirds		▼ up to 10%			
	Bronze Whaler		▼ 50%			
	Tiger Shark		▼ 10%		Decline more in the north and around islands.	
	Thresher Shark		▼ 10%		Patchy, declines larger in north and shallow waters.	
	Turtles		▼ 5-10%		Declines stronger if lose nesting sites.	
	Whales and dolphins		▲ up to 20%			
Eastern Tuna & Billfish	Striped Marlin		▼ up to 5%			Climate aware assessments and reference points for target and byproduct species. Track spatial extent, review zoning to ensure still delivering on objectives.
	Albacore		▼ 20-25%		Fairly uniform, move on shelf at southern extent.	
	Yellowfin Tuna		▼ 5-15%		Decline uniform spatially.	
	Bigeye Tuna		Steady		Food web interactions can cause a drop (by 60%).	
	Broadbill Swordfish		▼ 5-60%		Larger drops in some areas due to food web changes; strongest declines at the northern extent.	
	Blue Mackerel (bait)		▲ up to 30%		Decline uniform spatially.	
	Jack Mackerel (bait)		▼ 10%		Decline uniform spatially.	

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
	Yellowtail Scad (bait)		▲ up to 200%			
	Southern Bluefin Tuna		▼ 30-40%		Decline more in north, overlap more with tropical tunas.	
	Skipjack Tuna		▲ up to 20%		Spatially uniform.	
	Ray's Bream		▼ 10%			
	Escolar		▼ 10%		Decline uniform spatially.	
Eastern Tuna & Billfish	Oilfish		▼ up to 50%		Decline uniform spatially.	
	Yellowtail Kingfish		▼ 10-20%			
	Shortbill Spearfish		▼ 5%			
	Pacific Northern Bluefin		Steady		Decline along southern edge of extent, increase in the Coral Sea.	
	Mahi		▼ up to 50%		Decline strongest in the north.	
	Rusty Jobfish		▼ 10%		Spatially uniform.	
	Frigate Mackerel		Steady		Spatially uniform.	
	Bigeye Trevally		▲ up to 30%		Spatially uniform.	
	Dorab Wolf Herring		▼ 15%		Decline uniform spatially.	
	Mackerel Tuna		▲ 10%		Spatially uniform.	
	Dogtooth Tuna		▼ 10%		Spatially uniform.	
	Long-tail Tuna		▲ 20%		Decline strongest in the north.	
	Spanish Mackerel		Uncertain		From ▼ 50% to ▲ 5% (food web dependent).	
	Ocean Sunfish		▼ 10%		Decline strongest in the south.	
	Barracouta		▼ 10%		Spatially uniform.	
	Blue Shark		▼ 20%		Decline uniform spatially.	
	Tiger Shark		▼ 10%		Patchy, decline strongest in the north.	
	Whalers (sharks)		▼ up to 20-50%		Decline strongest in the north.	
	Oceanic Whitetip Shark		▼ 10%		Decline uniform spatially.	
	Brier Sshark		▲ up to 20%		Range contracts, especially off Tasmania and NSW.	
	Hammerhead Sharks		▼ 10-20%		Spatially uniform.	
	Shortfin Mako		▼ up to 40%			
	Turtles		▼ 20-80%			

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
	Dolphins and Toothed whales		▲ up to 20%			
	Seabirds		Uncertain		Steady to ▼ 60% (food web dependent).	
Heard Is., Macquarie Is.	Patagonian Toothfish		▼ up to 20-60%		Sea ice season decreasing. Marine heat waves occur on the plateau at a frequency consistent with other regions - so as much as 200 more days that are 2°C hotter than historically. Catchability could be affected.	Climate aware reference points and assessment. Operational and multi-year forecasts beneficial (so can redirect resources/effort in poor condition years).
Heard Is., Macquarie Is.	Mackerel Icefish		▼ 20%			As for Patagonian toothfish, redirect targeting to this species if it is less effected.
	Squid		▼ 15%			Squids might be good alternative target species, but phenology may be an issue.
	Lanternfish		▼ 5%			If phenology and processing technology (for mesopelagics) not a constraint then fishing mesopelagics/lanternfish may be an option, but economics may be questionable.
	Morid Cod		▼ 15-20%			
	Ribaldo		▼ 15-20%			Possible alternative target.
	Whiptails		▼ 15-20%			Possible alternative target.
	Oreos		▼ 15-20%			Possible alternative target.
	Skates		NA			
	Southern Lantern Shark		NA			
	Penguins		▼ 20%			
	Albatross		▼ 20%			
	Petrels		▼ 20%			

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
	Baleen whales		▲ 15%			TEP interactions could increase.
	Orcas		▲ 5-10%			Depredation could increase.
	Other toothed whales		▲ 15-20%			Depredation could decrease.
	Elephant Seals		▼ 25%		Dive patterns change due to salinity and changes in mesopelagic forage.	
	Other seals		▼ 25%			
Norfolk Island	Bight Redfish		NA			Inshore fishery so likely to be affected. If fishery grows will need to be pay attention to climate effects on reference points and implications for effectiveness of zoning.
	Red Gurnard		▼ 40%		Patchy, decline steeper in shallower waters.	
	Snapper		NA			
	Tusk		NA			
	Pink Ling		▼ 10-20%		Spatially uniform.	
	Ocean Perch		NA			
Norfolk Island	Blue Grenadier		Uncertain		▼ 15% through to ▲ 60%. Spatially uniform.	
	Ribaldo		Uncertain		▼ >50% through to ▲ 10+%. Spatially uniform.	
	Knifejaw		NA			
	Hapuku		NA			
	Latchet		NA			
	Gemfish		Uncertain		▼ 20% through to ▲ 10%. Spatially uniform.	
	Jackass Morwong		▼ up to 20%		Patchy but decline more in the northern extent of the fishery.	
	Blue Morwong		NA			
	Alfonsino		▼ 15-20%		Spatially uniform.	
	Elephantfish		▼ 5-20%		Patchy, decline steeper in shallower waters.	
	Pipefish		NA			
	Sawshark		NA			
	Whiptails		NA			
	Dogfish		▼ 40%			
	Skates		▼ 20%			
	Fur Seals		NA			
	Shearwaters		NA			

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
Northern Prawn	Banana Prawns		▼ 10%		Higher with variable rainfall, mangrove loss or dammed river flow. Decrease across the NPF, but especially the Gulf. Mangrove inundation expected to be most severe along southern gulf (as in 2016).	May need to move the dividing line to 140°E. May need changed (CPUE) reference points (climate aware) and shift to "frame based" management to account for projected high interannual variability with rainfall and mangrove die-offs.
	Endeavour Prawn		▼ >20%		Decline across the board, especially in northern extent of the NPF.	May need additional closures given differential distribution of projected declines.
	King Prawns		Steady		Potential for a decline in the centre and south.	CPUE thresholds (i.e. reference points) may need to be adjusted through time.
Northern Prawn	Tiger Prawns		Variable ▼ 10-20%		Food web interactions and seagrass health affect makes it uncertain. Variable due to rainfall influences (through salinity and plumes), major declines and high variability possible with extreme rainfall events/storms if dams do not buffer the level of the flows - this could affect both abundance and catchability. General decrease but potentially smaller impact in central gulf, or NW extent of NPF. Potential shift in timing of spawning etc due to changes in SST.	If rainfall related variability increases (and new dams do not prevent river flow) then 'frame based management' may be needed. May need to adjust the dividing line (to 140°), but (CPUE) reference points might need adjustment.
	Bug		▼ 15%		General decline, but especially around the eastern and southern gulf coasts, islands and off Groote and in the NT. Mangrove inundation expected to be most severe along southern gulf (as in 2016).	May need introduction of spatial management and adjusted (climate aware) reference points.
	Lobster		▼ 20%		Trophic interactions may moderate declines, but acidification could amplify them. Change	Climate aware reference points and assessments.

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
					in timing of spawning and movements due to changes in SST.	
	Mud crab		▼ 10%		Food web interactions cause uncertainty. Higher with variable rainfall, mangrove loss or dammed river flow. Declines across the Gulf and western end of NPF (i.e. NT end).	May need trip limit adjustment and 'frame-based management' (to account for variability due to rainfall and mangrove die-off – if northern dams put in so river flow always constrained then permanent change needed). Potentially need additional spatial management if sub-populations are to be protected.
	Cuttlefish		▼ <10%			
	Squid		Steady			
	School Mackerel		NA			
	Trevally		Steady			
Northern Prawn	Longtail tuna		Steady			
	Cobia		Steady		Decline in central gulf offset elsewhere.	
	Cods and Emperor		▼ 10-20%		Estuarine species status depends on river flow. Trophic interactions may moderate declines. General decrease but less extreme in central gulf, more extreme along coasts and especially in the north and west (e.g. off Groote).	May need trip limit adjustment. In hotspot locations, where decline particularly strong (e.g. in the western Gulf) spatial zones (closures) may be necessary.
	Rock Cods		▼ 15%		Trophic interactions may moderate declines. Catchability may be reduced (storms). Potential shifts in time of spawning due to SST changes. Bigger impact along the coastlines.	
	Mangrove Jack		▼ 20%		Dependent on river flow.	

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
	Spanish Mackerel		▼ <10%		Any potential decline occurs throughout the fishery.	
	Rays		▼ 10-25%			
	Sawfish		▼ 10-15%			
	Sharks		▼ 10-30%		General decrease but especially in the northern gulf and shallowest waters.	
	Sea Snakes		Uncertain		▼ up to 30% but also ▲ up to 30%.	
	Dugong		▼ 15%			Awareness program of climate effects.
	Dolphins		▼ 10-20%			
	Crocodiles		▲ >10%			
	Turtles		▼ 10-30%		Turtles could see collapse through egg inundation.	
	Seabirds		▼ 15-30%			
Northwest Trawl	Scampi		Steady			Track catch rates, trigger check if landings change significantly. Check spatial zoning still in the correct location to achieve objectives.
	Snapper		▼ 10%		Uncertain as food web interactions could see an increase instead. Shifts spatially uniform.	
	Stargazers		NA			
	Bight Redfish		▼ up to 20%			
	Elephantfish		▼ 10%		Patchy, but stronger to the north.	
	Chimeras		NA			
	Crabs		▲ 10%			
	Jack Mackerel		▼ 15%		Spatially uniform.	
	Pipefish and Seahorses		NA			
	Sharks		▼ up to 40%		Declines strongest in the north.	
Northwest Trawl	Sea snakes		NA			
	Turtles		▼ 50%			
	Dugong		▼ 25%			
	Dolphins		▼ 10-20%			
	Whales		▲ 15%			
	Seabirds		▼ 15-30%			
Southern Bluefin	Southern Bluefin Tuna		With no major change in recruitment		Possible for short term increases in biomass before decline. Projected decline begins in central GAB/Eyre peninsular and spreads increasingly offshore and to west. Bonney	Already familiar with dynamic ocean zone declaration and forecasts being used to help direct

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
			▼ > 10-20%, otherwise substantial declines possible		Upwelling area and through Bass Strait doesn't see much change. 100% drop in biomass projected in tropical areas (including the spawning area). Declines of up to 20-40% projected along the WA coast. Finding fish may be more difficult as in new locations. Acidification unlikely to impact larvae until later in the century. Temperature increases & lowered oxygen availability may result in: • increased parasite infection (requiring improved control measures); • increased fouling organisms on sea cages (requiring more frequent cleaning); • increased damage to mooring and sea cages; • potential for changed growth rates or product quality (may need to shift cade location, with associated logistics costs); • increased harmful algal blooms; • location of spawning site may shift, uncertain implications for juvenile movements; • potential for a shift in timing of spawning (or contraction/splitting of season), implications for timing of arrival of species in Australia waters.	where to fish. That will become more important into the future. Aquaculture practices may need to change (as likely already realise), though this will require carrying more costs or developing new technologies - future on shared offshore platforms? Changes in SBT availability may require updated resources sharing discussion between Commercial/recreational and traditional fishers. Modelling of implications of potential shift in spawning location or timing is a simple first step to considering implications of climate impacts in depth.
Southern Bluefin	Tommy Rough		Higher variability		Patchy, may increase in Victoria, decrease in central GAB.	
	Redbait (feed)		Uncertain		Increased variability, increases possible under light exploitation, declines under heavy exploitation (especially in the GAB).	May need to change catch limits if declines really occur.
	Australian Anchovy (feed)		▲ up to 30-60%			

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
	Sardine (feed)		Variable		50% ▼ in poor years, 20% ▲ up in good years. Spatially uniform.	
	Yellowtail Scad (feed)		Variable			
	Silver Trevally		▼ >20%		Decline strongest in central and eastern GAB, weaker decline in the west.	
	Skipjack Trevally		NA			
	Blue Mackerel (feed)		Uncertain. ▼ >20%, up to ▲ 200%		Declines at northern and western edges of distribution (especially off new south wales and from mid GAB and west). Short term increases in eastern GAB and off Tasmania.	Bring environmental correlate into quota rules and spatial zoning (optimise benefit from increases, buffer declines).
	Jack Mackerel (feed)		Uncertain. ▼ >10-25%, up to ▲ 200%		Spatially uniform.	Bring environmental correlate into quota rules and spatial zoning (optimise benefit from increases, buffer declines).
	Australian Salmon		▼ <10-40%		Spatially uniform decline.	
	Skipjack Tuna		▼ <10%		In some instances, do not decline, but hold steady. When decline generally evenly spatially distributed, but can have particularly strong declines in Bonney upwelling area depending on whether the upwelling weakens.	If trying to avoid then need good bycatch monitoring or environmental modelling to advise where to avoid.
	Albacore		▼ 10%		Not much change throughout most of the area, but strong increases along the outer shelf/shelf break from Victoria to Tasmania.	
	Yellowfin Tuna		▼ <10%		Possibility of localised hotspots on southern coasts (South Australia and Victoria).	
	Bigeye Tuna		Steady		In SBT area generally holds steady, but with localised decline off eastern Tas and increase in Tasman Sea.	
	Marlin		▼ <10%			
Southern Bluefin	Broadbill Swordfish		▼ <10%		Strong decline in Bonney upwelling, eastern GAB and coastal central GAB; increases offshore, in western GAB/WA, off western	

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
					Tasmania and Victoria, with increases (up to 10%) in Bass Strait and Tasman Sea.	
	Sharks		▼ >10-20%		General decline, but strongest in central GAB OR off Tasmania/Victoria (depending on the species).	Concern over TEP interactions to consider.
	Fur Seals		▲ 150+%		Strong increase in short term, but localised declines possible.	AFMA will need to be aware interactions more likely (given TEP sensitivities despite being large population size).
	Seabirds		▼ up to 60%		Strength of change dependent on food web.	
	Whales		▲ up to 40%		Short term increases likely (recovering from past exploitation), but can be reversed depending on summer forage in the Antarctic.	
Scallop	Commercial Scallop		Uncertain		▼ 20-25% but food web interactions can result in increases.	Monitor and adjust rules (e.g. reference points) as acidification effects clearer. Check zoning is delivering on objectives (are bed closures still in appropriate spots?); may need a distribution model to help check this.
	Doughboy Scallop		NA			
	Gould's Squid		Variable		Strong increases and decreases through time.	
	Southern Calamari		Variable		Strong increases and decreases through time.	
	Octopods		Variable		Strong increases and decreases possible (shallow water effected most strongly).	
	Eastern King Prawn		NA			
	Slipper Lobsters		NA			
	Oysters		▼ 40%			
	Other bivalves		▼ 20-40%		Declines stronger in shallower waters.	
	Tiger Flathead		▲ 10-50%			
	White Shark		Uncertain		▼ 5% through to ▲ 10%.	May require an education/ outreach scheme to explain what is happening to TEPS that is not fisheries related.
	Other sharks		▼ up to 40%		Declines stronger in shallower water.	
	Skates		▼ 20%			
	Seabirds		Uncertain		▼ 10% through to ▲ 5%.	
	Dolphins		▼ up to 20%			

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
Scallop	Whales		▲ 10-40%		Increase in short term, may decrease in future.	
Southern and Eastern Scalefish & Shark	Tiger Flathead		Uncertain		While ▲ 10-50% possible (especially in short term), if the environment continues to change declines are possible as suitable habitats are lost (but not for a few decades).	Use climate aware assessments and reference points. Check that spatial zoning still delivers on objectives. Look to relocate infrastructure as species range shift. Check implications for companion species assumptions in baskets and any multispecies rules.
	Ocean Perch		NA			
	Ocean Jacket		NA			
	Jackass Morwong		▼ up to 20%		Patchy but decline more in the northern extent of the fishery.	
	Silver Trevally		NA			
	Eastern School Whiting		▲ 10-50%			
	Latchet		▲ 10%		Spatially uniform.	
	Silver Warehou		Uncertain		▼ 30% through to ▲ 5-20%. Declines (if they happen) begin in the GAB first.	
	Blue Warehou		▼ 15%			
	Eastern Gemfish		Uncertain		▼ 20% through to ▲ 10%. Spatially uniform.	
	Red Gurnard		▼ 40%		Decline in shallows, increase in eddies.	
	Redfish		▲ 10-100%			
	Bight Redfish		Uncertain		▼ 20% through to ▲ 10%.	
	Deepwater Flathead		Uncertain		▼ 20% through to ▲ 10%.	
	Mirror Dory		▼ 15%			
	John Dory		▼ 40%			
	King Dory		▼ 15%			
	Silver Dory		▼ 15%			
	Pink Ling		▼ 40%		Spatially uniform.	
	Royal Red Prawn		Uncertain			
	Frostfish		▼ 15%		Spatially uniform.	
	Blue Grenadier		Uncertain		▼ 15% through to ▲ 60%. Spatially uniform.	
	Blue-eye Trevalla		▲ up to >50+%		Decline more in the east, may increase in Bonney upwelling area.	
	Orange Roughy		Uncertain		▼ 40% through to ▲ 10-60% (dependent on trophic interactions and oceanography). Spatially uniform.	
	Alfonsino		▼ 20%		Spatially uniform.	

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
	Ribaldo		Uncertain		▼ >50% through to ▲ 10+%. Spatially uniform.	
Southern and Eastern Scalefish & Shark	Oreodory		▼ 5-15%		Decline more in the east (and around Tasmania) than the west.	
	Cardinalfish		Uncertain		▼ 15% through to ▲ 10%.	
	Elephantfish		▼ 30%		Decline more in the northern extent of the fishery.	
	Redbait		Steady		Patchy, declines possible in shallower depths.	
	Blue Mackerel		Uncertain		▼ 15% through to ▲ 10-200+%. Decline more in the northern extent of the fishery.	
	Jack Mackerel		Uncertain		▼ 15% through to ▲ 5-10%. Spatially uniform.	
	Scaly Mackerel		▼ 30%		Spatially uniform.	
	Spanish Mackerel		▼ 20%		Spatially uniform.	
	Sardine		▲ 10-30%		Spatially uniform.	
	Oarfish		▼ 25%		Decline more in the northern extent of the fishery, increase around Tasmania.	
	Luderick		▲ 5%		Spatially uniform.	
	Hapuku		▼ 5-10%		Spatially uniform.	
	Whiptails		▼ up to 25%		Decline more in the northern extent of the fishery and in shallower waters. May increase in the area around the Bonney upwelling.	
	Yellowtail Kingfish		▼ 20%			
	Leatherjacket		Steady			
	Barracouta		▼ 10%		Spatially uniform.	
	Australian Salmon		▼ 10%		Spatially uniform.	
	Swordfish		▼ up to 5%		Move east, increasing in the Tasman Sea, potentially decline in south western waters .	
	Striped Marlin		▼ 10%			
	Skipjack Tuna		▼ 5%		Spatially uniform.	
	Albacore		▼ 20%		Spatially uniform, except that they intensify along shelf breaks.	
	Southern Bluefin Tuna		▼ 15%		Decline more in the northern extent of the fishery.	

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
	Tailor		▲ up to 5%		Decline more in the east.	
	Escolar		▼ 10%		Spatially uniform.	
	Imperador		▼ 15%		Spatially uniform.	
	Oilfish		▼ 40%		Spatially uniform.	
	Largehead Hairtail		▼ 10%		Spatially uniform.	
Southern and Eastern Scalefish & Shark	Pelagic Armourhead		▲ up to 5%		Decline more in the northern extent of the fishery, increase more around Tasmania.	
	Gould's Squid		Variable		Strong increases and decreases through time.	
	Southern Calamari		Variable		Strong increases and decreases through time.	
	Rock Lobsters		▼ 15-20%		Decline more in the northern extent of the fishery.	
	Gummy Shark		▲ up to 5%			Education scheme to explain the role of climate in what is happening to TEPS.
	School Shark		▼ up to 20%		Spatially uniform.	
	Thresher Sharks		▼ 10%		Patchy, declines strongest in shallower waters.	
	Whalers (Sharks)		▼ 30%		Decline more in the northern extent of the fishery and in shallower waters.	
	Gulper Shark		▼ 40%			
	Tiger Shark		▼ > 50%		Spatially uniform.	
	Blue Shark		Uncertain		▼ 5% through to ▲ 10%.	
	Hammerhead Sharks		▼ 20%			
	Grey Nurse Shark		▼ 50%			
	White Shark		Uncertain		▼ 5% through to ▲ 10%.	
	Basking Shark		▼ 5%		Spatially uniform.	
	Whitespotted Spurdog		▲ 15%			
	Skates		▼ 20%			
	Fur Seals		▲ 10-40%		Extend much further south and east.	
	Toothed whales		▼ 20-40%			
	Dolphins		▼ 20%			
	Orcas		▼ up to 40%		May hold steady (food web dependent).	
	Baleen whales		▲ 10-40%		Short term increases likely (recovering from past exploitation), but can be reversed depending on summer forage in the Antarctic.	
	Seabirds		Uncertain		▼ 10% through to ▲ 5%.	

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
Skipjack (East & West)	Skipjack Tuna		▼ 10%		Increases possible due to trophic interactions. Change is spatially uniform.	Climate aware assessments and reference points for target and byproduct species. Track spatial extent, review zoning to ensure still delivering on objectives.
	Striped Marlin		▼ 5-10%			
	Yellowfin Tuna		Uncertain		▼ 5-15% but increases possible dependent on trophic interactions. Change uniform spatially.	
	Bigeye Tuna		Steady		Food web interactions can cause a drop (by 60%).	
Skipjack (East & West)	Broadbill Swordfish		▼ 5%		Larger drops in some areas (especially Joseph Bonaparte Gulf and north eastern EEZ waters) and due to food web changes.	
	Albacore		▼ 20-25%		Fairly uniform, move on shelf at southern extent of the fishery.	
	Longtail Tuna		▼ 15%		Increases possible dependent on trophic interactions. Change uniform spatially.	
	Dogtooth Tuna		▼ 10%		Decline is spatially uniform.	
	Pacific Northern Bluefin		Steady		Decline in southern Coral Sea.	
	Southern Bluefin Tuna		▼ 15-40%		Decline more in north, overlap more with tropical tunas.	
	Escolar		▼ 10-40%		Decline is spatially uniform.	
	Mahi		▼ 30-50%		Decline strongest in the north.	
	Pomfrets		▼ 10-50%		Decline is spatially uniform.	
	Amberjack		▼ 50%		Decline is spatially uniform.	
	Black Kingfish (Cobia)		▼ 10%		Decline strongest off the Kimberly.	
	Yellowtail Kingfish		▼ 10-40%		Decline more in eastern waters.	
	Frigate Mackerel		Steady (E) ▼ 15% (W)		Steady in eastern waters, decline in north western waters.	
	Rake Gilled Mackerel		▼ 30%		Decline is spatially uniform.	
	Spanish Mackerel		Uncertain		From ▼ 50% to ▲ 5% (food web dependent), any declines are worst off the Pilbara.	
	Leatherjacket		Steady			
	Groupers		▼ 10-20%		Heterogeneous, but worse in northern extent of the fisheries.	

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
	Snapper		▼ 10%		Spatially uniform.	
	Barracouta		▼ 10%		Spatially uniform.	
	Blue Sprat		Variable		More increases than decreases, but increased variability common.	
	Anchovy		▲ 30-60%			
	Gummy Shark		▲ up to 5%			
	School Shark		▼ 15%		Decline is spatially uniform	
	Pelagic sharks		▼ 10-20%		Spatially uniform decrease in Thresher, Mako, Hammerhead and Oceanic Whitetip Sharks	
	Small toothed whales		▲ 20%		Small increases possible.	
Skipjack (East & West)	Baleen whales		▲ 10-40%		Short term increases likely (recovering from past exploitation) then steady, but can be reversed depending on summer forage in the Antarctic.	
	Seabirds		Uncertain		Many hold constant but could ▼ 60% depending on food web interactions.	
	Turtles		▼ 10-80%			
Small Pelagic Fishery	Bonnetmouths		▼ 30%		Strongest decline in mid GAB.	If drops occur or see increased variability, then will need climate aware reference points; may need frame-based management with monitoring to track population "state". Also check that spatial zones continue to make sense.
	Redbait		▼ 30%		Strongest decline in mid GAB.	
	Blue Mackerel		▼ 15-20%		Decrease in many areas, especially to the northern end of historical distribution, but increase around Tasmania.	
	Jack Mackerel		Steady		May ▼ 15% (depends on trophic interactions and tuna biomass).	
	Yellowtail Scad		Steady		May ▼ 15% (depends on trophic interactions and tuna biomass).	
	Sardine		Steady			
	Blue-eye Trevalla		Steady		Increase around upwellings, decline off northern edge of Bass Strait.	
	Blue Grenadier		▼ 15-60%		Spatially uniform change.	
	Silver Trevally		▼ >20%		Decline strongest in central and eastern GAB, weaker decline in the west.	
	Yellowtail Kingfish		▼ up to 40%			
	Blue Warehou		▼ 15%			

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
	Silver Warehou		Uncertain		From ▼ 30% to ▲ 5-20% (food web dependent). Any declines strongest and start earliest in central GAB.	
	Barracouta		▼ 10%		Spatially uniform decline.	
	Frostfish		▼ 15%		Spatially uniform decline.	
	Sharks		▼ up to 50%		Drop most in shallows and around Tasmania.	
	Fur Seals		▲ 10-40%		Increase the strongest in immediate future, then it depends on food web interactions.	Concern over TEPS interactions to consider – potentially increased interactions with some kinds and explain climate contribution to declines.
	Baleen whales		▲ up to 40%		Short term increases likely (recovering from past exploitation), but can be reversed depending on summer forage in the Antarctic.	
	Orcas		Steady		Food web dependent response.	
Small Pelagic Fishery	Petrels		▼ >10%		Strength of change dependent on food web.	
	Albatross		▼ up to 60%		Strength of change dependent on food web.	
Squid Jig	Gould's Squid		Variable			May need frame based approach to deal with good and bad years/population states.
	Barracouta		▼ 10%		Spatially uniform.	
	Mirror Dory		▼ up to 15%			
	Pelagic sharks		Uncertain		From ▼ 5% to ▲ 10% (food web dependent). Any declines stronger in shallower waters.	Education scheme may be required to explain what is happening to TEPS that is not fisheries related.
	Fur Seal		▲ 10-40%			
	Dolphins		▼ up to 20%			
	Toothed whales		▼ up to 40%			
	Baleen whales		▲ up to 40%		Short term increases likely (recovering from past exploitation), but can be reversed depending on summer forage in the Antarctic.	
	Petrels		Uncertain		From ▼ 10% to ▲ 5-20% (food web dependent).	
	Shearwater		Uncertain		From ▼ 10% to ▲ 5-20% (food web dependent).	

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
Torres Strait	Tropical Lobster		Uncertain		From ▼ >20-40%, but increase possible (food web and acidification dependent). Distribution could also change.	Need climate aware reference points. Also need research to reduce uncertainty around level of effect of acidification and distributional change.
	Blue Endeavour Prawn		▼ >20%			
	Brown Tiger Prawn		Variable		Food web interactions and seagrass health affect make it uncertain. Variable due to rainfall influences (through salinity and plumes), major declines and high variability possible with extreme rainfall events/storms, could affect both abundance and catchability. Potential shift in timing of spawning etc due to changes in SST.	If rainfall related variability increases, then frame based management may be needed.
	Red Spot King Prawn		Steady			
	Snapper		Uncertain		▼ 40% to ▲ 40%.	
Torres Strait	Maori Wrasse		▼ 10-20%		Declines stronger if habitat lost.	
	Barracouta		Steady			
	Sharks		▼ up to 80%			Education scheme may be required to explain what is happening to TEPS that is not fisheries related.
	Turtles		▼ 5-10%		Declines larger if lose nesting sites.	
	Dugong		Uncertain		Steady through to ▼ 20-60% depending on food web interactions and predator abundance.	
	Dolphins		▲ up to 20%			
Western Deepwater Trawl	Bight Redfish		▼ up to 20%			Monitor catch rates, trigger check on management rules if landings change significantly. Check spatial zoning still makes sense as species shift distributions.
	Red Gurnard		▼ 40%		Patchy but decline strongest at southern margin of the fishery.	
	Bar Cod		Uncertain		Increase possible.	
	Ruby Snapper		Uncertain		Increase possible.	
	Orange Roughy		Uncertain		▼ 40% through to ▲ 10% (dependent on trophic interactions and oceanography).	
	Bugs		▼ 40%		Spatially uniform.	
	Tang Snapper		Uncertain		Increase possible.	
	Scampi		Uncertain		Steady to ▲ 5%.	

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
	Deepwater Flathead		Uncertain		Increase possible.	
	Boarfish		Uncertain		Small increase possible, but ▼ 20% possible (if this occurs it is worse in the north).	
	Hapuku		▼ 15%		Spatially uniform.	
	Latchet		▼ 10%		Spatially uniform decline.	
	Cobia		▼ 10%		Decline worse in the north.	
	Rosy Jobfish		Uncertain		Increase possible.	
	Gemfish		▼ 5%		Spatially uniform decline.	
	Blue Mackerel		▼ 20%		Declines stronger on the margins.	
	Jack Mackerel		▼ 15%		Spatially uniform decline.	
	Hairtail		▼ 10%		Spatially uniform decline.	
	Spotted Warehou		▼ 20%		Spatially uniform decline.	
	Blue Warehou		▼ 20%		Decline strongest at southern margin of the fishery.	
	John Dory		▼ 30%			
	Mirror Dory		▼ up to 20%			
	Black Oreo		▼ up to 20%		Spatially uniform decline.	
	Spikey Oreo		▼ 15%		Decline stronger at margins of fishery..	
Western Deepwater Trawl	Smooth Oreo		▼ 5%		Declines stronger in the north	
	Silver Dory		▼ 20%			
	King Dory		▼ 20%			
	Silver Trevally		▼ 40%		Declines stronger in shallow waters and northern edge.	
	Ribaldo		▼ 50%		Spatially uniform decline.	
	Rusty Jobfish		▼ 10%		Spatially uniform decline.	
	Alfonsino		▼ 15%		Spatially uniform decline.	
	Veilfin		▼ up to 20%			
	Pink Ling		▼ 15%		Spatially uniform decline.	
	Blue-eye Trevalla		Steady			
	Blue Grenadier		▼ 15%		Spatially uniform decline.	
	Snapper		▼ 10%		Spatially uniform decline.	
	Frostfish		▼ 10%		Declines stronger in shallow waters.	
	Ocean Sunfish		▼ 20%		Decline stronger at margins of fishery.	
	Bronze Whaler		▼ 40%		Spatially uniform decline.	Education scheme may be required to explain what is
	Dusky Shark		▼ 30%		Spatially uniform decline.	

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
	Sorrah Shark		▼ 10%		Declines strongest at the northern extent.	happening to TEPS that is not fisheries related.
	Gummy Shark		▲ up to 5%			
	School Shark		▼ 15%		Spatially uniform decline.	
	Elephantfish		▼ 10%		Patchy but declines strongest at the margins of the fishery.	
	Pelagic sharks		▼ 10-40%		Declines in the north, but increases to the south.	
	Seabirds		▼ up to 60%		Strength of change dependent on food web.	
Western Tuna & Billfish**	Striped Marlin		▼ 10%		Decline strongest in Joseph Bonaparte Gulf.	Use climate aware reference points and assessments. May need to move infrastructure due to spatial relocation (tagging or forecasts based on oceanography are options to confirm spatial shift to show the need for such a move). Look to lower activity off Kimberley and Joseph Bonaparte Gulf, as many species show strong declines in this area.
	Yellowfin Tuna		Uncertain		▼ 10% possible, but increase possible due to food web interactions. Any decline uniform.	
	Bigeye Tuna		Uncertain		Steady or increasing (dependent on food web). Declines strongest in the north.	
	Broadbill Swordfish		▼ 5%		Decline strongest in Joseph Bonaparte Gulf.	
	Albacore		▼ 10%		Spatially uniform decline.	
	Pacific Northern Bluefin		▼ 5%		Spatially uniform decline.	
	Southern Bluefin Tuna		▼ 15%		More intense declines in the north.	
	Longtail Tuna		Uncertain		▼ 15%, but increase possible due to food web interactions. Spatially uniform decline.	
	Mackerel Tuna		▼ 10%		Decline most strongly in the north.	
Western Tuna & Billfish**	Dog Tooth Tuna		▼ 10%			
	Skipjack Tuna		▼ 10%		Spatially uniform decline.	
	Indo-Pacific Sailfish		▼ 5%			
	Shortbill Spearfish		▼ 10%			
	Frigate Mackerel		▼ 15%		Decline is uniform except off the Kimberley, where it increases.	
	Mahi		▼ 30%			
	Australian Salmon		▼ 25%			
	Luderick		▼ 15%		Spatially uniform decline.	
	Escolar		▼ 10%		Spatially uniform decline.	
	Snapper		▼ 10%		Spatially uniform decline.	
	Hapuku		▼ 15%		Spatially uniform decline.	
	Cobia		▼ 10%			
	Yellowtail Kingfish		▼ 40%			

Fishery	Species	Sensitivity	Preliminary projection	Confidence in projection	Comments on projection	Recommendations
	Rake Gilled Mackerel		▼ 30%		Spatially uniform decline.	
	Redbait (bait)		▼ 30%		Strongest decline in mid GAB.	If decline occurs use climate aware reference points. Population (egg) surveys needed to track state. may also need to be aware of increased environmental variability.
	Sardine (bait)		Uncertain		▼ 5% to ▲ 10% (dependent on food web).	
	Jack Mackerel (bait)		Uncertain		▼ 15% to steady (dependent on food web).	
	Blue Mackerel (bait)		Uncertain		▼ 15% through to ▲ 10+%.	
	Pelagic sharks		▼ 10-30%		Decline in most areas, increases possible off Carnarvon, western Joseph Bonaparte Gulf and south western corner.	Education scheme to explain the role of climate in what is happening to TEPS. For TEPS that increase more interactions possible (will need mitigation).
	Fur Seals		▲ up to 40%			
	Orca		▲ 5%			
	Dolphins		Uncertain		Increase possible (food web dependent).	
	Terns		Uncertain		Increase possible (food web dependent).	
	Petrels		Uncertain		Decrease possible (food web dependent).	
	Albatross		▼ up to 60%			

** Includes Christmas Island and Cocos Island fisheries

Appendix References

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