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Economic impact of climate change and climate change adaptation strategies for fisheries sector in Solomon Islands: Implication for food security

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ABSTRACT

Fisheries resources play a major role in the national economy and to food security in Solomon Islands. Climate change is likely to have a substantial impact on fish production that can lead to a fragile food security condition in the country. This paper assesses the potential economic impact of three important climate change adaptation strategies – natural resource management (NRM), fish aggregating devices (FAD) and aquaculture – in Solomon Islands. The study used a country-specific partial equilibrium economic model with six fish sub-sectors and analyzed potential impact of alternate climate change adaptation strategies for 2035 and 2050. The modeling and scenario analyses show that total fish demand is likely to surpass domestic fish production in 2050. Without appropriate climate adaptation strategy, per capita consumption of domestically produced fish will decline, which has serious negative food security implications for the country. The economic (welfare) analysis conducted based on modeling results show that the national level net economic gains due to climate change adaptation strategies are substantial. If cost and topographic conditions permit, low-cost inshore FADs are expected to be a good mechanism for augmenting domestic supplies of tuna and similar species in Solomon Islands.

1. Introduction

Solomon Islands is an archipelago comprising of almost 1000 islands and has a total water area and exclusive economic zone of 1,340,000 square kilometers (km^2). Given this expanse of sea area, the fisheries resources of the country play an important role in providing nutrition, income, employment and foreign exchange [1–3]. Fish and fish products are the primary source of animal protein in Solomon Islands, and these products contribute substantially to the food and nutrition security of Solomon Islanders [4–7]. The latest available household income and expenditure survey (2012/2013) indicated that fish and fish products accounted for 76.8% of total expenditure on animal protein in Solomon Islands; in some areas, fish make up more than 90% of the animal source food intake [8]. However, in the absence of policy changes, fish consumption in Solomon Islands is likely to decline in the future due to reduction in supply from coastal capture fisheries and increase in population pressure, which is a serious food security concern for the country [4,9].

Food security is a complex development issue. Like in other Pacific Island countries (PICs), food in Solomon Islands was previously secured primarily through subsistence farming, fishing, hunting and trading. This has, however, changed in recent years as national economic development has gradually shifted from agricultural-oriented production to service-based industries and export. Hence, the composition of food security has changed from locally produced food commodities to a mixture of local and imported food [1]). Such increased dependency on imported food has introduced a new kind of food insecurity and exposes Solomon Islands and other PICs to uncertainties in global food production and supply.

Climate change has a potential impact on the food production system and thus, food security in the PICs, including Solomon Islands. The most direct climate change impact includes further

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reductions of fisheries and aquaculture output resulting from increasing sea surface temperature, ocean acidification and rise in the sea level. Fish stocks will face massive problems with the destruction of coastal habitats and coral reefs [10]. Coastal fisheries, which are an integral component of the subsistence economy for the PICs, are likely to experience overfishing due to population increases, urban development, and loss of fish habitat [10]. In some cases, certain fisheries species may be favored by climate change but such advantages may be offset if extreme wet or dry condition exist [1,10].

Solomon Islands' fisheries sector can be placed into four broad categories: industrial offshore capture (foreign-based and locally-based), coastal capture (subsistence and commercial), freshwater capture, and aquaculture. Foreign fleets dominate offshore capture fisheries, and their catches are primarily for export markets. Coastal capture fisheries is the most important source of fish supply for domestic consumption in the country. The coastal subsistence fisheries are integral to food security and livelihood of the rural population[2] of Solomon Islands [4]. Though different studies have been conducted to measure the impact of climate change on biological and physical factors of the marine/coastal fisheries sector [11,12], studies exploring the economic impact on coastal subsistence fisheries and aquaculture sectors have been often overlooked [11].

People respond in different ways to climate changes in local settings [13], but the extent and benefit of such response or adaptation is still not very clear and is often location-specific [13,14]. There is a need to compile relevant literature and perform a quantitative analysis to identify the most viable climate change adaptation strategies for PICs. The current paper addresses this lacuna in knowledge, and measures the economic impact of climate change adaptation strategies in Solomon Islands by considering alternative scenarios and *ex-ante* impact indicators.

2. Climate change policy and related adaptation strategies for fisheries sector

The Solomon Islands *National Climate Change Policy 2012–2017* was developed by the Ministry of Environment, Climate Change, Disaster Management and Meteorology (MECDM) in 2012 [15]. The policy is guided by and linked to an existing framework of national, regional, and international policies and strategies. It aligns with the *Solomon Islands National Development Strategy 2011–2020* [16], complements other national policies and strategies, and is an expression of the country's commitment to international and regional multilateral environment agreements. The *National Climate Change Policy 2012–2017* has identified fisheries/aquaculture as an important sector [15]. However, specific climate change mitigation and adaptation strategies and their implementation in the sector are still very limited.

Before developing its *National Climate Change Policy 2012–2017*, the Solomon Islands Government (SIG) created the Solomon Islands National Adaptation Programme of Action (NAPA), established by the then Ministry of Environment, Conservation and Management (MECM) (currently MECDM) in 2008. The SIG created NAPA in response to the United Nations Framework Convention on Climate Change (UNFCCC) requirement to identify the country's specific needs resulting from the impacts of climatic change and the adaptation strategies being implemented to alleviate those impacts. The priority sectors of Solomon Islands for managing the effects of and enhancing resilience to climate change are agriculture and food security, water supply and sanitation, human settlements and human health, climate change adaptation on low-lying and artificially built-up islands, waste management, coastal protection, fisheries and marine resources, infrastructure development, and tourism [18, 19].

In the international and regional arenas, Solomon Islands has likewise participated in and signed several treaties and conventions specifically on climate change, including the UNFCCC in 1992, ratified in 1994; the Kyoto Protocol in 1998, ratified in 2003; submission of the Initial National Communication to the UNFCCC in 2004; participation in the Pacific Adaptation to Climate Change Project in 2000; endorsement of the *Pacific Island Framework for Action on Climate Change 2006–2015* in 2005 and disaster risk reduction and *National Disaster Risk Management Plan* in 2006; and completion of the Second National Communication to the UNFCCC [20].

Broadly speaking, Solomon Islands is implementing three main types of climate change adaptation strategies in the fisheries sector: (1) aquaculture; (2) natural resource management (NRM) approaches, and (3) low-cost inshore[3] fish aggregating devices (FADs). NRM approaches include (1) conservation and restoration of mangroves, (2) upstream watershed management, and (3) marine protected areas (MPAs) and locally managed marine areas (LMMAs).

MPAs fall under the Solomon Islands LMMAs. Govan [21] identified 127 LMMAs in the country, while the recent geographic information system of the Coral Triangle Atlas recorded 162 LMMAs [19]. The expansion of MPAs led to the 2007 establishment of the Solomon Islands LMMA Network. This in turn spearheaded the creation of the Protected Areas Act 2010 (No. 4 of 2010), Protected Areas Regulation 2012, and various national plans and frameworks on community-based resource management stipulated in the 2010 *Solomon Islands National Plan of Action* [19, 22]. The benefits and costs of MPAs are yet to be studied.

Low-cost inshore FADs have been in operation in various provinces of Solomon Islands since 2010, and additional FADs were deployed in 2011 [19]. FADs are a priority for the country, with an aim to increase national fish supply by attracting tuna and other offshore fisheries to inshore areas primarily for subsistence and small-scale fishers. A recent study examines the effect of FADs on the efficiency of fishing (catch rates) and the total fish landing in Solomon Islands [23]. FADs are expected to alleviate pressure on coastal reef fish [24].

Aquaculture was introduced in Solomon Islands in 1984. However, the political conflicts in the late 1990s prevented the full realization of the industry. To date, this industry is still underdeveloped. Most aquaculture is currently limited to seaweed, corals, and clams [19]. Culture species on the pipeline for aquaculture are milkfish, tilapia, black pearl, and edible oysters. As more rains are expected as a result of climate change, inland aquaculture of tilapia and milkfish is a potential key adaptation strategy for the country.

3. Methodology and data

The Solomon Islands model developed for this study considers four main groups: tuna, other oceanic finfish, coastal finfish, and coastal invertebrates. These fish species are found in mostly oceanic and coastal fishing areas of Solomon Islands. However, given the recent emphasis on aquaculture in Solomon Islands, two additional groups were considered in the model: freshwater finfish and freshwater invertebrates. Dey et al. [25], a companion

[2] According to the 2009 population census, 80.2% of the population is considered rural [17].

[3] It is also known as 'nearshore' FAD.

article in this special section of Marine Policy, provide the details of the model.

Data collected from both primary and secondary sources were utilized to run our model. Primary data used in the modeling were gathered with the application of the expert opinion survey (EOS) and focus group discussion (FGD). EOS was conducted in Honiara in August 2012. Experts from MECDM, the Ministry of Fisheries and Marine Resources, the National Project Management Unit-ANZDEC (now Finnish Consulting Group-ANZDEC), and national research partners (NRPs) participated in the survey.

A field visit to Isabel province was made to pre-test the FGD for capture fishers in March 2012. A second round of the FGD survey for capture fishers was implemented in August 2012, in which more than 60 representatives participated as leaders and members of various groups from the coastal and upland/inland villages that are likewise users of the Maringe Lagoon. Representatives of coastal villages were from Buala, Hovikoilo, Jejevo, Kubolota, Maglau, Nareubu, Popoheo, Solona, Tasia, and Tithiro, while representatives of inland/upland villages were from Bara, Gneulahage, Kolomosa, Kolokofo, Kulosori, Sugolona, Tholana, and Tirotongga. The FGD for fish farmers was not conducted in Isabel province because fish farming is not yet practiced in Buala and other south–east–west villages.

Three climate change adaptation scenarios in the modeling exercise were considered: aquaculture development (AQ), low-cost inshore FAD, and NRM. Scenario 1 (AQ) involves improvements in the productivity of freshwater (both finfish and invertebrate) aquaculture; scenario 2 (FAD) addresses the increase in tuna and oceanic fish catch; and scenario 3 (NRM) addresses production and productivity in coastal and oceanic capture fisheries due to management regime shifts and adoption of resource enhancement practices.

These scenarios and baseline scenarios with two different growth rates of per capita real income: a moderate growth rate of 2% per annum and a high growth rate of 3% per annum, were ran using the model. The projected populations of 969,920 in 2035 and 1,245,774 in 2050 were applied.

The model, the data used in the model, and the preliminary results were presented to various stakeholders at a “model validation meeting” held in Honiara on June 20, 2013. Based on comments received at the validation meeting, as well as comments from other experts, some minor adjustments were made to the model. The validated baseline data (production, consumption, trade, and price), supply elasticities, and demand elasticities used in the fish sector model for the Solomon Islands model are given in Appendix Tables A.1, A.2, and A.3, respectively. The supply volumes reported in Table A.1 and used in the analysis include catch by national fleets in both national and international waters, but do not include catch by foreign fleets in national waters. As discussed in Dey et al. [25], tuna catch by foreign fleets were treated as a residual sector, exogenous to the model. Unlike in Fiji and Vanuatu, tuna catch by foreign vessels is substantial in Solomon Islands.

The modeling exercise requires that information for each fish type be organized into a balance sheet, where the total supply of each fish type must be equal to its demand. The total supply (S) is equal to imports (M) and the sum of outputs from capture fisheries (Q_{cf}) and aquaculture (Q_a). On the other hand, the total fish demand is the sum of exports (X) and household demand (HD). In the end, it must be the case that $S=D$ or $M+Q_{cf}+Q_a=X+\text{HD}$ or $Q_{cf}+Q_a=X-M+\text{HD}$ for each of the fish types (see Appendix Table A.1). In Solomon Islands, like in most countries, there is no single source for all the data needed for the balance sheet and there are inconsistencies among various data sources. There is also documented evidence that questions the reliability of the published data on coastal fisheries production in Solomon Islands [26].

Four main sources of raw data (FAO [27], Gillett [2], 2005/06 household Income and expenditure survey [28] and the Sea Around Us Project of the University of British Columbia [26]) were used for the construction of the balance sheet. The raw data were then adjusted and reconciled in consultation of the experts knowledgeable about the fisheries sector in the region. The basic principle in adjusting the raw data was to retain as much as possible the original values for which relatively reliable data were available. The variables were adjusted to ensure that the balance sheet identities are satisfied for all fish types. It is important to note that the main purpose of this paper is to estimate the effect of climate change adaptation strategies based on comparative static analysis (compared to baseline situation). Therefore, the emphasis was on consistent and reliable estimates of balance sheet, not on precise estimates of fish production, consumption and trade during the base period (2006–2009).

The fish demand elasticities used in the model reflect consumers' preference patterns in Solomon Islands and the substitutability of various fish products with other sources of animal protein in the country. Given the artisanal nature of fisheries and relatively subsistence aquaculture, supply elasticities used in fish sector model for Solomon Islands are inelastic; absolute values of most of the supply elasticities are close to zero (the highest value is 0.30). Alternative sets of elasticities were likewise applied to test the sensitivity of the model and found that changes of elasticities within the possible range do not alter the main results.

The overall shifts in the supply curve as a result of climate change (i.e., effect of climate change on fish production) and various climate change adaptation strategies in Solomon Islands in 2035 and 2050 are reported in Appendix Table A.4. The projection of the Spatial Ecosystem and Population Dynamics Model (SEAPODYM) [29] was used for the likely effects of climate change on tuna catch under relatively low- and high-emission scenarios. Like in Fiji and other case study countries, the data on the likely effect of climate change under baseline conditions were taken (for 2035) or extended (for 2050) from Bell et al. [30], Gehrke et al. [31], Lehodey et al. [32], Pichering et al. [33], and Prachett et al. [34]. Climate change is likely to have positive effects on tuna and oceanic fish production in the shorter term [32] and negative effects on coastal fish production [34] in Solomon Islands. However, the likely positive effects of climate change on tuna catch are much smaller for Solomon Islands than those for Fiji and Vanuatu [32].

The likely effects of various climate change adaptation strategies on the shift in fish supply curves were estimated based on secondary literature [5,23,35] and primary data collected through the EOS and FGD, and are reported in columns 3, 4, 5, 7, 8, and 9 of Appendix Table A.4. The positive (or negative) values of the shift (λ) show an increase (or decrease) from the initial production level and/or a reduction (or increase) in the cost of fish production/capture. The use of FADs will allow coastal fishers to catch tuna and other oceanic fish in coastal waters. This will increase the supply of tuna and other oceanic species, and will shift their supply curves to the right. Various NRM strategies (such as MPAs and LLMAs) are likely to reduce some of the negative effects of climate change on coastal fisheries and shift the supply curves for coastal species to the right.

4. Results and discussion

This section reports and discusses the results of four scenarios (baseline and three climate change adaptation strategies) based on

Table 1
Percentage change (%) in projected price, production and consumption of key fisheries categories and aquatic ecosystems at 2% annual growth per capital real income, baseline and climate change adaptation strategies, Solomon Islands, from current (2006–2009) to 2035.
Source: Model projections by authors

Key fisheries categories/aquatic ecosystems	Baseline (trend+CC)	Climate change adaptation strategies		
		AQ (trend, CC, AQ)	FAD (trend, CC, FAD)	NRM (trend, CC, NRM)
Price				
Tuna	−2.34	1.50	−3.33	−1.59
Other oceanic finfish	−10.00	0.67	−13.71	−7.26
Coastal finfish	2.62	5.05	0.86	3.87
Coastal invertebrates	3.22	0.22	4.05	2.55
Freshwater finfish	21.53	0.35	27.29	16.03
Freshwater invertebrates	−5.05	−2.01	−6.39	−4.02
Production				
Oceanic	0.70	0.96	9.23	−0.03
Coastal	−3.36	−5.51	−6.27	3.30
Freshwater	1,935.90	3265.73	1642.05	1787.82
Consumption				
Oceanic	87.79	76.69	87.78	86.78
Coastal	49.41	58.21	46.45	50.90
Freshwater	28.20	59.83	20.20	35.64

Notes: AQ=aquaculture development; CC=climate change; FAD=fish aggregating device; NRM=natural resource management.

Table 2
Percentage change (%) in projected price, production and consumption of key fisheries categories and aquatic ecosystems at 3% annual growth per capital real income, baseline and climate change adaptation strategies, Solomon Islands, from current (2006–2009) to 2035.
Source: Model projections by authors

Key fisheries categories/aquatic ecosystems	Baseline (trend+CC)	Climate change adaptation strategies		
		AQ (trend, CC, AQ)	FAD (trend, CC, FAD)	NRM (trend, CC, NRM)
Price				
Tuna	−1.92	2.02	−2.48	−1.12
Other oceanic finfish	−9.74	0.89	−10.54	−7.00
Coastal finfish	4.26	6.53	4.40	5.49
Coastal invertebrates	3.30	0.28	3.34	2.62
Freshwater finfish	21.58	0.43	21.68	16.08
Freshwater invertebrates	−5.60	−2.61	−5.77	−4.58
Production				
Oceanic	0.63	0.94	9.71	−0.09
Coastal	−3.28	−5.52	−5.58	3.39
Freshwater	1879.39	3150.58	1311.62	1725.06
Consumption				
Oceanic	123.46	108.37	125.39	121.66
Coastal	71.40	80.98	69.65	73.00
Freshwater	47.75	83.22	47.20	56.14

*Notes:*AQ=aquaculture development; CC=climate change; FAD=fish aggregating device; NRM=natural resource management.

various assumptions mentioned earlier. Some sensitivity analysis had been undertaken with different estimates of baseline data (production, consumption and trade data for the 2006–2009 period) and alternatives values of elasticities, and main conclusions on these adaptation strategies remained unchanged.

Table 3
Percentage change (%) in projected price, production and consumption of key fisheries categories and aquatic ecosystems at 2% annual growth per capital real income, baseline and climate change adaptation strategies, Solomon Islands, from current (2006–2009) to 2050.
Source: Model projections by authors

Key fisheries categories/aquatic ecosystems	Baseline (trend+CC)	Climate change adaptation strategies		
		AQ (trend, CC, AQ)	FAD (trend, CC, FAD)	NRM (trend, CC, NRM)
Price				
Tuna	−0.41	2.98	−1.96	0.55
Other oceanic finfish	−5.99	1.32	−9.51	−3.51
Coastal finfish	8.80	9.19	7.67	9.69
Coastal invertebrates	2.36	0.40	3.08	1.76
Freshwater finfish	16.17	0.59	21.80	10.79
Freshwater invertebrates	−5.52	−3.70	−6.73	−4.65
Production				
Oceanic	1.94	1.19	14.52	1.26
Coastal	−9.58	−12.62	−13.13	−3.13
Freshwater	1881.97	3829.60	1228.10	1705.93
Consumption				
Oceanic	203.27	180.60	209.36	199.24
Coastal	122.33	131.10	118.14	124.52
Freshwater	101.75	134.38	90.12	113.17

Notes: AQ=aquaculture development; CC=climate change; FAD=fish aggregating device; NRM=natural resource management.

Table 4
Percentage change (%) in projected price, production and consumption of key fisheries categories and aquatic ecosystems at 3% annual growth per capital real income, baseline and climate change adaptation strategies, Solomon Islands, from current (2006–2009) to 2050.
Source: Model projections by authors

Key fisheries categories/aquatic ecosystems	Baseline (trend+CC)	Climate change adaptation strategies		
		AQ (trend, CC, AQ)	FAD (trend, CC, FAD)	NRM (trend, CC, NRM)
Price				
Tuna	0.45	3.80	−1.15	1.43
Other oceanic finfish	−5.57	1.67	−9.08	−3.10
Coastal finfish	11.01	11.26	9.96	11.96
Coastal invertebrates	2.46	0.49	3.18	1.86
Freshwater finfish	16.17	0.68	21.81	10.80
Freshwater invertebrates	−6.28	−4.57	−7.48	−5.39
Prooduction				
Oceanic	1.97	1.21	14.58	1.27
Coastal	−9.61	−12.72	−13.18	−3.11
Freshwater	1759.22	3626.60	1097.73	1579.74
Consumption				
Oceanic	283.07	253.48	292.64	277.46
Coastal	169.52	179.86	164.93	171.68
Freshwater	145.32	184.01	131.81	158.96

Notes: AQ=aquaculture development; CC=climate change; FAD=fish aggregating device; NRM=natural resource management.

4.1. Changes in fish prices

Tables 1–4 show projected changes in the real prices of different fish species groups in 2035 (medium term) and 2050 (long term). The model projects that the real price of tuna will decrease by about 2.0% during 2009–2035 under the baseline scenarios. Given that the concentration of skipjack and bigeye tuna are likely to be located further east due to climate change [32], this result is highly likely. The model predicts that the implementation of FADs will further decrease the real price of tuna in 2035 and 2050 relative to other scenarios. Even with higher growth in per capita income, implementation of this adaptation strategy is expected to reduce tuna prices by 2050. Given the relatively high contribution of tuna to fish and seafood consumption in Solomon Islands, adoption of low-cost inshore FADs is likely to substantially enhance the country's food security.

The projected decline in real prices of other oceanic fish species under the baseline scenarios is mainly the result of higher imports of this fish category. At present, Solomon Islands imports this category of fish primarily in the form of processed anchovies and sardines. Given the higher domestic price relative to the world price of this fish category, imports of this fish are likely to increase and real prices are likely to decline under the baseline scenarios.

The coastal finfish category is the most important fish type for domestic consumption. The real price of coastal finfish and invertebrates are expected to rise in the medium-term (2035) and long-term (2050). Adoption of FADs is likely to halt the rise of coastal finfish prices at least under the scenario of lower (2%) growth in per capita income. The model predicts that the aquaculture development strategy will reduce the real price of coastal invertebrates.

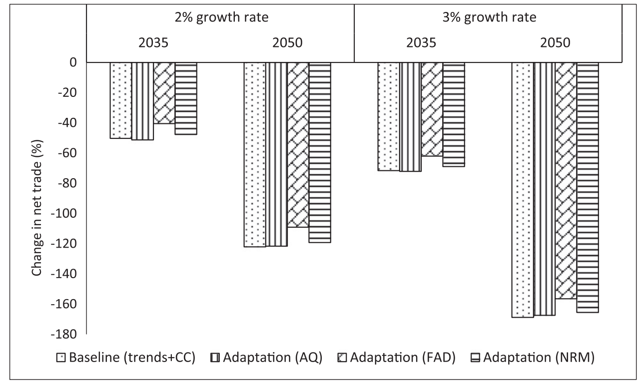
4.2. Changes in fish production

The model projects that oceanic fish production will marginally increase over the period (2006/9 to 2035 and 2006/9 to 2050) under the baseline scenarios. Among the various adaptation strategies considered in the modeling exercise, adoption of FADs is likely to have the highest positive impact on oceanic fish supply (Tables 1–4). The model predicts that FADs will increase supply of oceanic fish by about 9–10% of the current level in 2035 and by about 14%–15% in 2050. Given that oceanic fisheries is an important contributor of fish supply in Solomon Islands, use of FADs is expected to have a significant positive impact on the fisheries economy and food security of Solomon Islands. As in the assessment for the other countries, that projected rate of increase in national tuna production due to increased investment in FADs is well within the sustainable tuna catch (see, for example, [32,36]). Other adaptation strategies (aquaculture and NRM) are not expected to have any significant positive impact on oceanic fish supply.

The results show that NRM strategy is likely to have positive impacts on coastal fish supply in the medium term (2035) and long term (2050) (Tables 1–4). The model projects that FADs may have a negative impact on coastal fisheries supply, mainly because of the substitution effect between coastal and oceanic fish supplies. FADs are expected to reduce fishing pressure on coastal resources, providing an opportunity for over-exploited resources to recover and to build resilience to climate change.

The freshwater fisheries/aquaculture sector is still a very minor supplier of fish in Solomon Islands[4]. The model predicts that aquaculture development will increase freshwater fish production by about 31 to 33 times (from a very low base) in the medium term (2035) and by about 36 to 38 times in the long term (2050) (Tables 1–4). Aquaculture development is also likely to have some negative impact on the coastal sector, primarily due to substitution effect between coastal and freshwater fish supplies.

[4] Very high numbers of percentage increase in freshwater fish production reported in Tables 1 to 4 are due to extremely low base.



Notes: AQ = aquaculture development; CC = climate change; FAD = fish aggregating device; NRM = natural resource management

Fig. 1. Percentage change (%) in net trade of baseline and climate change adaptation strategies with annual growth of per capita real income at 2% and 3% from current (2006–2009) to 2035 and 2050, Solomon Islands.

Table 5
National-level economic gain (equivalent variation) resulting from climate change adaptation strategies in Solomon Islands, annual value in 2035 and 2050.
Source: Authors, calculated based on model projections.

Climate change adaptation strategies	Economic gain per year (US$ in 2009 prices)	
	2035	2050
Aquaculture	228,620	370,466
Fish aggregating devices	6,955,473	10,079,458
Natural resource management	2,620,743	2,571,135

4.3. Changes in fish consumption

The model projects that aquaculture development will increase consumption of freshwater fish in 2035 and 2050, and that the impact will increase along with per capita real income (Tables 1–4). While adoption of FADs and NRM strategies may not increase fish consumption, increased fish production from these strategies is likely to replace imports with domestic supply.

4.4. Changes in net trade (export minus import)

Fig. 1 shows the likely effects of different climate change adaptation strategies on fish trade in Solomon Islands in medium term (2035) and long term (2050). Among various adaptation strategies examined, FADs are expected to significantly reduce the country's likely dependence on fish imports in the long term. As suggested by Bell et al. [24], FADs promise to increase access to tuna in coastal rural areas and to some extent in urban areas. However, where transshipping occurs, small tuna and bycatch will supply most of the additional low cost fish needed by urban populations over and above catches available from coastal demersal fisheries. The role of FADs will be even more important if the country's per capita real income rises at a faster rate.

4.5. National-level economic gains resulting from climate change adaptation strategies

Table 5 shows the estimated national-level net economic gains to both consumers and producers as a result of various climate change adaptation strategies in Solomon Islands. These estimates show that the yearly net economic gain from aquaculture, FAD, and NRM adaptation strategies are around $0.37 million, $10.08 million, and $2.57 million in 2050 (in 2009 constant price), respectively. These estimated net economic gains from various adaptation strategies are significantly higher compared with their investment costs. Among the various adaptation strategies, FADs appear to be the most economically attractive adaptation strategy for Solomon Islands. The production increase (supply curve shift) resulting from FADs assumed in the model will require a yearly investment[5] of about $230,000 and is expected to generate a yearly income of more than $6.95 million in 2035 (a more than 30-fold increase in yearly net return).

5. Summary and conclusion

The review and analysis of available literature; the discussions at the national, provincial, and community levels through the EOS and FGD; and the modeling results and assessment carried out for this paper generated key messages for Solomon Islands with and without climate change adaptation strategies.

Without any climate adaptation strategies, domestic demand for fish is likely to surpass the supply from domestic sources (i.e., the domestic fishing industry and aquaculture farms, but not including the catch of foreign fishing fleets) in the long term (2050). The major part of this increased demand will be for oceanic fish species, such as tuna. If Solomon Islands cannot catch more oceanic fish than otherwise harvested by foreign vessels, the country may have to import fish in large volumes in the long term to meet the projected demand. Increases in the domestic supply of tuna and other oceanic species will be helpful to meet the growing demand for this category of fish. Strategies to increase domestic supply may include harvest of tuna and other oceanic pelagic species by domestic fleets, use of FADs to capture tuna and other oceanic fish in coastal waters, and onshore processing of tuna for domestic markets. Bell et al. [24] described various management measures and supporting policies that are required for increasing local access to tuna.

Among the various adaptation strategies considered in the modeling, adoption of FADs is likely to have the highest positive impact on oceanic fish supply, which will increase by about 9–10% of the current level in 2035 and by about 14–15% in 2050. Implementation of FADs as an adaptation strategy will decrease the real price of tuna in 2035 and 2050. Even with higher growth in per capita income, FADs are expected to reduce tuna prices by 2050. Use of FADs is expected to significantly enhance the country's fisheries economy and food security.

The real price of coastal finfish and invertebrates are projected to rise in 2035 and 2050. With lower (2%) growth in per capita income, adoption of NRM strategies is likely to halt the rise of coastal finfish prices. Also, aquaculture development strategies will reduce the real price of coastal invertebrates.

NRM strategy is likely to have some positive impact on coastal fish supply. The model projects that FADs may have a negative impact on coastal fisheries supply, thereby reducing fishing pressure on coastal resources and providing an opportunity for overexploited resources to recover and to build resilience to climate change.

Aquaculture development will increase consumption of freshwater fish in 2035 and 2050. This impact will increase along with per capita real income. Although FADs and NRM strategies may not increase fish consumption, increased fish production from these strategies is likely to replace imports with domestic supply.

Among various adaptation strategies examined, FADs are expected to significantly reduce the country's likely dependence on fish imports in the long term. The role of FADs in reducing net import (increasing net export) will be even more important if the country's per capita real income rises at a faster rate.

The national-level net economic gains were calculated at US $0.37 million for aquaculture, US$10.08 million for FAD, and US $2.57 million for NRM strategies in 2050 (in 2009 constant price). Of these three climate change adaptation strategies, FAD appears to be the most economically viable adaptation strategy for Solomon Islands. Modeling results indicated that an annual investment of about US$230,000 in FAD will eventually generate annual income of about US$7 million in 2035. It is however important to note that these strategies are not "either or" options; they should all be implemented [38].

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Appendix

See Tables A.1, A.2, A.3, A.4.

Table A.1
Aggregated fish balance sheet for Solomon Islands fish model, 2006–2009.
Sources: EOS, Honiara, Solomon Islands, August 2012; FGD, Isabel Province, Solomon Islands, August 2012; post-survey validation meeting, Honiara, Solomon Islands, June 2013; FAO [27]; Gillet [2]; Solomon Islands National Statistical Office [28]; Doyle et al. [26].

Fish Group	Production (*t*)	Consumption (*t*)	Net Trade (*t*)	Price ($/t)
Tuna	22388.75	5672.75	16716.00	3700
Other oceanic finfish	3624.50	296.50	3328.00	3700
Coastal finfish	11500.00	9829.00	1671.00	3381
Coastal invertebrates	1910.33	1683.33	227.00	7500
Freshwater finfish	30.00	30.00	0	2560
Freshwater invertebrates	1.0	1.0	0	7500
Total	39454.58	17512.58	21942.00	–

Note: Net trade positive = net export and Net trade negative = net import.

[5] Refer to Sharp [37] for detailed discussions on the cost of FADs in the Pacific.

Table A.2
Validated supply elasticity estimates for various fish groups used in Solomon Island fish model.
Sources: Dey et al. [39]; EOS, Honiara, Solomon Islands, August 2012; FGD, Isabel Province, Solomon Islands, August 2012; post-survey validation meeting, Honiara, Solomon Islands, June 2013

Fish Group	Tuna	Other oceanic finfish	Coastal finfish	Coastal invertebrates	Freshwater finfish	Freshwater invertebrates
Tuna	0.30					
Other oceanic finfish	0.10	0.30				
Coastal finfish	−0.15	−0.20	0.35			
Coastal invertebrates	−0.15	−0.05	−0.05	0.30		
Freshwater finfish	−0.05	−0.05	−0.05	−0.05	0.25	
Freshwater invertebrates	−0.05	−0.10	0.10	0.00	−0.05	0.10

Table A.3
Validated demand elasticity estimates for various fish groups used in Solomon Islands fish model.
Sources: Dey et al. [39]; EOS, Honiara, Solomon Islands, August 2012; FGD, Isabel Province, Solomon Islands, August 2012; post-survey validation meeting, Honiara, Solomon Islands, June 2013.

Fish group	Tuna	Other oceanic finfish	Coastal finfish	Coastal invertebrates	Freshwater finfish	Freshwater invertebrates
Price elasticity						
Tuna	−1.05					
Other oceanic finfish	0.20	−1.00				
Coastal finfish	0.20	0.05	−0.95			
Coastal invertebrates	0.10	0.05	0.10	−0.95		
Freshwater finfish	0.10	0.15	0.15	0.00	−1.00	
Freshwater invertebrates	0.00	0.05	0.00	0.00	0.15	−0.90
Income elasticity	0.45	0.50	0.45	0.70	0.45	0.70

Table A.4
Shift in supply curve[a] (%) from current (2006–2009) to 2035 and 2050, under alternative climate change adaptation strategies in Solomon Islands.
Sources: Authors. Calculated based on secondary literature [5, 23, 30–35], and on primary data (EOS, Honiara, Solomon Islands, August 2012; FGD, Isabel Province, Solomon Islands, August 2012; post-survey validation meeting, Honiara, Solomon Islands, June 2013).

Species group	2035				2050			
	Baseline (trend)	AQ	FAD	NRM	Baseline (trend)	AQ	FAD	NRM
Tuna	3	3	10	3	3	3	13	3
Other oceanic finfish	3	3	10	3	3	3	13	3
Coastal finfish	−5	−5	−5	0	−10	−10	−10	−5
Coastal Invertebrates	−5	−5	−5	0	−10	−10	−10	−5
Freshwater finfish	12.5	75	12.5	12.5	25	100	25	25
Freshwater invertebrates	25	25	25	25	25	25	25	25

Note: [a]This shift in supply curve has been denoted in equation (2) of Dey et al. [25] as (λ_0) for baseline scenarios and as (λ_1) for various climate change adaptation scenarios. AQ=aquaculture; FAD=fish aggregating device; NRM=natural resource management.

References

[1] M. Ahmed, J. Maclean, R.V. Gerpacio, M.A. Sombilla, Food Security and Climate Change: Rethinking the Options, Asian Development Bank (ADB): Pacific Studies Series, 2011 ⟨http://www.adb.org/publications/food-security-and-climate-change-pacific-rethinking-options⟩.

[2] R. Gillett., Fisheries in the Economies of the Pacific Island Countries and Territories, Asian Development Bank (ADB): Pacific Studies Series, 2009 ⟨http://www.adb.org/sites/default/files/publication/27511/pacific-fisheries.pdf⟩.

[3] N. Weeratunge, D. Pemsl, P. Rodriguez, O.L. Chen, M.C. Badjeck, A.M. Schwarz, C. Paul, J. Prange, I. Kelling, Planning the use of fish for food security in Solomon Islands, Coral Triangle Support Partnership, 2011, pp. 51. ⟨http://www.coraltriangleinitiative.org/sites/default/files/resources/1_Planning%20the%20Use%20of%20Fish%20for%20Food%20Security%20in%20Solomon%20Islands.pdf⟩.

[4] J.D. Bell, M. Kronen, A. Vunisea, W.J. Nash, G. Keeble, A. Demmkea, S. Pontifex, S. Andrefoue, Planning the use of fish for food security in the Pacific, Mar. Policy 33 (2009) 64–76, http://www.sciencedirect.com/science/article/pii/S0308597X08000778.

[5] N. Cleasby, A.M. Schwarz, M. Phillips, C. Paul, J. Pant, J. Oeta, T. Pickering, A. Meloty, M. Laumani, M. Kori, The socio-economic context for improving food security through land based aquaculture in Solomon Islands: a peri-urban case study, Mar. Policy 45 (2014) 89–97, http://ac.els-cdn.com/S0308597X13002741/1-s2.0-S0308597X13002741-main.pdf?_tid=475b421e-b2f9-11e5-8ada-00000aacb35e&acdnat=1451922122_2cc15a83894b0666a6d29ed9fced8495.

[6] S.J. Foale, D. Adhuri, P. Aliño, E. Allison, N. Andrew, P. Cohen, L. Evans, M. Fabinyi, P. Fidelman, C.A. Gregory, N. Stacey, J. Tanzer, N. Weeratunge, Food security and the Coral Triangle Initiative, Mar. Policy 38 (2013) 174–183 ⟨http://www.sciencedirect.com/science/article/pii/S0308597X12001315⟩.

[7] M.G. Allen, R.M. Bourke, B.R. Evans, E. Iramu, R.K. Maemouri, B.F. Mullen, A. A. Pollard, M. Wairiu, C. Watoto, S. Zotalis, Solomon Islands Smallholder Agriculture Study provincial reports, AusAid Australian Government, Canberra (2006), p. 154.

[8] Solomon Islands National Statistics Office, Solomon Islands 2012/13 Household Income and Expenditure Survey, National Analytical Report (Volume I) and Provincial Analytical Report (Volume II). Honiara, Solomon Islands, 2015.

[9] WorldFish, the Solomon Islands Ministry of Fisheries and Marine Resources, and the Secretariat for the Pacific Community. Aquaculture and food security in the Solomon Islands – Phase 1, Final Report, 152 pp, 2011.

[10] J.D. Bell, J.E. Johnson, A.J. Hobday (Eds.), Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change, Secretariat of the Pacific Community, Noumea, New Caledonia, 2011 ⟨⟨http://www.spc.int/en/component/content/article/257-climate-book/969-climate-book.html⟩⟩.

[11] A.C. Haynie, L. Pfeiffer, Why economics matters for understanding the effects of climate change on fisheries, ICES J. Mar. Sci. 69 (7) (2012) 1160–1167, ⟨http://dx.doi.org/10.1093/icesjms/fss021 ⟨⟨http://icesjms.oxfordjournals.org/content/early/2012/02/27/icesjms.fss021.full.pdf+html⟩⟩.

[12] T. Daw, N. Adger, K. Brown, M.C. Badjeck, Climate change and capture fisheries, in: K. Cochrane, C. De Young, D. Soto, T. Bahri (Eds.), Climate Change Implications for Fisheries and Aquaculture: Overview of Current Scientific Knowledge, 530, FAO Fisheries and Aquaculture Technical Paper. FAO, Rome, 2009, pp. 95–135 ⟨⟨http://www.fao.org/docrep/012/i0994e/i0994e03.pdf⟩⟩.

[13] C. Shelton, Climate change adaptation in fisheries and aquaculture – compilation of initial examples. FAO Fisheries and Aquaculture Circular No. 1088. Rome, FAO, p. 34, 2014. ⟨http://www.fao.org/3/a-i3569e.pdf⟩.

[14] M.L. Perez, A.J.U. Sajise, P.J.B. Ramirez, J.K.B. Arias, A.H. Purnomo, S.R. Dipasupil, P.A. Regoniel, K.A.T. Nguyen, G.J. Zamora, Economic analysis of climate

change adaptation strategies in selected coastal areas in Indonesia, Philippines and Vietnam. WorldFish, Penang, Malaysia. Project Report: 2013-32, ⟨http://pubs.iclarm.net/resource_centre/WF-2013-32.pdf⟩.
[15] Government of Solomon Islands, National Climate Change Policy 2012–2017, ⟨http://www.gcca.eu/sites/default/files/catherine.paul/si_climate_change_policy.pdf⟩.
[16] Government of Solomon Islands, Solomon Islands National Development Strategy 2011–2020, 2011. ⟨http://www.adb.org/sites/default/files/linked-documents/cobp-sol-2015-2017-sd.pdf⟩.
[17] Solomon Islands National Statistics Office, Solomon Islands 2009 population and housing census, 2012. ⟨http://www.spc.int/prism/solomons/index.php/sinso-documents?view=download&fileId=60⟩.
[18] Government of Solomon Islands, Solomon Islands National Adaptation Programmes of Action, Ministry of Environment, Conservation and Meteorology, November 2008, ⟨http://unfccc.int/resource/docs/napa/slb01.pdf⟩.
[19] H. Kauhiona, A. Vevekaramui, National Climate Change Policies, Development Plans and Strategies Affecting Coastal Communities in Solomon Islands, Paper presented during the Final Regional Workshop of the Climate Change and Development Strategies for Coastal Communities of the Pacific Coral Triangle Countries, Port Vila, Vanuatu, pp. 18–19 September 2013.
[20] Government of Solomon Islands, Second National Communication to the UNFCCC, Ministry of Environment, Conservation and Meteorology (MECDM), 2012.
[21] H. Govan, Achieving the potential of LMMA in the South Pacific Region, SPC Traditional Marine Resource Management and Knowledge Bulletin, vool. #25, 2009, ⟨http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/TRAD/25/Trad25_16_Govan.pdf⟩.
[22] Government of Solomon Islands, Solomon Islands National Plan of Action, 2010, ⟨http://www.sids2014.org/content/documents/151NAPA.pdf⟩.
[23] J.A. Albert, D. Beare, A.M. Schwarz, S. Albert, R. Warren, J. Teri, F. Siota, N. L. Andrew., The contribution of nearshore fish aggregating devices (FADs) to food security and livelihoods in Solomon Islands, PLoS ONE 9 (12) (2014) e115386, ⟨http://dx.doi.org/10.1371/journal.pone.011538 ⟨http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0115386⟩.
[24] J.D. Bell, V. Allain, E.H. Allison, S. Andréfouët, N.L. Andrew, M.J. Batty, et al., Diversifying the use of tuna to improve food security and public health in Pacific Island countries and territories, Mar. Policy 51 (2015) 584–591 ⟨http://www.sciencedirect.com/science/article/pii/S0308597X1400267X⟩.
[25] M.M. Dey, M.W. Rosegrant, K. Gosh, O.L. Chen, R. Valmonte-Santos, Analysis of the economic impact of climate change and related adaptation strategies for fisheries sector in Pacific coral triangle countries: Model, estimation strategy, and baseline results, Mar. Policy 67 (2016) 156–163, ⟨http://dx.doi.org/10.1016/j.marpol.2015.12.011⟩.
[26] B. Doyle, S. Harper, J. Jacquet, D. Zeller. Reconstructing marine fisheries catches in the Solomon Islands: 1950-2009. pp. 119–134. In: Harper, S., Zylich, K., Boonzaier, L., Le Manach, F., Pauly, D., and Zeller D. (eds.) Fisheries catch reconstructions: Islands, Part III. Fisheries Centre Research Reports 20(5). Fisheries Centre, University of British Columbia [ISSN 1198-6727]. 2012.
[27] FAO (Food and Agricultural Organization) 2012. FishStatJ. Fisheries Statistics Database. FAO, Rome, Italy. ⟨http://www.fao.org/fishery/statistics/software/fishstatj/en⟩.
[28] Solomon Islands National Statistics Office, Household Income and Expenditure Survey 2005/6, Provincial report (part two), Honiara, 2006. ⟨http://www.spc.int/prism/solomons/index.php/sinso-documents?view=download&fileId=107⟩.
[29] P. Lehodey, I. Senina, R. Murtugudde, A spatial ecosystem and populations dynamics model (SEAPODYM) – Modeling of tuna and tuna-like populations, Prog. Ocean. 78 (2008) 304–318 ⟨⟨http://www.sciencedirect.com/science/article/pii/S007966110800116X⟩⟩.
[30] J.D. Bell, J.H. Adams, J.E. Johnson, A.J. Hobday, A. Sen Gupta, Chapter 1. Pacific communities, fisheries, aquaculture and climate change: An introduction, in: J. D. Bell, J.E. Johnson, A.J. Hobday (Eds.), Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change, Secretariat of the Pacific Community, Noumea, New Caledonia, 2011 ⟨⟨http://cdn.spc.int/climate-change/fisheries/assessment/chapters/1-Chapter1.pdf⟩⟩.
[31] P.C. Gehrke, M.J. Sheaves, D. Boseto, B.S. Figa, J. Wani, Chapter 10. Vulnerability of freshwater and estuarine fisheries in the tropical Pacific to climate change, in: J.D. Bell, J.E. Johnson, A.J. Hobday (Eds.), Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change, Secretariat of the Pacific Community, Noumea, New Caledonia, 2011 ⟨⟨http://cdn.spc.int/climate-change/fisheries/assessment/chapters/10-Chapter10.pdf⟩⟩.
[32] P. Lehodey, J. Hampton, R.W. Brill, S. Nicol, I. Senina, B. Calmettes, H.O. Pörtner, L. Bopp, T. Ilyina, J.D. Bell, J. Sibert, Chapter 8. Vulnerability of oceanic fisheries in the tropical Pacific to climate change, in: J.D. Bell, J.E. Johnson, A.J. Hobday (Eds.), Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change, Secretariat of the Pacific Community, Noumea, New Caledonia, 2011 ⟨⟨http://cdn.spc.int/climate-change/fisheries/assessment/chapters/8-Chapter8.pdf⟩⟩.
[33] T.D. Pickering, B. Ponia, C.A. Hair, P.C. Southgate, E.S. Poloczanska, L.D. Patrona, A. Teitelbaum, C.V. Mohan, M.J. Phillips, J.D. Bell, S. De Silva, Chapter 11. Vulnerability of aquaculture in the tropical Pacific to climate change. In, in: J. D. Bell, J.E. Johnson, A.J. Hobday (Eds.), Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change, Secretariat of the Pacific Community, Noumea, New Caledonia, 2011 ⟨⟨http://cdn.spc.int/climate-change/fisheries/assessment/chapters/11-Chapter11.pdf⟩⟩.
[34] M.S. Pratchett, P.L. Munday, N.A.J. Graham, M. Kronen, S. Pinca, K. Friedman, T. D. Brewer, J.D. Bell, S.K. Wilson, J.E. Cinner, J.P. Kinch, R.J. Lawton, A.J. Williams, L. Chapman, F. Magron, A. Webb, Chapter 9. Vulnerability of coastal fisheries in the tropical Pacific to climate change, in: J.D. Bell, J.E. Johnson, A.J. Hobday (Eds.), Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change, Secretariat of the Pacific Community, Noumea, New Caledonia, 2011 ⟨⟨http://cdn.spc.int/climate-change/fisheries/assessment/chapters/9-Chapter9.pdf⟩⟩.
[35] P. Cohen, S.J. Foale, Sustaining small-scale fisheries with periodic closures, Mar. Policy 37 (2013) 278–287 ⟨⟨http://www.sciencedirect.com/science/article/pii/S0308597X1200098X⟩⟩.
[36] J.D. Bell, A. Ganachaud, P.C. Gehrke, S.P. Griffiths, A.J. Hobday, O. Hoegh-Guldberg, J.E. Johnson, R. Le Borgne, P. Lehodey, J.M. Lough, R.J. Matear, T. D. Pickering, M.S. Pratchett, A. Sen Gupta, I. Senina, M. Waycott, . Mixed responses of tropical Pacific fisheries and aquaculture to climate change, Nat. Clim. Chang. 3 (2013) 591–599, ⟨http://dx.doi.org/10.1038/NCLIMATE1838.
[37] M. Sharp, The benefits of fish aggregating devices in the Pacific, SPC Fish. Newsl. 35 (2013), May–August 2011 ⟨http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/135/FishNews135_27_Sharp.pdf⟩.
[38] J.D. Bell, N.L. Andrew, M.J. Batty, L.B. Chapman, J.M. Dambacher, B. Dawson, A. S. Ganachaud, P.C. Gehrke, et al. Chapter 13. Adapting tropical Pacific fisheries and aquaculture to climate change: Management measures, policies and investments. In Bell, J.D., J.E. Johnson and A.J. Hobday (eds). Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change. Secretariat of the Pacific Community, Noumea, New Caledonia. 2011. ⟨http://cdn.spc.int/climate-change/fisheries/assessment/chapters/13-Chapter13.pdf⟩.
[39] M.M. Dey, R.M. Briones, Y.T. Garcia, A. Nissapa, U.P. Rodriguez, R.K. Talukder, A. Senaratne, I.H. Omar, S. Koeshendrajana, N.T. Khiem, T.S. Yew, M. Weimin, D.S. Jayakody, P. Kumar, R. Bhatta, M.S. Haque, M.A. Rab, O.L. Chen, L. Luping, F. J. Paraguas, Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poorer Households in Asia, The WorldFish Center, Penang, Malaysia (2008), p. 180, WorldFish Center Studies and Reviews No. 1823 ⟨http://pubs.iclarm.net/resource_centre/WF_1798-A4.pdf⟩.