ECONOMIC IMPACTS OF CLIMATE CHANGE ON AUSTRALIAN FISHERIES AND ASSOCIATED SECTORS BY 2030

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ABSTRACT

This study investigates the economic impact to fisheries and associated sectors if wild fisheries continue operating to 2030 without considering the effects of climate change. Estimates of climate change impacts in Australian fisheries and their associated probability distributions were derived from the literature and expert consultations. An Input-Output model of the Australian economy was used to determine the flow-on effects of these impacts. Monte Carlo simulations were undertaken on the basis of the associated uncertainties to climate change predictions. The results present a baseline for evaluating the benefits of future climate change adaptations. The results, based upon the best available biological projections, indicate most Australian fisheries considered may in fact see economic benefit as a result of climate change by 2030. Adaptation strategies should consider minimising losses and maximizing the benefits that could be brought by climate change.

Keywords: Wild fisheries, global warming, climate change, scenarios, input-output analysis

INTRODUCTION

Climate change has already modified the atmospheric and oceanographic conditions on the planet (IPCC, 2007). In turn, these physical changes have resulted in changes on biology, including distribution, abundance, phenology and physiology (IPCC, 2007; Parmesan and Yohe, 2003; Rosenzweig *et al.*, 2008). These changes have been documented for land and sea, for exploited and non-exploited species in many countries and oceans. An understanding of the implications of these changes for dependent economic systems is critical in prioritising resource allocation to facilitate adaptation responses.

Preliminary prediction of climate change impacts on the abundance of exploited species in Australia indicate both positive and negative production benefits for fisheries (Hobday *et al.*, 2008). For example, in the north, banana prawn catches could increase with the predicted rise in sea level and increase in rainfall, while tiger prawn catches are expected to decline due to a likely increase in the frequency and intensity of cyclones (Rothlisberg *et al.*, 1988). The rock lobster fishery in Western Australia is likely to benefit from warmer water temperature, but the influence on recruitment from a weaker Leeuwin current is less certain (Caputi, 2008). However, despite a number of studies attempting to assess the likely consequences of climate change for major fisheries in Australia, none consider the follow-on effects these impacts will ultimately have on fishers, fish farmers, the industries supplying inputs to the fishery (i.e., equipment), those industries demanding fish products (i.e., processors) and consumers. Further, the existing studies focus on a particular area or fishery, so an overall picture of the impacts of climate change needs to be presented.

Australia specializes in high-value, low-tonnage fisheries such as; lobsters, salmon, abalone, and tuna. Totalling over AU$2 billion in 2006-07 (including aquaculture) (ABARE, 2008) and primarily located in coastal areas outside major metropolitan centres, Australia's fisheries are a significant local primary industry. Changes to fisheries production will impact the profitability of the fisheries and fishers' wages. This in turn will have subsequent flow on effects to the rest of the economy since fishers' will adjust their demand for other products accordingly to their income. Similarly, wild and farmed fishing industries will adjust their supply of fisheries products and demand for other products to and from suppliers respectively depending on their level of production. This will have subsequent flow on effects in terms of production, incomes and employment to these other industries.

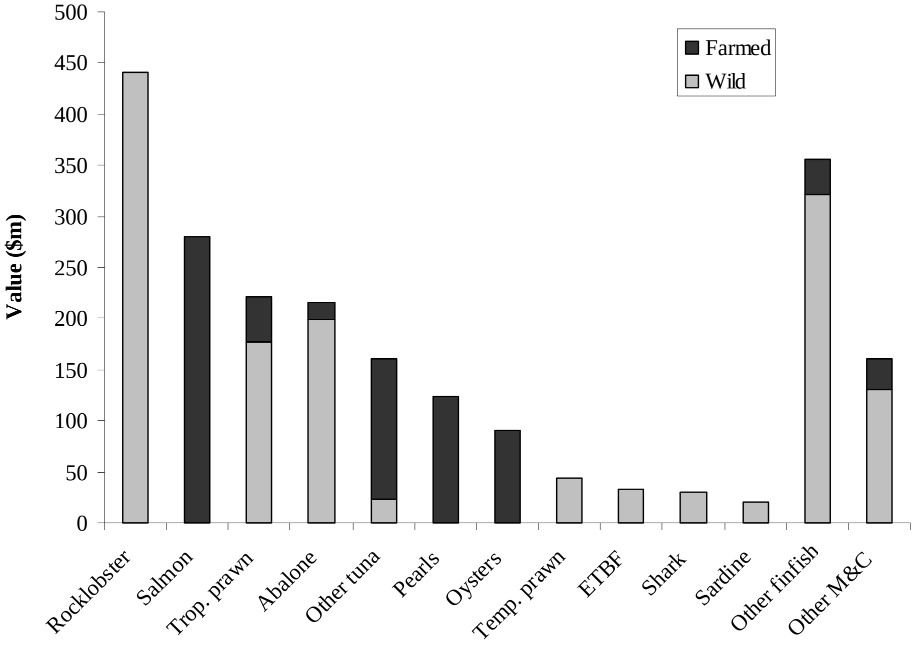
Despite the complexity and uncertainty associated with identifying the impact of climate change on fisheries (Brander, 2009), two things are certain: (1) a need to quantify what these changes might mean in economic terms should fishers and fish farmers carry on with business as usual; and (2) the necessity to consider strategies for adaptation to mitigate any potential losses, and for strategies to maximise benefits.

The purpose of this paper is to address the first of these questions, and to do so, the analysis occurs in three steps. The first step is to consider available biological production predictions, and their associated uncertainties, of the impact of climate change on Australian fisheries by 2030. The changes expected in the global climate in 2030 are largely independent of the particular climate change scenario, as the future climate is "locked in" based on the release of greenhouse gases to date (IPCC 2007). The second step is to link the productivity predictions and their uncertainties to an Input-Output model of the Australian economy in order to determine the broader economic impact of these changes. The final step is to carry out Monte Carlo simulations on impacts of climatic change on fisheries in terms of fishers' wages, the fishery profitability and the flow on effects to other sectors in the economy. Our results will quantify and illustrate the economic necessity (or otherwise) for adaption at the fishery level, and will also provide a 'baseline' scenario against which costs and benefits of strategies for adaption can be compared.

Australian fisheries and predicted climate change effects

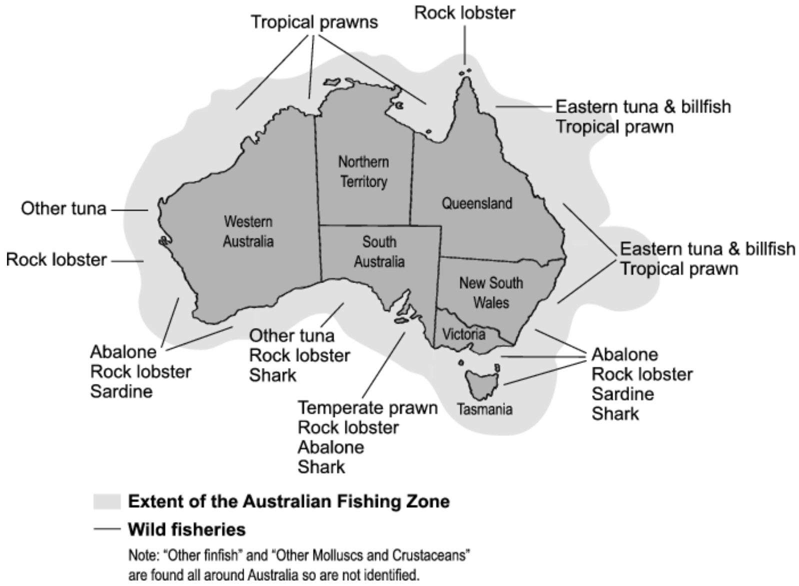
The Australian fishing zone is one of the largest in the world, covering an area of over 8 million square kilometres. It is also extremely diverse, including tropical, temperate and cold water marine systems. The large area covered by Australia and the different systems allow a wide range of wild and farmed fisheries that are valuable to the economy. This study has grouped all Australia's wild industries into 10 groups based on similarity between fisheries, geographic spread, availability of data, and economic value (Figure 1, Figure 2).

Figure 1. Value of production, Australian fisheries 2006-07 source: (ABARE, 2008)



The wild fisheries include the rock lobster fishery, which is geographically spread throughout Australia and is the most valuable, accounting for 20% of total fisheries revenue in 2006-07. The tuna fishery includes the eastern and western tuna and billfish fisheries, southern bluefin tuna and the skipjack tuna fishery. Of this, the eastern tuna and billfish fishery (ETBF), which has the highest tonnage of catch (Hohnen *et al.*, 2008), is considered as a separate group to the other tuna. Another fishery (sharks) include the large pelagics (mainly sharks) caught by the gillnet, hook and trap sector. The range of inshore demersal species and other mid-trophic level finfish has been grouped as "other finfish". The prawn fisheries have been divided into tropical and temperate (Figure 2). The abalone and sardine fisheries are mainly fished in the southern regions and in smaller numbers in the West (Figure 2). Finally, "other mollusc and crustacean" fisheries around Australia have been grouped into a single group.

Figure 2. Approximate location of wild fisheries



All wild and farmed fish are physiologically adapted to particular environmental characteristics. Thus, fish in Australia's northern regions are adapted to warm and consistent tropical conditions, whilst fish from the southern regions exist in a cold temperate climate with marked seasonality. Whilst fish can adjust to climate variation over time, current physical trends predict conditions outside the bounds of previous experience due to climate change (Brander, 2007). These changes are expected to have severe impacts on fisheries in Australia and elsewhere (Hobday et al 2008; Allison et al 2009). We briefly describe the predicted physical changes for different regions around Australia, as context for the expected changes in a number of Australian fisheries.

There is little difference in the predictions of global warming between mid-range and high-range (A1FI) scenarios for 2030 (IPCC, 2007), since the warming over that time scale is largely predetermined due to gases already in the atmosphere. Hence, we describe general changes expected under emission scenario A1B in the Australian region based on the CSIRO Mk 3.5 climate model (Hobday *et al.*, 2008). This model, the only Intergovernmental Panel of Climate Change (IPCC) model constructed in the Southern Hemisphere, suggests that by 2030 waters around Australia will warm by 1-2^{o}C with the greatest warming off south-east Australia. Acidity (pH) will decline around Australia by around 0.1 units. Rainfall will, on average, decrease by 0 to 5% over most of Australia, although the frequency of storms throughout the country and cyclones in the north is expected to increase. Sea level is projected to rise by 0.3-0.5 m around Australia (Hobday *et al.*, 2008). The strength of the East Australia Current will also increase, however, the behaviour of the west coast Leeuwin current is less certain. Overall, Australia's south eastern fisheries are expected to be most affected by changes in water temperature; northern fisheries by changes in rainfall; and western fisheries by changes to the Leeuwin current (Hobday *et al.*, 2008). Further, fisheries, for higher trophic level species (e.g. tunas), will also be indirectly impacted by climate change through flow on effects from primary producers (Brown *et al.*, 2010).

The specific impact that climate change will have on different fisheries is difficult to quantify due to several reasons. First, the uncertainties surrounding global warming predictions and in particular those for specific locations, especially for variables other than temperature (IPCC, 2007). Second, the difference in resilience and tolerance of different species to the physical variables (e.g., pH, currents, temperature) that are expected to vary with climate change (Brander, 2009). Third, the potential complexity of changes to species interactions and ecosystem processes (Brander, 2009). Fourth, the impact of other pressures, such as fishing mortality, pollution etc, on the sensitivity of marine systems to climate variability (Brander, 2009; Perry *et al.*, 2010; Planque *et al.,* 2010). By focusing on shorter-time frames, however, predictions of the physical and biological change and hence economic impacts are possible. Such estimates, however approximate, are needed to allow managers, fishers and policy makers to begin to plan for a changed future.

METHODS

Evaluating the impact of climate change to wild fisheries production

In order to estimate the economic impacts of climate change, we assume the management of Australian fisheries operate in 2030 in the same way as they do today. We then carry out the economic analysis in three steps. The first step requires estimates of the impacts of climate change on Australian fisheries production, and the associated uncertainties. Then, we develop an input-output model to estimate how the climate change impacts to fisheries will affect other sectors in the economy given the expected changes in the fishing industry. Finally, we run Monte Carlo simulations using the input-output model to consider the effects of the uncertainties associated with the climate change predictions and their impacts.

The set of existing studies investigating changes to Australian fisheries production due to climate change generally focus on one or several key physical variables for each fishery. The physical variables considered most often are temperature, winds and currents, rainfall, acidification, sea level changes and extreme weather conditions. Both direct and indirect impacts from these variables on fisheries production are considered, the latter arising from the flow on effects from primary producers (e.g. phytoplankton) to fisheries, which are located at higher trophic levels. The key assumptions used in the analysis and their associated uncertainties based on the available studies are presented in the Appendix, Tables A1-A3.

Input-Output model and data used to generate the Input-Output Table

The impacts on the broader economy were derived using input-output (I-O) analysis, which is based on the general concept of economic multipliers. For example, the capture of fish by fishers requires inputs such as bait, food, ice, fuel, boats, insurance, etc. In turn, the manufacturers of these other goods will need to buy goods from their suppliers and so on, thereby creating a so-called multiplier effect. The flow of goods and services (in value) between all the individual sectors of an economy over a stated period of time (usually a year) is summarised in an I-O transaction Table. This table is the base of the I-O model and it is defined in terms of a series of equations, given as:

$$\sum_{j=1}^{s} x_{ij} + Y_i = X_i \quad (i = 1,2,..,s) \tag{1}$$

where x_{ij} is the proportion of total production of industry i that is sold to industry j as an intermediate input into industry j, Y_i the sales from industry i to final demand, X_i the total sales of industry i, and s the number of industry sectors. In matrix form, this can be expressed as $(I - A)X = Y$. The level of production in each sector can therefore be determined by $X = (I - A)^{-1}Y$, where $Z = (I - A)^{-1}$ is the Leontief inverse. The income multiplier (I_j) is defined as the total income generated in all industries in the economy as a result of one extra dollar of income in the industry being studied. This multiplier is given by:

$$I_j = \frac{\sum_{i=1}^{s} b_{ij} W_i}{D} \tag{2}$$

Where *bij* is the elements in the Leontief inverse matrix which shows the direct, indirect and induced effect in industry *i* of a one-unit change in final demand from industry *j*, *D* is the initial (direct) effect and W_i is the wage coefficient, which is the ratio of total wages in industry *i* to total sales in the same industry.

The I-O model was derived from the latest national I-O table available (2004-05), produced by the Australian Bureau of Statistics (ABS). The 109 sectors in the ABS national I-O table were aggregated into 10 sectors,[i] and the fishing sector (one of the 10) was disaggregated into 16 sectors (10 capture fisheries and 6 aquaculture). We focus in the 10 wild capture fisheries in this paper. The disaggregation of the different fisheries sectors was based on the values of production, potential differences in impacts due to climate change, cost structure information and the distribution of production to other intermediate sectors and final consumers.

ANALYSIS APPROACH

We use Monte Carlo simulations to incorporate uncertainties surrounding the predicted climate change effects to fisheries production by 2030 into the Input-Output model. Each simulation is run 1000 times to allow for random changes to fisheries production caused by likely climatic changes to physical variables (e.g., temperature). The impacts of changes to physical variables on fisheries production are uncertain, but can be constrained to a probable range of values (See Appendix, Tables A1-A3). Therefore, for each simulation run we drew a value from a uniform distribution spanning the possible range around the "best estimate" for each physical variable. These are then aggregated across the set of key variables to obtain an estimate of the overall impact for each fishery. The production changes for each fishery are then fed into the input-output model to obtain for each of the 1000 repetitions along with the fishers' wages, the profitability of the fishery and the economic multiplier of every fishery. In addition, these parameters were calculated for the base year (2004-05).

RESULTS

Income multipliers of Australian fisheries

The estimation of the income multiplier from the Input-Output table has allowed quantifying for the first time, the impact that changes to fisheries income, due to climate change, will have to the Australian economy. The income multiplier for the 10 wild fishing sectors for the base year (i.e. 2004-05) and the climate change scenario (average of the 1000 repetitions) are given in Table 1. From the base model, for each Australian dollar spent in wages by the ETBF there will be a total of $4.67 respectively in income generated by other sectors in Australia. Of this amount, $1.00 is solely the result of a direct change in income for the ETBF; the rest ($3.67) represent the additional production induced and consumption induced effects in other sectors of the economy. A value greater than two implies that the induced effects (both production and consumption) of a change in income (depending on what the multiplier measures) are greater than the direct effects.

Table 1. (Type 2) Income multipliers in the scenario analysis

Fisheries	Base year (2004-05)	Average Climate Change effects
Sharks	2.12(a)	2.04
ETBF	3.23(a)	2.81
Tropical prawns	3.24(a)	2.94
Other finfish	3.34(a)	3.39
Abalone	2.31	2.70
Rock lobster	2.61	2.54
Other Tuna	2.76	2.61
Sardine	2.09	1.97
Temperate prawns	2.45	2.30
Other C & M	2.98	2.89

(a) The capacity of the fishery has been reduced to approximate the reduction achieved after (2004-05)

Income effects of climate change to wild fisheries, other sectors and the overall economy

In Table 2, the average income effects to fisheries (wages and profits), other sectors (induced income), the whole economy (total for all sectors) and the net income changes between our base year (2004-05) and the climate change scenario are presented. The production and consumption induced income effects to the economy were estimated by multiplying the wages obtained in fisheries (from Table 2) by the appropriate income multiplier (from Table 1), after the direct impact had been subtracted (value of 1) from the multiplier. The values in the climate change scenario represent the average from the 1000 repetitions in the Monte Carlo simulation. Furthermore, the coefficient of variation has been included in Table 2 to indicate the dispersion between the simulation results.

Table 2. Economic benefits to wild fishers and other sector for the different scenarios

Wild Fisheries	**Income effects**	Base year (2004-05)	Average Climate Change effects	Coefficient of variation (CV)
Sharks	Fisheries Wages	14.9(a)	18.0	13%
	Fisheries Profits	24.2(a)	30.4	16%
	Induced Income	16.7(a)	18.7	8%
	Total	55.9(a)	67.1	13%
	Net Income		**12.1**	
ETBF	Fisheries Wages	7.5(a)	10.2	11%
	Fisheries Profits	18.0(a)	28.8	16%
	Induced Income	16.7(a)	18.5	4%
	Total	42.2(a)	57.5	11%

	Net Income		**16.1**	
Tropical prawns	Fisheries Wages	55.2(a)	67.9	4%
	Fisheries Profits	32.6(a)	66.5	10%
	Induced Income	123.6(a)	131.9	1%
	Total	211.4(a)	266.3	4%
	Net Income		**58.6**	
Other finfish	Fisheries Wages	80.4(a)	78.0	28%
	Fisheries Profits	46.7(a)	36.3	157%
	Induced Income	187.9(a)	186.3	8%
	Total	315.0(a)	300.7	32%
	Net Income		**-12.2**	
Abalone	Fisheries Wages	49.8	31.0	5%
	Fisheries Profits	153.7	78.1	9%
	Induced Income	65.0	52.8	2%
	Total	268.5	161.9	6%
	Net Income		**-106.6**	
Rock lobster	Fisheries Wages	143.4	154.8	10%
	Fisheries Profits	124.5	144.1	19%
	Induced Income	230.9	238.3	4%
	Total	498.8	537.1	9%
	Net Income		**38.3**	
Other Tuna	Fisheries Wages	10.2	11.9	13%
	Fisheries Profits	4.4	7.4	35%
	Induced Income	18.0	19.2	5%
	Total	32.7	38.6	13%
	Net Income		**5.9**	
Sardine	Fisheries Wages	8.1	11.0	11%
	Fisheries Profits	15.2	20.9	11%
	Induced Income	8.8	10.7	7%
	Total	32.1	42.6	10%
	Net Income		**10.5**	
Temperate prawns	Fisheries Wages	10.9	13.5	3%
	Fisheries Profits	16.1	21.6	4%
	Induced Income	15.8	17.5	1%
	Total	42.7	52.6	3%
	Net Income		**9.9**	
Other C & M	Fisheries Wages	32.2	34.4	1%
	Fisheries Profits	52.4	58.7	1%
	Induced Income	63.7	65.1	0%
	Total	148.3	158.2	1%
	Net Income		**9.9**	

(a) The capacity of the fishery has been reduced to approximate the reduction achieved after (2004-05)

For all fisheries (Table 2), direct income effects (wages and profits) and production and induced income effects have increased when assumed climatic changes increased fisheries production and vice versa. In particular, fishers (wages) and induced income have increased the most in the sardine fishery, with an increase of 36% (from 8.1 to 11 million) and 22% (from 8.8 to 10.7 million) respectively (Table 2). Fisheries profits have grown the most in tropical prawns, where profits more than doubled compared to the base year. Wages and induced income have also increased but not nearly as much as profits. This is likely to be due to the recent reduction in capacity that has reduced inputs into the fishery to maximise profits.

The average net income effects (Table 2) and the associated variations for the wild fisheries are presented in Figure 3. The variation arising from the Monte Carlo simulations in our climate change scenarios highlight the uncertainty surrounding the climate change predictions. In general, climatic changes to wild fisheries could benefit the overall economy with the exception of abalone and finfish. In particular, the abalone fishery could experience the largest loss (-A$106million; range -$A89 to 131 m). Whilst tropical prawns could achieve the largest gain (A$59 m, range A$22-87 m).

Figure 3. Average, net economic effect to wild (in white bars) and farmed (in grey bars) fisheries from climate change (minimum and maximum presented in error bars)

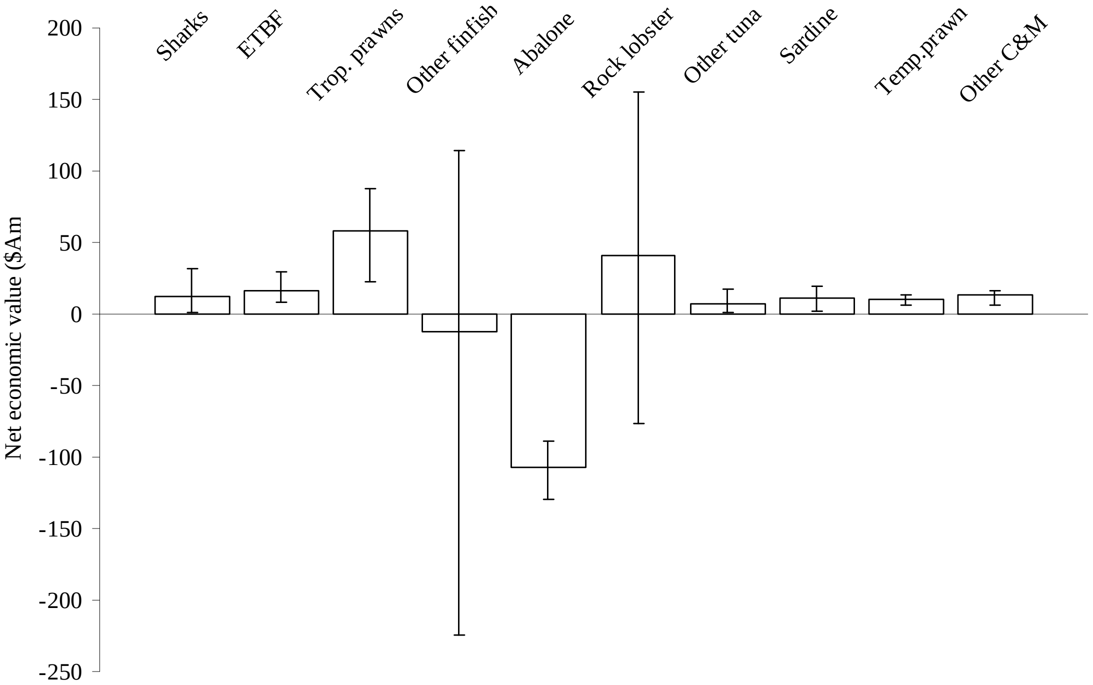
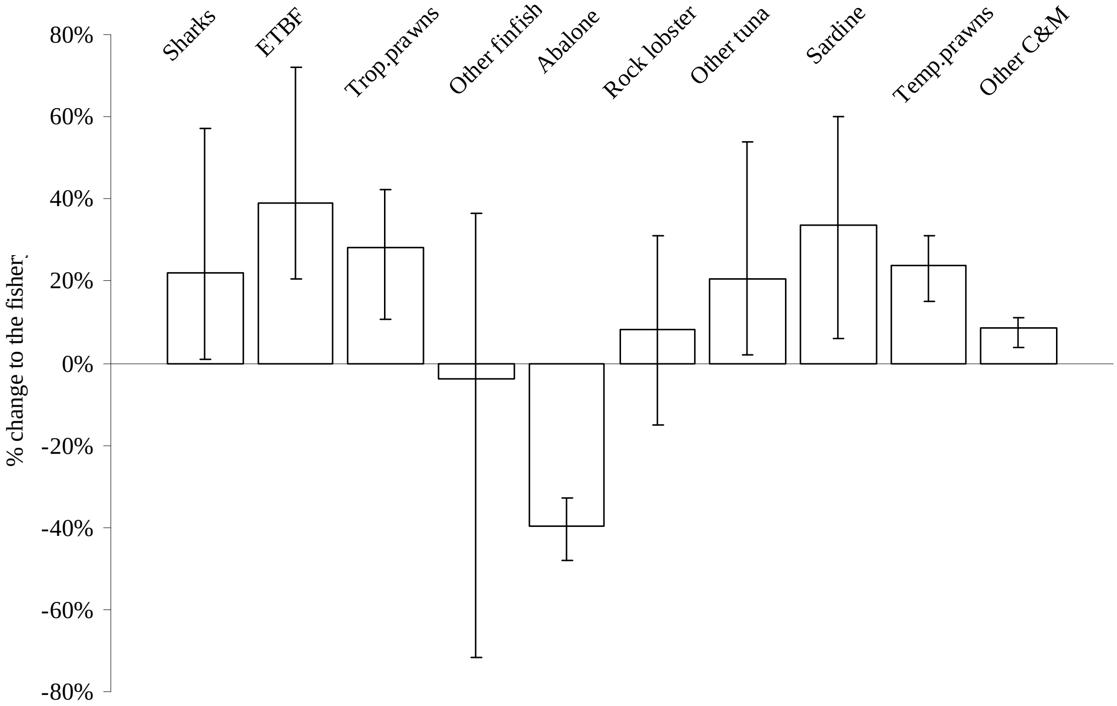


Figure 4. Average % change to wild (in white bars) and farmed (in grey bars) fisheries from climate change (minimum and maximum presented in error bars)



The percentage change between the average total economic gain (fishers' wages, fisheries profits and induced income) in the base year and the climate change scenario and the associated variations between the minimum and maximum values are presented in Figure 4. The variation between the 1000 repetitions in our climate change scenarios highlight the uncertainty surrounding the climate change predictions. The largest economic growth in percentage terms are observed in the ETBF and sardine fisheries. In particular, the ETBF followed by the sardine fishery could experience the largest percentage growth (39% and 34% respectively). However, uncertainties on climatic effects could vary growth between 21% and 72% in the ETBF and 6% and 60% in the sardine fishery.

DISCUSSION

Here we have investigated the net economic impact that climate change may have on Australian wild fisheries in 2030, if current management strategies in these fisheries continue and fishing capacity is held constant at current or MEY levels. The results are important to fisheries managers and policy makers since they highlight the potential benefits and losses to fisheries and other sectors in the economy if future climate change adaptations are not considered. This study provides a reference point for future studies assessing economic benefits and costs of adaptations to climate change.

The uncertainties surrounding physical predictions have motivated this study to concentrate in 2030 since the changes to physical variables (e.g., temperature, acidity etc) for this time period are expected to be the same independently of the greenhouse gas emission scenario (IPCC, 2007). However, there are further uncertainties as to the impact that changes to physical variables will have on individual species' growth, reproduction, mortality and behaviour as well as different species interaction and ecosystem responses (Brander, 2009).

This study used scenarios based on available predictions together with their associated uncertainties to estimate the impact that changes to physical variables will have on Australian fisheries production. These predictions were then incorporated into an input-output model of the Australian economy and the associated uncertainties were simulated on the basis of that model. This has allowed us to consider the direct impacts that climate change could have on fisheries, the flow on effects to other sectors of the economy and the overall gain or loss to the economy overall (net economic impact).

The specific impacts that climate change could bring to individual sectors would vary between wild fisheries depending on whether the sum of the physical impacts to individual species increases biomass growth and vice versa. Overall, climatic changes to the sardine fishery could bring the largest growth to fishers' wages and induced income whilst profits could grow the most in tropical prawns. Bringing all the sectors together, in average, the ETBF, followed by the sardine and tropical prawn fishery will grow the most while the abalone fishery will decline the most. Nevertheless, high uncertainty levels in the predictions could vary the results. With respect to the net income value to the economy, climatic changes to wild fisheries could bring benefits with the exception of the abalone and other finfish fisheries. In particular, the abalone fishery could bring the biggest net economic loss to the economy. This loss almost doubles the net economic gain from the tropical prawn fishery which is the biggest gain, in absolute terms, to all wild and farmed fisheries.

The results from this study can be used as a baseline for evaluating the benefit of adaptation options. Nevertheless, decisions should be made carefully, as the uncertainties for many fisheries are large due to the considerable uncertainties associated with the climate change projections. As a general rule of thumb, adaptations for fisheries experiencing losses should be considered a priority (i.e., wild abalone). Furthermore, those fisheries that could experience large gains or losses due to substantial uncertainty levels (i.e., rock lobster, other finfish) should also be a priority. Finally, the design of measures to adapt to climate change should also consider fisheries expecting gains (i.e. wild tunas). This is because adaptations will not only allow minimising losses but also maximising the benefits obtained from climate change.

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APPENDIX

A.1. Assumptions and data sources used in the analysis

Fisheries	Prim. product.	Uncert.	Specific spp	Temp.	Uncert.	Winds / Currents	Uncert.	Acidification	Uncert.
Abalone	2	±1%	*H. rubra*	-40	(±5%)	No estimates identified		0	(-3%,0%)
	Predictions from Brown et al.(2010). The study does not provide uncertainty values so assumed + or - 25% from predictions			80% mortality of *H. tuberculata* due to virus *V. harveyi at* 18^{o}C or higher (Travers *et al.*, 2009). If similar impact in Australia, all locations affected except Tasmania (which represents 50% of production)				Lower impacts in crustaceans than molluscs (Cooley and Doney, 2009). Calcification in oysters at pCO2 level= 450ppm is 3% (Gazeau *et al.*, 2007).	
Rock lobster	4	±1%	*P.cygnus*	10	(±3%)	-12	(±12%)	0	(-3%,0%)
				Average increase in catches following an extra 1^{o}C in WA has been calculated from 8 locations and their deviations from Lestang et al(2007).		Assumed the weakening of the LC will lead to catches between yrs with weak LC (pessimistic) and average LC (optimistic). Catches at different LC strengths obtained from Caputi (2008)		Same explanation as above	
			J. edwardsii	9	(-44%, +59%)	Also included in Pecl et al (2009)		0	(-3%,0%)
				Average Tasmanian East Coast Rock Lobster catch following CC (A1B1) to EAC, temperature, competition with sea urchin, and reduction in recruitment by 2030 (Pecl *et al.*, 2009). The estimates assumed equivalent to catches in VA and SA				Same explanation as above	
			Tropical *Panulirus*	0	0	0	0	0	(-3%,0%)
	Same explanation as above			Abundance likely to be influence by environmental variables like temperature, wind strength and direction and oceanographic conditions (Dennis et al, 2006). However, based in personal communications, it is assumed conditions at 2030 are unlikely to have big impacts on production				Same explanation as above	

In grey physical impacts could not be identified in the literature

A 2. Assumptions and data sources used in the analysis (continuation)

Fisheries	Prim. Product.	Uncert.	Specific spp	Temp.	Uncert	Acidification	Uncert.	Sea level	Uncert.	Cyclone	Uncert.	Rainfall	Uncert.
Temp. prawns	17%	±4%	*M. latisulcatus*	8%	±3%	0%	-3%, 0%	No estimates identified		No estimates identified		No estimates identified	
	Predictions from Brown et al (2009). Assumed +/- 25% uncertainty from predictions			Growth is related to temperature as in P. monodon (Jackson and Wang, 1998)		Lower impacts in crustaceans than molluscs (Cooley and Doney, 2009). Calcification in oysters at pCO2 level= 450ppm is -3% (Gazeau *et al.*, 2007)							
Tropical prawns	11%	±2.75%	*P. merguiensis*	8%	±3%	0%	-3%, 0%	6%	±4%	No estimates identified		4%	±12%
				Same explanation as above		Same explanation as above		Assumed 1to5% increase in mangrove area (400- 2000 ha) (Dowling and MacDonald, 1982). Higher catches due to inundation of mangrove swamps (Loneragan *et al.*, 2005)				A 40% increase in rainfall will increase catch by 45% (Rothlisberg *et al.*, 1988). Asumed linear relationship between rainfall & catch	
			P. semisulcatus *P.esculentus*	8%	±3%	0%	(-3%,0%)	No estimates identified		-1%	±0.03%	No estimates identified	
	Same explanation as above			Same explanation as above		Same explanation as above				Cyclone wind speeds could increase 10% by 2030 (Henessy *et al.*, 2006). Preliminary estimates from unpublished model (Sean Pascoe CSIRO pers. comm, July 2009)			
Other M&C	6%	±1.5%		No estimates identified		0%	(-3%,0%)	No estimates identified		No estimates identified		No estimates identified	
	Same explanation as above					Same explanation as above							

A.3. Assumptions and data sources used in the analysis (continuation)

Fisheries	**Primary productivity**	Uncertainty	**Direct physical impacts**	Uncertainty
ETBF	28%	±2.8%	0%	(-10%+40%)
	Predictions from Brwn et al (2010). The study does not provide uncertainty values so assumed + or - 25% from predictions		Preliminary estimates relating to large pelagics derived from unpublished ecosystem modelling work, (Beth Fulton, CSIRO, pers. comm, July 2009).	
Other tuna	10%	±1%	0%	(-10%+40%)
	Same explanation as above		Same explanation as above	
Sharks	13%	±1.3%	0%	(-10%+40%)
	Same explanation as above		Same explanation as above	
Sardines	36%	±3.6%	0%	±20%
	Same explanation as above		Preliminary estimates relating to small pelagics derived from unpublished ecosystem modelling work, (Beth Fulton, CSIRO, pers. comm, July 2009).	
Other finfish	8%	±0.8%	0%	(-80%,30%)
	Same explanation as above		For mid-trophic level carnivors (-50%,+30%) and inshore habitat dependent demersals (-80%,0%) Preliminary estimates derived from unpublished ecosystem modelling work, (Beth Fulton, CSIRO, pers. comm, July 2009).	

ENDNOTES

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[i] The ten aggregated industries were agriculture and forestry; fishing; mining; processed food and drinks; textile and wood products; fuel, chemicals and metal products; boats, machinery and equipment; construction, manufacture and repairs; and government and services.