A contribution to

An analysis of medium to long-term impacts on the Australian Oceans

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1.1 Global fishery projections

There are two major global fisheries production models: the IMPACT Model documented in the Fish to 2020 (Delgado *et al.* 2003; Rosegrant and IMPACT Development Team 2012) which was later modified for the World Bank-IFPRI-FAO Fish to 2030 model (World Bank 2013); and the OECD – FAO Fisheries Model which we will refer to as the FAO Fisheries Model (Lem *et al.* 2014). The OECD predicts fishery production for OECD countries using the FAO model.

The IMPACT model was developed by the International Food Policy Research Institute in the early 1990s to examine alternative futures for global food supply, demand, trade, prices, and food security, income and population. IFPRI can provide not only fundamental, global baseline projections of agricultural commodity supply and demand, trade, prices and malnutrition outcomes but also projections based on current research in areas such as climate change and changing diet/food preferences (Delgado *et al.* 2003).

Overall, the IMPACT model is a "relatively straightforward partial equilibrium global agricultural sector model" written in GAMS (Generalised Algebraic Modelling System) (Delgado *et al.* 2003). It comprises 115 country or regional sub-models each of which are essentially a set of supply and demand equations that estimate supply, demand, and prices for agricultural commodities such as cereals, soybeans, roots and tubers, meats, milk, eggs, oils, meals, vegetables, fruits, sugar, and other foods. Each country sub-model is linked to the rest of the world through trade. The world price of a commodity is the mechanism by which the model equilibrates in response to a shock, eventually affecting price and then supply and demand until world net trade is zero.

It is driven by population growth, demographics, and relative income of population (GDP) all of which determines consumption of fish per capita and price of fish products.

The World Bank made several improvements to the original IMPACT model in response to several shortcomings identified in the Fish to 2020 study of Delgado *et al.* (2003). Several additional scenarios were added to the baseline scenario: 50% faster growth in aquaculture, increasing utilization of fish–processing waste as fish food, shrimp disease outbreak in Asia, higher demands by China, increased growth in capture resulting from recovering stocks and MSY harvest strategy and 2 climate change scenarios, of either a) mitigated warming and acidification trends by 2020 i.e. global emissions kept to 2000 level or b) no mitigation where emissions continue to rise according to IPCC scenario, impacting fish productivity (Figure 1).

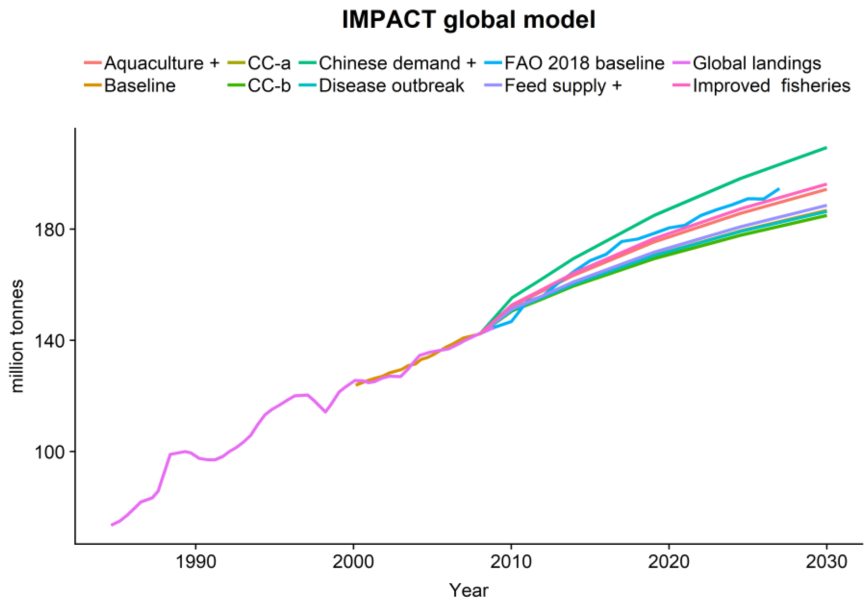

Figure 1 The IMPACT global fisheries model (World Bank 2013). Historical landings and model projections of global fishery production for 2000-2030 (baseline) or 2008-2030 (all other scenarios) were captured using Graph Grabber v2.0. For comparison, the baseline projection from the FAO Fisheries model for 2008-2027 is shown. NB The additional scenario trajectories were extrapolated from the baseline trajectory for which we had a full data set and re-aligned to the 2030 endpoints as reported in World Bank report (Cassou 2018) therefore the trajectories are not a true representation from model output.

The FAO Fisheries Model (Figure 2) was jointly developed by FAO and OECD in 2010 as a satellite model to their Aglink-Cosimo model (FAO 2012). It covers the same 56 countries and regions as the Aglink-Cosimo model which is a multi-market, partial equilibrium model. It models capture and aquaculture production (both marine and inland) and is linked to the broader agriculture markets through demand for feed for aquaculture, through substitution between fish and other animal products, and between fishmeal and fish oil and their oil substitutes (FAO 2012). Commodity prices such as meat prices, US dollar and limited growth of capture fisheries production, as well as energy costs, including crude oil and feed costs are input into the model. Medium-term projections (over a ten-year horizon similar to the agriculture outlooks) are modelled every year for *The State of the World Fisheries and Aquaculture*.

The main driver is demand for food and, as in the IMPACT model, factors such as population growth and demographics, income per capita and preferences will influence consumption rates.

The FAO model scenarios modelled by Lem *et al.* (2014) (Figure 2) were:

- Baseline - which assumes an increase in aquaculture production from 66.2 million tonnes in 2012 to 85 million tonnes in 2022, i.e. a total increase of 28.5% and an average annual growth rate of 2.54%
- Intermediate - which assumes an increase in aquaculture production to 92 million tonnes in 2022, i.e. increase of 39.6% and an average annual growth rate of 3.39%.
- Optimistic- which assumes an increase in aquaculture production to 99 million tonnes in 2022, i.e. total increase of 50 % and an average annual growth rate of 4.14%.
- Mixed - which assumes an increase in aquaculture production to 99 million tonnes in 2022, as in optimistic but with most of the growth in Asia: annual growth outside of Asia will be as in the base case while growth in Asia will be such that a total production of 99.3 million tonnes will be reached in 2022. This gives an average annual growth rate of 4.14%.

- Revised demand elasticities - which introduces a new set of demand elasticities but is identical scenario to the “mixed” scenario for production and also results in an average annual growth rate of 4.14%.

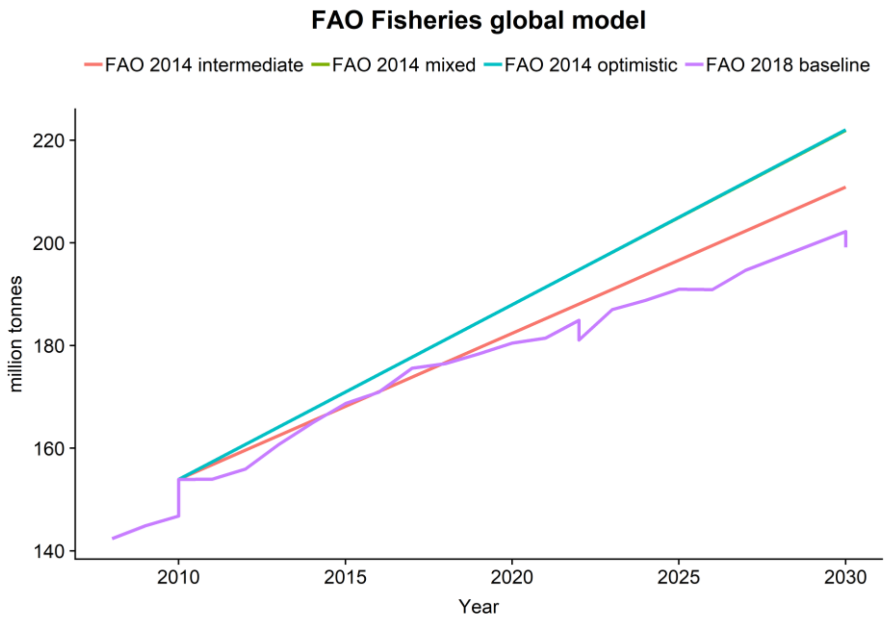

Figure 2. The FAO Fisheries model. Global fisheries production for 2008-2027 (baseline) from *OECD-FAO Agricultural Outlook for 2018-2027* (OECD 2018) and other scenarios from Lem, Bjorndal et al. (2014) and our estimates for 2030. NB the ‘revised demand elasticities’ and ‘optimistic’ scenario estimated values for 2022 and 2030 are, or almost are, identical to the ‘mixed’ scenario and are not shown. All 2030 values were estimated from regression trendlines for 2008 - 2022 and are not estimates from actual model projections.

Both global fisheries models project continued growth over their forecast periods (Figures **Error! Bookmark not defined.** & 2). The main contributor to increased fishery production in the IMPACT model projections was assumed to be growth in aquaculture of up to 62% of all human-consumption fish production by 2030 (World Bank 2013). Both models predicted that global aquaculture continued to grow across all scenarios but at a slowing pace e.g. the FAO model predicts a lower rate of growth to that of the preceding decade (1.5% per annum *cf* 4.4% per annum) but still higher than that for capture species (OECD 2018).

The most recent update, *OECD-FAO Agricultural Outlook for 2018-2027*, predicted that total fisheries production worldwide will expand by only a little over 1% per annum–much lower than observed during the previous decade–to a total of 13.4% with an annual production of 195 million tonnes per annum by 2027 (Figure 2) This projection accounts for potential El Niño events (in 2021 and 2026) the effects of which are based on previous behaviour. The contribution from capture fisheries production is expected to decline by 0.01% per annum to about a million tonnes less in 2027 than in the base period (2005-7). This fall in capture fisheries is due to lower landings resulting from China’s latest 5 year plan (2016-2020) to improve efficiency and sustainability (OECD 2018). Another major revision of the model was an upward revision of the value of Chinese aquaculture production resulting from new information being made available which has had a significant impact on the global fish production affecting prices, trade, and consumption (OECD 2018). Aquaculture production, at a growth rate of 30.1%, is expected to overtake capture fisheries by 2020 (OECD 2018).

FAO also acknowledges the influence of challenges and uncertainties in these model projections such as “natural productivity of fish stocks and ecosystems, environmental degradation and habitat destruction, overfishing, illegal, unreported and unregulated fishing (IUU), climate change, weather patterns, transboundary issues with respect to natural resource utilisation, poor governance, invasion of non-native species, diseases and escapes, accessibility and availability of sites and water resources, as well as to technology and finance. Furthermore, trade policies, trade agreements and market access remain important factors influencing the overall dynamics of the fish markets. From the perspective of market access, issues include those related to food safety and traceability, the need to demonstrate that products are not derived from illegal and proscribed fishing operations." (OECD 2018).

The FAO has also developed a new short-term projection model specifically for decision-making (Cai and Leung 2017) to assess and monitor fish supply and demand over a five-year period and is updated annually (FAO 2018). It uses the same macro-economic assumptions and prices as the agricultural projections from the larger model but assumes no change in prices. It is driven by population growth and expected income, and estimates the difference between the potential change in demand for fish over the projected five-year period and the benchmark fish supply. The growth rate in aquaculture necessary to cover the potential gap can then be estimated. The latest results indicated that only 40% of the projected global demand for fish in the early 2020s could be covered by aquaculture production at the current growth rate and that it would need to grow at nearly 10% per year to fill the gap (FAO 2018).

1.2 Australian fishery projections

Consumers in developed countries, such as Australia, with ageing populations and already relatively high rates of consumption per capita, are also becoming increasingly concerned about sustainability, animal welfare and food safety issues, therefore there is limited potential for much increase in consumption per capita fish (OECD 2015) despite the acknowledgement of the health benefits. The fisheries sector is one of the most globalised of the food sectors (OECD 2015) and therefore trade opportunities are very influential in the growth of fishery production in Australia. In particular, China is an increasing market.

Estimates of total Australian fishery and aquaculture production were specifically made only in the global FAO Fisheries model (Table 31: Lem *et al.* (2014)) from which we derived numerical projections over the period 2012-2022 (Figure 3). However, the projections were based only on two points (2012 & 2022) for each of the FAO scenarios and so represent only the trendlines and not an actual model trajectories. There was no discrimination between the baseline, mixed and mixed/revised elasticities scenarios which all predicted an increase of 13.9% by 2022 while increases of 17.6 and 21.1% were expected from the intermediate and optimistic scenarios respectively (Lem *et al.* 2014). However, the simplification of the equations that account for the Australian data and the uncertainty of the accuracy of the underpinning data used by the global models, raise doubt about the robustness of those predictions. Our comparison of the official ABARES fisheries data and those reported by the FAO showed under-accounting in the FAO data, also demonstrated by Kearney *et al.* (2003). In addition, they estimated that 30 000kg of fish are caught by recreational fishers annually, a significant component of the marine ecosystem that needs to be considered in the Australian modelling (Fulton *et al.* 2012).

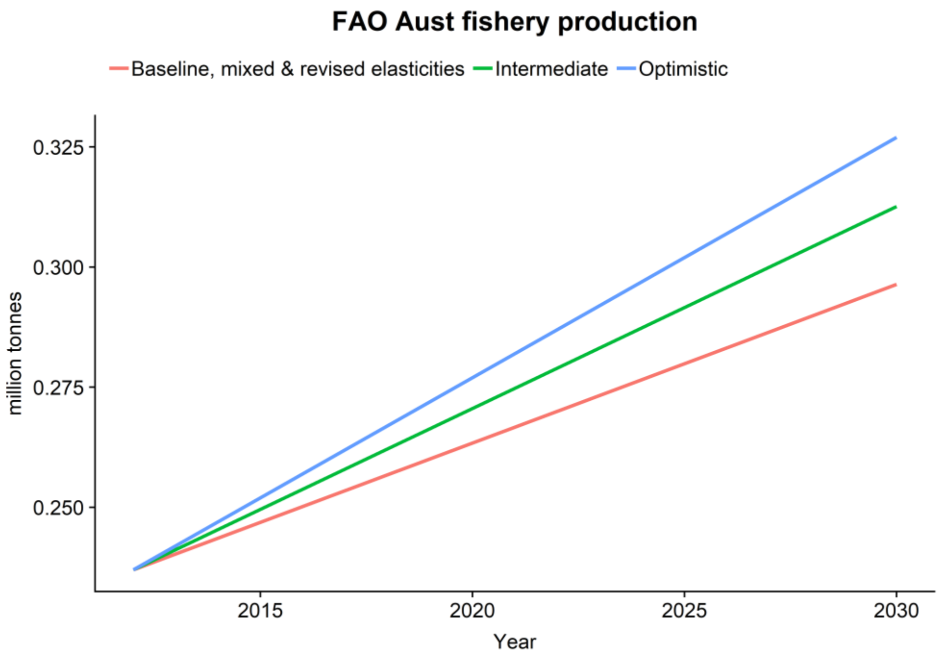

Figure 3 FAO Fisheries Model estimates for Australian total fishery production projected to 2030 based on estimates for 2012 & 2022 from Lem *et al.* (2014).

The Australian Stocks and Flows Framework (ASFF) (Foran and Poldy 2002) is an Australia-specific model that was developed to assesses the biophysical sustainability of the whole Australian economy with detailed accounting for physical processes. It is therefore a different type of model to the economic global models and in fact does not use monetary values as its "currency". It is also not a predictive model but it conditions its dynamics from historical trends and time series to provide possible futures for scenario. To simulate future fish production in Australia, historical data for 220 fish species from the Australian fisheries were incorporated and their trends were analysed by Kearney *et al.* (2003) and Lowe *et al.* (2003).

Drivers of the model is domestic consumption per capita derived from population growth and per capita consumption. The model calculates fish "flows" or catches from fish stocks and accounts for the boats, fuel, labour, and infrastructure required to produce those catches. However, only the logistic model of the fishery catch data impacts the fish stocks and no consideration is given to the broader ecosystem influences apart from fur seal predation. Individual responses for each fish stock are simulated and aggregated. In that sense the ASFF model is part way between the global food models- without their thoroughness of market prices and implications from trade- and whole-of-ecosystem models.

The Atlantis modelling software is a whole-of-ecosystem model that also accounts for the biophysical system as well as the social and economic systems. It was developed with a fishery focus explicitly model system processes and components of the marine system including the trophic interactions, habitats and fisheries, aquaculture and other marine industries but was expanded to include the environment and socio-economics (Fulton and Gorton 2014). Atlantis uses GDP and population growth in the implementations where socio-economic modelling is enabled e.g. Fulton and Gorton (2014), but they are not coupled therefore do not allow feedback. They have been used extensively to evaluate management strategies particularly and socio-economic and climate change drivers but more recently biodiversity and evolution modules have been added. Atlantis models have been developed for large regions of the Australian marine domain e.g. Fulton and Gorton (2014), Fulton *et al.* (2007), Johnson *et al.* (2011), Savina *et al.* (2008) but not for the whole as yet, and therefore are unable to provide comparable projections for the Australian economy.

1.2.1 Australian wild capture projections

Based on data from Lem *et al.* (2014), we calculated that the FAO model predicted Australian wild fish capture production to increase by 0.4% per year to 2022 to around 167 000 tonnes (Figure 4) for the majority of scenarios. The proportion of capture fishery of the total fishery production would decline from 70% to 60%.

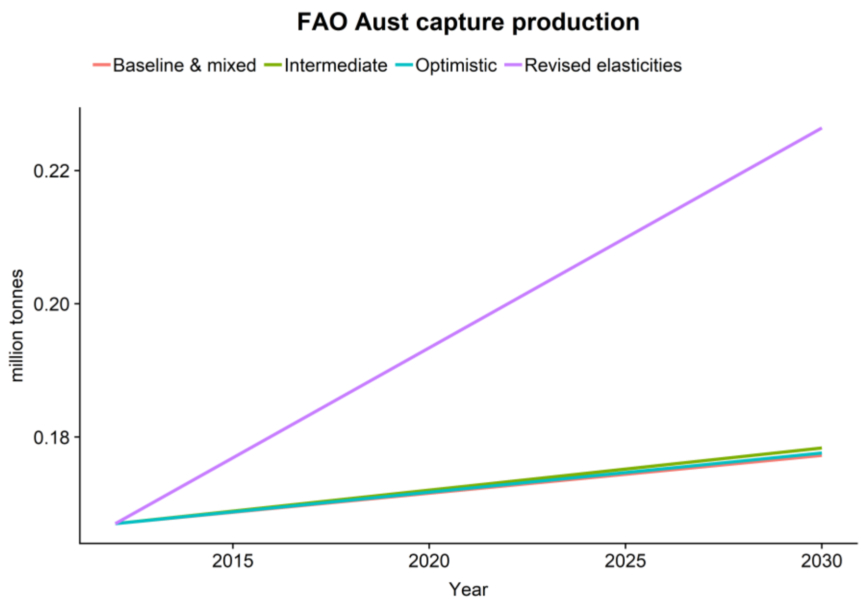

Figure 4 FAO Fisheries Model estimates for Australian wild capture production projected to 2030 based on estimates for 2012 & 2022 from Lem *et al.* (2014).

The ASFF model modelled three fisheries management sceanrios representing a range of active management :

> 'Cautious' which attempts to catch, from 2001 onwards, the average catch from the preceeding decade (1991-2000). If the fishery is reduced to below 20% virgin biomass, the fishery is closed until it regains the 20% level.
>
> 'Optimal long-term' which aims to increase biomass and resilience of fish stocks with initially lower catches. Where stocks are near virgin, catch rates are set to decrease to 72% of maximum sustainable yields (MSY) but where stocks are low, rates are set to 80% of annual growth rate.
>
> 'Continuous'fishing' which attempts to catch, in each fishery, the average catch from the predceeding decade but does not implement better mangement when stocks are low. Current markets and low discount rates dominate management decisisons. This represented the worst case management scenario.

The ASFF projections all fell from peak of about 200 000 tonnes suggesting overfished stocks and then continued to either decline steadily to 138 000 tonnes (continuous fishing), or to remain steady at 165 000 tonnes (cautious) or gradually increase to 188 000 tonnes (optimum long-term) (Figure 5).

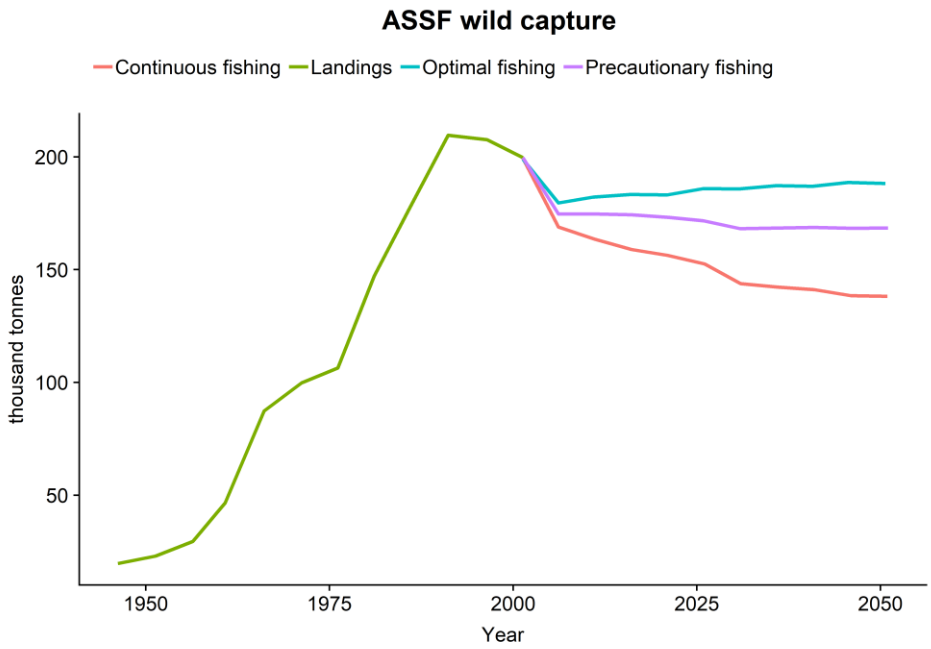

Figure 5 ASFF model projections for Australian wild capture production from 2001 and historical catches (1942-2001) (reproduced from Kearney *et al.* (2003) using Graph Grabber v2).

1.2.2 Australian aquaculture projections

Australian aquaculture is in a strong global position due to a high demand for protein from higher incomes and population growth, and represents a "viable and sustainable" alternative to capture fisheries (Deloitte Access Economics: http://www2.deloitte.com/au/en/pages/consumer-business/articles/where-are-growth-opportunities-australian-agriculture.html accessed 13 February 2019) and is growing rapidly, similarly to the rest of the world (Lehane 2013). Based on ABARES statistics for the decade 2003-2013, aquaculture production increased at a rate of 6.25% per annum similar to the rest of the world particularly since the late 1980s while that of wild capture production decreased at a rate of 3.21 % per annum.

In the decade from 2006-7, Australian aquaculture production increased by 53% and the value by 32%, resulting in a 44% share of the total fish production in Australia and ($1.35 billion) driven largely by the doubling of salmonid production (52,799 tonnes) and value ($756 million) (Mobsby 2018). The Tasmanian salmonid fishery in particular is the largest Australian fishery sector by value ($739 million in 2016-7) (Mobsby 2018), and alone is larger than all other Tasmanian aquaculture and wild-fishery sectors combined. Bluefin tuna and tiger prawns are two other high-value species farmed in Australia, along with rainbow trout, barramundi and various species of molluscs (Lehane 2013). Despite the growth of the industry, it contributes only 0.15% to total global production and 1% by value with the most important exports being farmed SBT to Japan and live lobster and abalone to Hong Kong, China and Vietnam (Mobsby 2018).

Only the FAO Fisheries model provided actual projections based on all but the mixed/ revised elasticities scenario. It predicted growth in Australian aquaculture from 39% (baseline) to 63% (optimistic) (Fig 6) (Lem *et al.* 2014).

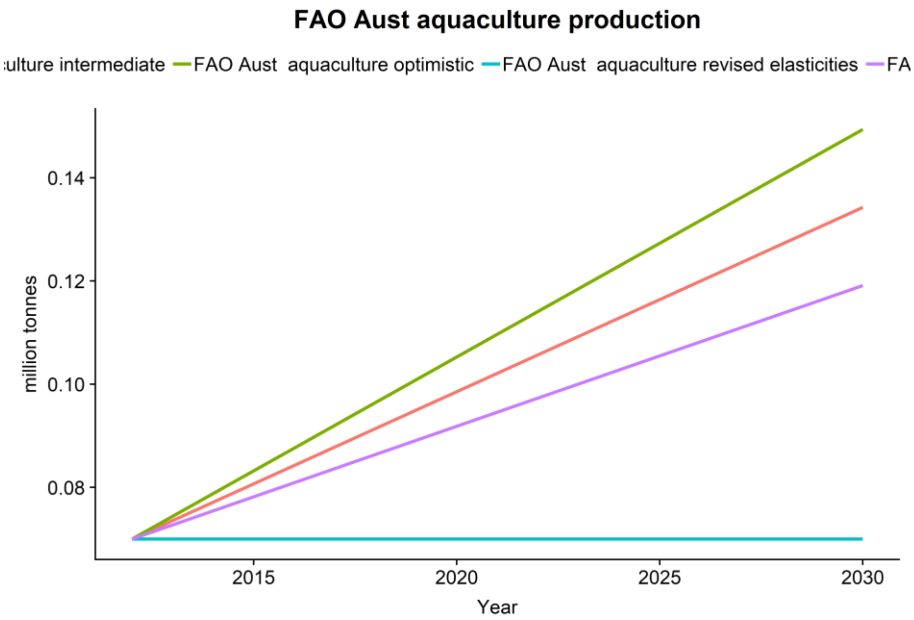

Figure 6. FAO Fisheries Model projection for Australian aquaculture production (FAO 2014; Lem *et al.* 2014).

The Futures to 2050 project (Kearney *et al.* 2003; Lowe *et al.* 2003) did not model aquaculture production but simply assumed a doubling from 2000 to 2020 (to 66 000 tonnes) and then doubled again by 2050 (130 000 tonnes). Therefore, aquaculture production was predicted to increase to about 30% of all fishery production (cautious scenario) slightly less than the predictions of the FAO model (39%-63% across all scenarios).

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