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Economic Impacts of Climate Change on Two Mexican Coastal Fisheries: Implications for Food Security

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Abstract
This paper has a twofold objective: First, to estimate the changes in landings value by 2030 for two Mexican coastal fisheries, specifically shrimp and sardine fisheries, as a consequence of climate change; and second, to discuss the implications of such impacts for food security. A dynamic panel model was used for the Mexican fisheries sector, with data from 1990 through 2009. The results suggest that shrimp production will be negatively affected, while in contrast, the sardine fishery is expected to benefit from the increase in temperature. Most losses/gains would be observed in the NW Mexican Pacific, where the fishing sector has an important role in the local economy, representing a risk to food security in both direct and indirect ways.

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Keywords Monetary estimation; climate change; Mexico; shrimp fishery; sardine fishery; food security

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1 Introduction

The fisheries sector is important for food security in the developing world, both directly as nourishment and indirectly as a source of income to buy foodstuffs (Allison 2011; Daw et al. 2009; Delgado et al. 2003; Garcia and Rosenberg 2010; Hall et al. 2013; Kent 1997; McClanahan et al. 2013). After all, several countries in Asia and Latin America are among the major fishing nations in the world (FAO 2012). In fact, about 3 billion people receive nearly 20% of their protein intake from fish products and 4.3 billion receive about 15% of their protein intake from this source (FAO 2012: 5).

The issue of food security and fisheries deserves special attention. On the one hand, the potential effects of climate change (CC) on fisheries and food security are a source of concern (Allison 2011; Daw et al. 2009; FAO 2007; Garcia and Rosenberg 2010; Hall et al. 2013; McClanahan et al. 2013). For example, Bell et al. (2009) point out that coastal fisheries will be able to meet the demand for fish products in only 6 out of 22 Pacific island countries and territories. Furthermore, projections under the Special Report on Emission Scenarios (SRES) A1B suggest a decline in the fish protein supply in West Africa by 2050. On the other hand, Rice and Garcia (2011) estimate that fisheries production would have to increase by about 50% over the coming decades in order to satisfy the nutritional demand worldwide. This is feasible, according to Merino et al. (2012), only if the fish stocks are sustainably managed. However, the trend seems to be moving in the wrong direction: fisheries' overcapacity must be curtailed because it is already threatening food security in a number of regions in the developing world (Hall et al. 2013; Smith et al. 2010; Srinivasan et al. 2010). In spite of the relevance of the research conducted since the key contribution made by Kent (1997), few studies have dealt with the links between CC, food security, and fisheries (McClanahan et al. 2013).

This paper, therefore, has a twofold objective. First, we estimate the changes in landings value by 2030 for Mexican fisheries as a consequence of climate change. Second, we discuss the implications of such impacts for food security within a conceptual framework. In the next section, we present a brief review of the relevant literature on CC and fisheries. Then, we explain the conceptual framework upon which our discussion of food security and adaptation is based. Next, we explain the methods we used, and in a later section, we present our results and discussion. The entire database and procedures are available in a spreadsheet file as supplementary material.

1.1 Literature Review

Recent reviews on CC and fisheries have been presented by Allison et al. (2009), Barange and Perry (2009), Brander (2007), Daw et al. (2009), Dulvy et al. (2010), Hanna (2010), Perry (2011), Perry et al. (2010), and Rice and Garcia (2011), among others. Several conclusions can be drawn from these reviews:

- First, physical and ecological effects mainly concern changes in the distribution and abundance of fisheries resources. For example, species will move toward higher latitudes and migrations will change patterns. Moreover, ocean acidification will have a direct impact on species with calcium carbonate skeletons, including a number of invertebrate fisheries (Perry 2011).
- Second, such modifications will alter fisheries' productivity; thus, in some regions, catches will decrease for some species, whereas in others, production will increase. For example, Cheung et al. (2010) project a total global maximum catch potential variation of about 1% between 2005 and 2055, with the larger reductions in the tropics, semi-enclosed seas, and inshore waters.
- Third, economic impacts will be generated in both costs and profits. However, studies of monetary impacts are scarce. In one study, Sumaila and Cheung (2010) predict that by 2050 the estimated global losses in landed catch value will total between US$7 and US$19 billion for developing countries and between US$2 and US$8 billion for developed countries. Indeed, the economic contexts of the fishery and the fishing region are factors that will influence profitability (Hanna 2010). According to the World Bank (2010), the monetary loss in landed values of fish catches by 2050 (discount rate = 0%) will amount to as much as US$10.9 billion in East Asia and the Pacific region and US$2.2 billion in Latin America and the Caribbean, while Europe and Central Asia, in another scenario, will have positive profits of about US$0.01 billion. Lam et al. (2012) predict, under the SRES A1B scenario, a 21% decrease in the

annual total landed value of West African fisheries, with Côte d'Ivoire, Ghana, and Togo being the most affected countries (up to a 40% decrease by 2050). These authors also estimate a 50% loss of fisheries-related jobs and a total annual loss of US$311 million in West Africa.

As for studies on a smaller scale or for specific fisheries, only a few exist. For instance, losses from small pelagic fisheries are predicted at between US$1 million and US$300 million in Thailand, between US$53 million and US$210 million in India, and between US$165 million and US$700 million in the Philippines (Dulvy et al. 2010). With respect to the US mollusk fishery, Cooley and Doney (2009) estimate a net present value of ex-vessel revenue losses (discount rate = 4%) of between US$0.32 billion and US$1.36 billion by 2060 due to ocean acidification. Although the Iberian–Atlantic sardine fishery will not be affected in the short run (Rocha et al. 2013), a drop of about 1.3% in annual profits is predicted by 2030 (Garza et al. 2010). Finally, for both Greenland and Iceland, a positive impact of CC on both fish stocks and gross national product is likely to occur over the next 50 years (Arnason 2007).

- Fourth, fisheries' vulnerability to CC will be exacerbated by poor management strategies. Actually, fisheries' vulnerability is likely to be higher where overcapacity is already observed (Brander 2007; Daw et al. 2009). Therefore, future research must focus on identifying the most vulnerable regions (Allison et al. 2009; Brander 2007). It should also be recognized that climate variability and direct human stressors (e.g. overfishing) are inexorably linked (Brander 2007; Dulvy et al. 2010; Hanna 2010; Perry 2011) and that adaptation will depend on the heterogeneity of the fisheries sector (Daw et al. 2009).

These reviews demonstrate that the existing literature on CC and fisheries deals primarily with global studies. Furthermore, fewer studies on CC and fisheries focus on tropical and subtropical seas than on temperate waters (Barange and Perry 2009). The latter point raises an important issue: the scale of analysis (Daw et al. 2009). On the one hand, smaller spatial scales would improve the performance of the predictive models (Brander 2007; Perry 2011). On the other hand, both fisheries management (Hanna 2010; Perry et al. 2010) and food security (Ericksen et al. 2009) in a changing climate should be implemented at either regional or national levels (Allison et al. 2009; Barange et al. 2010). Furthermore, fish stocks become more vulnerable in the short term due to overfishing, not because of natural climate variability (Dulvy et al. 2010). Thus, we argue that short-term analysis should be embedded into long-term policy goals. Long term in CC analyses implies 50–100 years, which is a rather correct time span for industries such as forestry, but other natural resources, such as fisheries, need shorter periods for implementing management actions before collapse. A shorter span would be useful for redirecting and adapting policies concerning natural resource conservation in changing climate conditions. Hence, since policies for adaptation to CC in the fishing sector need to be coupled with fisheries management actions, analyses covering shorter spans at smaller spatial scales are warranted.

2 Conceptual Framework

CC analysis may be approached in several ways; consequently, a number of different conceptual frameworks analyze either vulnerability (e.g. Füssel 2007; Lovendal and Marco 2006; Turner II et al. 2003) or adaptation and/or mitigation (e.g. Eisenack and Stecker 2012; Hallegatte et al. 2011; Lim 2004; Nelson et al. 2007). Since food security is a major concern in our study, it is important that conclusions acknowledge adaptation issues. Hence, we have chosen the conceptual framework proposed by Eisenack and Stecker (2012), since it deals with adaptation actions and places a stronger emphasis on actors, institutions, and barriers to adaptation. Furthermore, it is compatible with the concepts and definitions of the Intergovernmental Panel on Climate Change. We reckon that the combination of economic impacts and food security implications in the Mexican fisheries sector is a suitable subject of analysis under such a framework.

The core concepts within this framework are the following (Eisenack and Stecker 2012):

- The main focus is placed on purposeful activities (i.e. adaptation actions), which are carried out by human actors, rather than ecosystems.
- Actors appear in different functional roles.

- An adaptation action requires that an actor (i.e. operator) performs an activity with an intention or purpose to adapt, and implies that resources or means are needed in order to achieve such an aim.
- Means are featured as: available means (available to an operator), employed means (actually used by an operator), and necessary means (required for success).
- An operator is a social entity (either individual or collective) that responds (or exercises adaptation).
- A receptor is an actor or system that is the target of an adaptation (i.e. the purpose).
- A stimulus is a statistical change in biophysical variables, and is relevant only when it has an impact on an exposure unit.
- Biophysical variables may be characterized as either meteorological effects (e.g. temperature and precipitation patterns) or indirect effects (e.g. rising sea level, frequency of floods).
- An exposure unit is defined as an actor, or a social, technical, or non-human system, that depends on climatic conditions.
- The impact of CC requires the combination of a stimulus and an exposure unit.
- Processes are sequences of events in biophysical, technical, or social entities or systems.
- Conditions are constraints and resources that cannot be controlled by an operator.
- Barriers are sets of conditions that undermine adaptation actions. Examples of barriers are: missing operators, missing means, unemployed means, or complex actor relations.

Furthermore, in line with Eisenack and Stecker (2012), adaptation can be classified according to:

- The relationship between receptor and exposure unit: direct (the receptor is an exposure unit) or indirect (the receptor and exposure unit are different).
- The purpose of the operator: facilitating (the operator acts to change something for other actors) or reflexive (the operator acts to change something for him/herself).

- The target of the adaptation: explicit (direct adaptations with a purpose targeting an impact of CC), implicit (indirect adaptations, in which the purpose is not to target an impact of CC), and incidental (no intentions and thus no actions are targeting an impact of CC).

Applying these concepts to our analysis, catch landings' value and food security are both exposure units affected by statistical changes in both temperature and rainfall (i.e. stimuli). The receptors that would be the target of adaptation actions are both the fisheries sector and the consumers of seafood products. The main operators are represented by the government agencies concerned (e.g. CONAPESCA), which intend to direct adaptation actions to these receptors in order to target the impacts of CC. Therefore, we are dealing, in general, with indirect, facilitating, and explicit adaptations with respect to the fisheries sector. Concerning food security, government actions are in fact directed towards alleviating poverty in the short term rather than specifically dealing with direct CC impacts. In this case, therefore, the adaptations related to food security would be indirect, facilitating, and implicit. We will discuss these terms below.

3 Methods

3.1 Study Area

Our study assesses the Mexican fishing sector, which is an important source of food and employment at the local level (Ibarra et al. 2000). Mexico is an emerging economy with a variety of oceanic and ecological regimes that result in a high level of marine diversity. Martínez-Arroyo et al. (2011) describe in detail the oceanographic and ecological features relevant to Mexican fisheries and CC. For a summary of the Mexican fishing sector and fisheries management, see Fernandez et al. (2011) and OECD (2006), especially for Mexican coastal fisheries.

Mexico is among the top 15 fishing nations in capture fisheries volume (FAO 2012). Its fisheries sector's exposure to the climate by 2050 for the IPCC scenario B2 is moderate (Allison et al. 2009). The economic dependence on fisheries in Mexico with respect to: (a) fishers as a proportion of the economically active population is moderate, (b) fisheries landings is high, (c) the export value of fisheries' products expressed as a proportion of the total value of all exports is low, and (d) fish consumption as a proportion of the total animal protein consumption is low (Allison et al. 2009). According to Hughes et al. (2012), Mexico presents high adaptive capacity but very high sensitivity with respect to coral reef-based fisheries. Its vulnerability, sensitivity, and adaptive capacity to the impacts of CC on fisheries are all moderate (Allison et al. 2009).

Cheung et al. (2010) analyze aggregated Mexican fish production and conclude that the catch potential would have a negative change of about 4–5% by 2055 under the “SRES-AB1” and “stabilization at 2000-level” scenarios.

As most impacts of CC in local economies in Mexico are expected in coastal areas (Guzman-Amaya et al. 2010), we analyze two important coastal fisheries: the shrimp and sardine fisheries. These fisheries were chosen for the following reasons:

- Food security in fisheries is regarded in two ways: direct (seafood intake) and indirect (source of income) contribution to protein intake (Rice and Garcia 2011). Hence, on the one hand, shrimp is an export commodity from which earnings allow the buying of food and the generation of employment. On the other hand, sardines are eaten mostly by low-income consumers. In fact, sardines are included in an official “basic basket” that contains the minimum requirement of food for a Mexican nuclear family. In addition, sardines are used as fishmeal by the livestock sector.
- Both fisheries accounted for 60.5% in volume and 50.7% in value of the total catch in Mexico in 2009 (CONAPESCA 2009: 4, 9).
- Reliable time-series data sets are available for both fisheries, allowing for more accurate estimates of CC impacts.

Nevertheless, we are aware that our analysis did not include other important Mexican fisheries. We focused on the classification proposed by Martinez-Arroyo et al. (2011) for the most vulnerable marine and coastal environments in Mexico: 1) lagoons, estuaries, and wetlands; 2) upwelling areas; 3) marine current and frontal systems; and 4) coral reefs. For the former two we analyzed the shrimp and sardine fisheries. With respect to marine systems, we reckoned that a different method of modeling is needed (e.g. Stock et al. 2011; Suárez-Sánchez et al. 2004) because fishing fleets behave in a very different way due to straddling stocks (e.g. tuna). Finally, it is difficult to gather reliable data on fishing linked to coral reefs.

In spite of this shortcoming, we provide an initial monetary assessment of CC impacts in specific Mexican fisheries, hoping to inspire more studies of this type.

3.2 Variables

We estimated the output equations using panel data from the Mexican fisheries sector from 1990 through 2009. This is an appropriate time span for analyzing CC impacts in fisheries (see Cheung et al. 2010). The panels comprised yearly data for 17 coastal Mexican provinces (i.e. states). The spreadsheet containing the entire database is provided as supplementary material.

The fishing outputs (tons in live weight) for shrimp and sardine fisheries were used as dependent variables.

We used the definition proposed by Dalton (2001) for fishing effort as the number of vessels or boats landing an individual species. We assumed variable and fixed costs to be directly proportional to the fishing effort. Data were gathered from the annual records of the Mexican fisheries agency (CONAPESCA, several years). We used the number of people hired in fishing activities (CONAPESCA, several years). Following Allison et al. (2009), we assumed that strong dependence on fisheries for employment may reflect high absolute dependence (i.e. a large number of fishers). Capital and labor (production inputs) are variables typically used in a production function, as they measure the extent to which the supply depends on the inputs used by the producer of such goods. The total output, total effort, and effort from other fisheries were incorporated in order to check for potential impacts in other fisheries.

We included a variable with annual financing amounts from both government and private agencies (CONAPESCA, several years) in order to measure the impact of credits and subsidies on fish output. According to Dulvy et al. (2010), reductions in financial capital can be observed as a consequence of climatic variability.

We used the average price of the total output at constant prices in each province (CONAPESCA, several years) and the National Consumer Price Index for the fishing and hunting sector (BANXICO, 2012). Given that shrimp and sardines are both individual commodities in a world market, we assumed a perfectly elastic demand.

Two variables accounting for climate effects were considered: the average annual sea surface temperature (SST) and average annual rainfall. The sources are:

- Version 2 of the National Oceanic and Atmospheric Administration (NOAA) monthly optimum interpolation (OI.v2) SST analysis (Reynolds et al. 2002).
- The 0.5° latitude × 0.5° longitude gridded monthly rainfall data (mm/month) from the Global Precipitation Climatology Centre (GPCC) data set, managed by the World Climate Research Programme's (WCRP) Global Climate Observing System (GCOS) project (Rudolf et al. 2010).

The optimum interpolation sea surface temperature analysis is produced weekly on a one-degree grid. The NOAA OI.v2 SST monthly fields are derived by a linear interpolation of the weekly optimum interpolation version 2 fields to daily fields, then averaging the daily values over a month. The temporal coverage of the monthly data extends from 1981/11 to 2011/07 (both weekly and monthly data are available at: http://www.emc.ncep.noaa.gov/research/cmb/sst_analysis/). The GPCC V5 0.5 precipitation monthly data are available from 1901 to 2009. The gridded GPCC analysis products are available at http://gpcc.dwd.de. We used the annual averages for each coastal province.

As the El Niño/La Niña Southern Oscillation is a major event in climate variability affecting Mexican fisheries (Martinez-Arroyo et al. 2011), we included a dummy variable in years when a moderate/strong El Niño or moderate/strong La Niña was present.

Finally, models were run with and without natural logs for each variable. Time-lagged variables were also introduced as instruments (see the explanation below).

3.3 Model

A dynamic panel model was employed to assess the impact of economic and CC variables on capture fisheries' production. The estimator employed is the one proposed by Blundell and Bond (1998), which is a system GMM (generalized moments method) estimator. The use of such an estimator is appropriate in this context, because the fish supply is often modeled as a dynamic process and the ordinary least squares (OLS) and the within-group estimators are both biased and inconsistent when estimating highly persistent data. Nevertheless, we carried out the estimations for alternative models in order to have a benchmark for comparison. We applied the OLS and generalized least squares (GLS) estimators and instrumental variables in the system GMM (see below).

More specifically, to determine whether climate stimuli have a lasting impact on fish production, we estimated production equations that combine individual specific effects with dynamics as follows:

$$p_{i,t} = \delta p_{i,t-1} + x_{i,t}\beta + \alpha_i + u_{i,t} \qquad (1)$$

where $p_{i,t}$ stands for a type of fish production for a specific province per year; α_i is an unobservable province-specific effect that is constant across time; $x_{i,t}$ is a vector of explanatory variables (described above); and $u_{i,t}$ is a random disturbance term. In other words, we estimated an equation in which the supply of a type of fish catch (i.e. shrimp or sardine) is the response variable, whereas lagged fish output, capital, financing, and labor are the main determinants of catches. Indeed, our model includes lagged fish supply, reflecting that the supply of fish is often considered a persistent phenomenon.

From an econometric point of view, Equation (1) faces two problems:

a) The factor inputs (capital and labor) are likely to be endogenous if there is contemporaneous correlation between the error term and such factors due to simultaneity problems.
b) There is the possibility of unobserved province-specific effects correlated with the explanatory variables, including lagged fish output.

Thus, it seems desirable to control for simultaneity problems and the existence of individual effects to obtain unbiased and consistent parameter estimates. In order to obtain consistent estimates of the parameters of interest, a better approach would be to transform Equation (1) by taking first differences of the data, thus eliminating the problem of correlation between lagged fish output and province-specific effects. Thus, the alternative specification for equation (1) would be:

$$\Delta p_{i,t} = \delta \Delta p_{i,t-1} + \Delta x_{i,t}\beta + \Delta u_{i,t} \qquad (2)$$

where the province-specific effects (α_i) have been eliminated, but by construction, there is still a correlation between the lagged differences of fish production and the error term. To purge such a correlation, we used the Arellano and Bover (1995) system GMM estimator, which allowed us to use lags of the level of fish output or lags of the first-differenced fish output and of the regressors ($p_{i,t-2}$ or $\Delta p_{i,t-2}$) as valid instruments. Hence, the Arellano–Bover estimator computes the production of Equation (2) and all the orthogonality conditions that exist between the lagged values of fish output and the disturbances. Furthermore, it is the most efficient estimator for exploiting additional moment conditions by combining, in a single system, the fish production equation in differences and levels. Thus, each equation is provided with a specific set of instrumental variables as follows:

$$\Delta p_{i,t} = \delta \Delta p_{i,t-1} + \Delta x_{i,t} \beta + \Delta u_{i,t} \qquad (3)$$

$$p_{i,t} = \delta p_{i,t-1} + x_{i,t} \beta + \alpha_i + u_{i,t} \qquad (4)$$

Equation (4) denotes the output data-generating process in levels in which the province-specific effect is not eliminated but must be controlled for through the use of instrumental variables. In our model, both the FINANCING and the TEMPERATURE variables were treated as exogenous, and the rest of the explanatory variables and their lags (predetermined variables) were included as instruments in the GMM estimates. Therefore, this set-up is the best one, since it exploits all the moment conditions and gives us substantial efficiency gains over the other estimators. This discussion is important because although all the dynamic panel estimators are an improvement over the cross-sectional estimators, not all of them will perform equally well.

To assess the reliability of our output equation estimations, it is advisable to carry out specification tests. The so-called Sargan test for over-identifying restrictions is one such test. It allowed us to ensure the validity of the instruments by analyzing the sample counterparts of the moment conditions used in the estimation process. Another important specification test is a non-serial correlation test. Such a test verifies whether the residual of the regression in differences is first- or second-order serially correlated. We expect that the differenced residuals are first-order serially correlated, unless they follow a random walk. However, we also expect to find that such residuals are not second-order serially correlated so as to ensure the validity of the postulated instruments.

3.4 Scenario Analysis[1]

Once the coefficients had been obtained from the dynamic panel model, scenarios were generated for the expected changes in fish production. We assumed the estimates obtained by Martinez-Arroyo et al. (2011: 115–116), who predict that by 2030, the average temperature in the Gulf of Mexico will increase by between 0.0 and 1.0 degrees Celsius, while in the Mexican Pacific it will increase by between 0.5 and 1.5 degrees Celsius. We used the annual averages for both fish output and temperature for each province to determine the corresponding percentage increase in temperature specified by Martinez-Arroyo et al. (2011). Thus, variations were obtained (either positive or negative) by multiplying the model semi-elasticities by the average value (in 2009 USD) according to the level of change in degrees Celsius by 2030. Finally, the net present value of the change in catch value (discount rates = 1% and 4%)[2] in 2030 was computed as a monetary measure of the impact of climate change.

A sensitivity analysis was carried out by varying several scenarios. For the baseline scenario we assumed a constant price and a constant fish stock within the range of temperature increase and discount rates described above. The other two scenarios included changes in price and in resource availability. First, we computed the price percentage change during the last ten years with the deflated 2000 price and the current 2009 price for each province. We used the negative and positive values of this percentage as lower and upper bounds of price changes, respectively. Second, we calculated the catch per unit of effort (CPUE) percentage change for both shrimp and sardine fisheries in 2000 and 2009 for each province. This percentage change in CPUE (either negative or positive) was used as an

1 Detailed scenario computation is provided in a spreadsheet file as supplementary material, available on the journal's home page or by request from the authors.

2 There is an on-going debate in CC studies on the level of discounting. Following the discussion of Gollier (2009), we decided to apply two scenarios: a rather low discount rate (1%) and an actual discount rate of 4% (Mexican Central Bank estimate).

indicator of resource biomass fluctuation. Third, each scenario was computed with the formula based on the price dynamics model proposed by Turner et al. (1993: 211). The net present value estimates were obtained by multiplying the price for the catch change, divided by the discount factor. However, in this case, both the price and the catch include a dynamics factor used to simulate the price changes and the stock fluctuation:

$$NPV = \frac{P(1+r)^t C(1+b)^t}{(1+d)^t} \qquad (5)$$

where: NPV is the net present value of the loss catch by 2030; P is the price in 2009; r is the price change rate; C is the catch in 2009; b is the resource change rate; d is the discount rate; and t is time. For the baseline scenario, that is to say, when r = 0 and b = 0 (i.e. constant price and stock), the resulting estimates are identical to those of Ibarra et al. (2012). Hence, a total of 816 scenarios were run: 2 species in 17 provinces for an upper and lower bound of temperature change, under 1% and 4% discount rates, assuming constant, upper, and lower bounds of price changes, and assuming a constant and ten-year average resource biomass fluctuation.

4 Results and Discussion

4.1 Estimates of Monetary Impacts

4.1.1 Methodological Issues

Estimates of the dynamic panel model coefficients (i.e. semi-elasticities) resulting from the production solution are shown in Table 1. We report the ordinary least squares (OLS), the generalized least squares (GLS), and the generalized moments method (GMM) estimates for comparison purposes. Nevertheless, in econometrics, it is widely known that in the presence of persistence (i.e. lags), the most robust estimator in a dynamic panel is the GMM estimator, since it is unbiased and consistent (Greene 2000). Hence, our discussion focuses on the coefficients obtained with the GMM estimator. The results of both the Sargan tests and the AR(1) and AR(2) tests are displayed in Table 1.

Table 1: Results for the shrimp and sardine output models

Independent variable	Shrimp			Sardine		
	OLS***	GLS**	GMM-SYS*	OLS***	GLS**	GMM-SYS*
SHRIMP OUTPUT$_{(t-1)}$	0.932 (0.021)	0.685 (0.317)	0.413 (0.060)	0.929 (0.055)	0.696 (0.096)	0.430 (0.093)
SHRIMP OUTPUT $_{(t-2)}$	-	-0.246 (0.207)	0.361 (0.041)	-	0.251 (0.099)	-0.003 (0.166)
TEMPERATURE	-0.068 (1.820)	-1.048 (0.450)	-0.011 (0.010)	1.698 (5.309)	0.049 (5.265)	0.040 (0.025)
TEMPERATURE$_{(t-1)}$	1.903 (2.123)	-1.062 (5.558)	0.007 (0.008)	-3.254 (6.582)	-2.593 (5.232)	0.018 (0.025)
TEMPERATURE$_{(t-2)}$	-1.875 (1.862)	-	-0.014 (0.008)	0.374 (5.496)	-0.021 (5.499)	0.012 (0.025)
TEMPERATURE$_{(t-3)}$	-	3.536 (5.470)	-	-	0.125 (4.727)	0.053 (0.026)
TEMPERATURE$_{(t-4)}$	-	-	-	-	-	0.027 (0.019)
TEMPERATURE$_{(t-5)}$	-	-	-	-	1.494 (4.429)	0.021 (0.020)
CAPITAL	-0.037 (0.125)	-0.414 (0.356)	0.044 (0.049)	-0.314 (0.406)	-0.215 (0.148)	0.134 (0.030)
CAPITAL$_{(t-1)}$	0.050 (0.111)	0.687 (0.333)	-	0.007 (0.318)	0.189 (0.684)	-
CAPITAL$_{(t-2)}$	0.004 (0.097)	-	0.090 (0.047)	0.224 (0.294)	-	-
CAPITAL$_{(t-3)}$	-	0.484 (0.258)	-	-	-0.132 (0.266)	0.069 (0.099)
CAPITAL$_{(t-4)}$	-	-	-	-	0.041 (0.114)	0.069 (0.121)
LABOR	0.082 (0.245)	0.388 (0.753)	0.013 (0.011)	0.229 (0.684)	0.550 (0.524)	-

Table continued

Independent variable	Shrimp			Sardine		
	OLS***	GLS**	GMM-SYS*	OLS***	GLS**	GMM-SYS*
LABOR$_{(t-1)}$	0.055 (0.340)	-0.036 (1.037)	0.013 (0.010)	0.546 (0.899)	0.162 (0.693)	0.146 (0.053)
LABOR$_{(t-2)}$	-0.077 (0.247)	0.145 (0.918)	0.023 (0.011)	0.309 (0.135)	-0.365 (0.504)	-
LABOR$_{(t-4)}$	-	0.219 (0.572)	-	-	-	0.179 (0.074)
FINANCING	0.011 (0.025)	0.140 (0.045)	0.078 (0.069)	-0.342 (0.178)	0.124 (0.067)	-
FINANCING$_{(t-1)}$	-0.012 (0.031)	-	-	1.697 (5.309)	-	-
FINANCING$_{(t-2)}$	0.044 (0.027)	-	-	0.063 (0 .141)	-	-
Constant	-0.375 (1.026)	-	-	2.728 (2.965)	-	-
Wald (joint)$^{+}$	-	-	(0.000)	-	-	(0.000)
Wald (dummy)$^{+}$	-	-	(0.000)	-	-	(0.000)
Wald (time)$^{+}$	-	-	(0.000)	-	-	(0.000)
Sargan test^{++}	-	-	(0.999)	-	-	(0.999)
AR(1)	-	-	(0.095)	-	-	(0.068)
AR(2)	-	-	(0.254)	-	-	(0.409)

Notes: Both dependent and independent variables are logarithmic. The OLS model does not present multicollinearity since the variance inflation factor test values were 1.54 for the sardine model and 1.39 for the shrimp model (see Appendix B).

* Estimated in the second stage, including time dummies.

** The regressions do not include time dummies.

*** Ordinary least squares, including time dummies.

$^{+}$ Wald (joint), Wald (dummy), and Wald (time) are joint-significance tests for time dummies and individuals.

$^{++}$ The Sargan tests show that the model is over-identified.

- Model for shrimp:

Arellano–Bond test for AR (1) in first differences: z = -1.672 > Pr > z = 0.095

Arellano–Bond test for AR (2) in first differences: z = -1.140 > Pr > z = 0.254

- Model for sardine:

Arellano–Bond test for AR (1) in first differences: z = 1.828 > Pr > z = 0.068

Arellano–Bond test for AR (2) in first differences: z = 0.8257 > Pr > z = 0.409

The variables that resulted as statistically significant are shown in Table 1. TEMPERATURE presented a negative coefficient for shrimp output, but a positive one for sardine output. Such results suggest that CC has a meaningful influence on the fish catch; furthermore, such effects will be differentiated according to the fishery and provinces (see the next section). Indeed, our estimates involve the monetary value of fish landings due to CC impacts (either positive or negative). Similar results have already been observed on either a global (e.g. Cheung et al. 2010; Hanna 2010) or a regional scale (e.g. Lam et al. 2012. It is worth mentioning that LABOR and CAPITAL (i.e. the number of boats) positively affect fish production for both shrimp and sardine fisheries, just as fisheries economic theory predicts (Hannesson 1993). It is important to note that LABOR was an aggregated variable and boats from the artisanal fleet were not included in our models. This is a drawback to our analysis, but, as noted by McClanahan et al. (2013), obtaining accurate data on tropical fisheries is rather difficult. In spite of this, our results are congruent with similar reports in the literature (as noted above). FINANCING resulted as positively significant for shrimp output, presumably due to the subsidies granted on fuel to the shrimp fleet.

We are aware that a welfare measure (e.g. resource rent), rather than the net present value of landings value, is better for analyzing the economic impacts of CC in fisheries (Sumaila et al. 2011). Nevertheless, the net present value of gross profits is an accepted measure for linking CC impacts to fisheries production (e.g. Lam et al. 2012; Rocha et al. 2013).

Further research should focus on the adaptation and mitigation costs of the fishing sector. This, however, is no simple task. As noted by Parry et al. (2009), the costs of adaptation have frequently been underestimated in a number of studies for developing countries. Also, the food sector has proven to be a difficult one for reliable estimates of both adaptation costs (Wheeler and Tiffin 2009) and food security impacts (Ericksen et al. 2009). In our case, our scenarios are created through a direct link between temperature patterns and fish production. However, the latter might be influenced by other factors, such as coastal degradation, pollution, increasing demand for fish products, or changes in prices. These factors might well undermine fisheries' productivity, potentially resulting, as in the case of shrimp, in greater losses than those estimated in our models.

4.1.2 Scenarios of Monetary Impacts

Monetary changes in catch value (live weight) by 2030 were obtained for both shrimp and sardine fisheries in each province (please refer to the spreadsheet provided as supplementary material). Figures 1 and 2 show the worst/best scenarios for the shrimp/sardine fisheries (see below). Most losses/gains would be observed in the NW Mexican Pacific, where the fishing sector has an important role in local economies. The monetary gains from the sardine fishery in the Gulf of Mexico are rather small. Hence, Sonora (SON) and Sinaloa (SIN) provinces would be the most affected, followed by Tamaulipas (TAMPS), Nayarit (NAY), and Campeche (CAMP). The least affected would be Baja California (BC) and Baja California Sur (BCS). For the first group, dependence on shrimp fishing would be decisive, while the provinces of the Baja peninsula would be better off due to sardine increase. However, overall, the monetary losses would be higher than the gains for most provinces.

Comparing our results with those of other studies is rather difficult due to the scarcity of work dealing with cost estimation and due to differences in approaches, time scale, discounting, and scenario construction. Besides, most studies are large-scale-oriented (e.g. Sumaila and Cheung 2010; World Bank 2010) and hide the differentiated effects of CC. For example, in the case of Mexico, Cheung et al. (2010) find a negative change in the maximum fisheries catch potential by 2055 under two scenarios (SRESA 1B and stabilization at the 2000 level). Their study includes the aggregated catch of all Mexican fisheries, but in our study, we found that effects from CC would be differentiated according to species and regions. Further research on Mexican fisheries should disentangle the matter of which species are either negatively or positively affected by CC in both landings volume and value. It would be interesting to verify whether or not the final balance is negative, as Cheung et al. (2010) suggest.

a) Shrimp Fishery

We found that shrimp production would be negatively affected by about a 1.1% decrease in catch for every 1% of temperature increase (Table 1). The monetary impacts for the Mexican shrimp fishery are negative overall (Table 2). The worst-

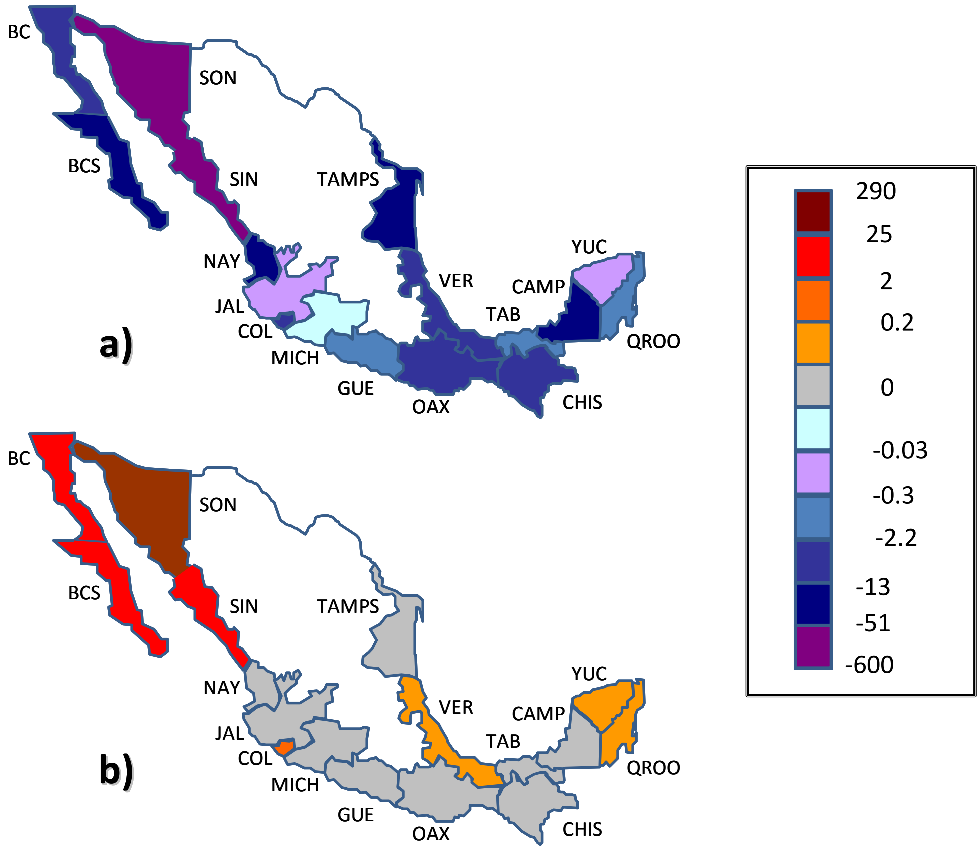

Figure 1: Map showing the net present value (millions of US dollars) of Mexican coastal provinces in the worst/best-case scenario for the a) shrimp/b) sardine fishery. It would be an upper bound temperature increase by 2030, with a discount rate of 1%, an increasing price, and a stock fluctuation at the same rate as it has been for the past 10 years. See Appendix A for the province codes.

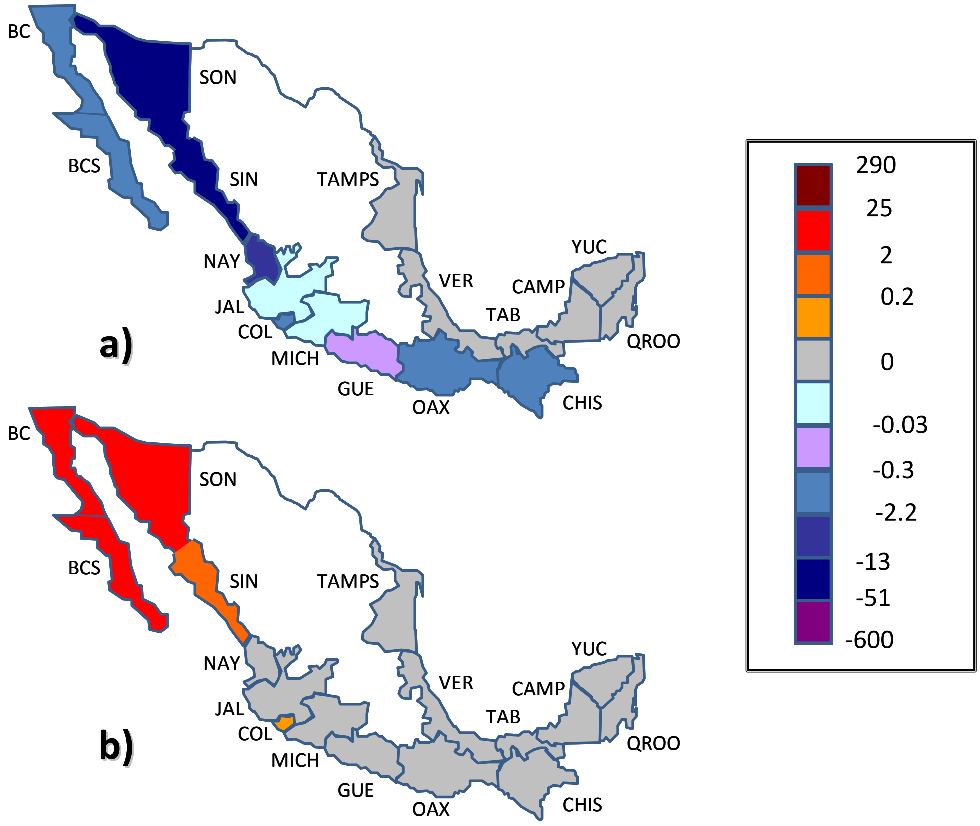

Figure 2: Map showing the net present value (millions of US dollars) of Mexican coastal provinces in the best/worst-case scenario for the a) shrimp/b) sardine fishery. It would be a lower bound temperature increase by 2030, with a discount rate of 4%, a decreasing price, and no stock fluctuation. See Appendix A for the province codes.

Table 2: Total monetary impacts in net present value ('000 USD) by 2030 for the Mexican shrimp fishery

	Temperature increase							
	Lower bound				Upper bound			
	Discount rate				Discount rate			
	1 %		4 %		1 %		4 %	
	Stock fluctuation		Stock fluctuation		Stock fluctuation		Stock fluctuation	
Price dynamics	10-y trend	constant	10-y trend	constant	10-y trend	constant	10-y trend	constant
Lower bound	-171,421	-93,374	-124,971	-73,183	-572,098	-334,787	-418,811	-261,957
Constant	-243,117	-125,416	-171,419	-94,924	-801,056	-443,679	-567,337	-335,808
Upper bound	-354,268	-175,116	-242,028	-127,759	-1,153,143	-609,941	-785,692	-445,706

case scenario for the shrimp fishery (losses of US$1,153.1 million in NPV) would be an upper bound temperature increase by 2030, with a discount rate of 1%, an increasing price, and a stock fluctuation at the same rate as it has been for the past 10 years (Figure 1a). The best-case scenario for the shrimp fishery (losses of US$73.2 million in NPV) is a lower bound temperature increase by 2030, with a discount rate of 4%, a decreasing price, and no stock fluctuation (i.e. constant biomass) (Figure 2a).

In fact, shrimp fisheries are highly dependent on mangroves and wetlands, which are ecosystems that are among the most vulnerable to both CC and other threats, such as land use, pollution, salinity changes, and sea level rises (Martinez-Arroyo et al. 2011). Due to ocean acidification, organisms with calcium carbonate skeletons, such as shrimp, will be negatively affected (Perry 2011).

As far as we know, no studies concerning the costs for shrimp fisheries due to CC are available. For the US mollusk fishery, Cooley and Doney (2009) report ex-vessel revenue losses of between US$0.32 and US$1.36 billion by 2060 (discount rate = 4%). Differences between mollusk and crustacean fisheries are evident, but both are especially vulnerable to increasing ocean acidification (Cooley and Doney 2009; Perry 2011).

Furthermore, according to Guzman-Amaya et al. (2010), shrimp fisheries will suffer not only biological impacts, but consequences for facilities in terms of storage and distribution will also be observed. In fact, distribution and storage in many coastal communities are mostly devoted to shrimp landings during the fishing season. It is worth mentioning that other fisheries (aside from shrimp) will be affected by CC in relation to coastal facilities. No data are available for Mexico, but, for example, reef-based industries will suffer heavy impacts in tropical countries (Marshall et al. 2010), and in the USA, the sea level rise will bring changes to economic and recreational activities (Scavia et al. 2002) as well as land use changes in fisheries-related ports (Portman et al. 2011). We could expect similar effects to be observed on Mexican coasts by 2030 and onwards.

b) Sardine Fishery

In contrast, the sardine fishery would benefit by an approximate 4% increase in production for every 1% increase in temperature (Table 1). The monetary impacts for the Mexican sardine fishery are positive overall (Table 3). The best-case scenario for the sardine fishery (gains of US$347.9 million in NPV) would be an upper bound temperature increase by 2030, with a discount rate of 1%, an increasing price, and a stock fluctuation at the same rate as it has been for the past 10 years (Figure 1b). The worst-case scenario for the sardine fishery (gains of US$37.3 million in NPV) is a lower bound temperature increase by 2030, with a discount rate of 4%, a decreasing price, and no stock fluctuation (i.e. constant biomass) (Figure 2b).

Sardine stocks, nevertheless, present high natural variations in abundance; therefore, assessing how great an impact they will receive from CC is rather uncertain (Perry et al. 2010). However, there are conditions that may indicate consequences from CC. One of these consists of the ENSO effects on small pelagic fish (Chavez et al. 2003; Dulvy et al. 2010). For example, Allison et al. (2009) point out that the ENSO warming effects off Peru are associated with a decline in anchovies, but with the opposite effect on sardines. According to Martinez-Arroyo et al. (2011), a greater abundance of sardines in the Easter Tropical Pacific may be associated with warmer regimes and the presence of eddies in the California Current. In this respect, King et al. (2011) point out that fluctuations of Pacific sardine stocks will continue in this region, probably with

Table 3: Total monetary impacts in net present value ('000 USD) by 2030 for the Mexican sardine fishery

	Temperature increase							
	Lower bound				Upper bound			
	Discount rate				Discount rate			
	1 %		4 %		1 %		4 %	
	Stock fluctuation		Stock fluctuation		Stock fluctuation		Stock fluctuation	
Price dynamics	10-y trend	constant	10-y trend	constant	10-y trend	constant	10-y trend	constant
Lower bound	62,923	47,795	47,158	37,249	188,791	143,699	141,498	103,281
Constant	84,498	61,207	61,305	46,325	253,518	183,977	183,937	139,247
Upper bound	115,986	80,074	81,554	58,832	347,982	240,634	244,685	176,804

more frequent periods of great abundance. Furthermore, the coastal upwelling off California will intensify due to CC (Snyder et al. 2003).

Brander (2007) points out that due to the high level of uncertainty regarding both climatic and economic conditions, predictions for future fish production imply low confidence estimates. Indeed, the predictions for sardine stocks influenced by CC become highly uncertain and depend on both species and region. Hence, on the one hand, our finding that sardine fisheries would be positively influenced by future warmer conditions has been observed off California (King et al. 2011; Snyder et al. 2003) and off West Africa (Binet 1997). On the other hand, some studies contradict our results. For example, Dulvy et al. (2010) report losses for small pelagic fisheries (e.g. sardines and anchovies) in Asian countries of between US$1 million (in Thailand) and US$700 million (in the Philippines). In the same vein, the Iberian Atlantic sardine fishery would lose between 0.36% and 1.27% of its annual profits (discount rate = 5%) by 2030 (Garza et al. 2010; Rocha et al. 2013). Therefore, it would be difficult either to recommend or to forecast an influx of financial capital into sardine fisheries, due to the associated high degree of variability and uncertainty. Hence, we could not suggest that increases in sardine stocks would help to alleviate food insecurity.

4.2 Adaptation Actions and Food Security

Applying the conceptual framework developed by Eisenack and Stecker (2012) to our analysis, the catch landings value and food security would both be exposure units affected by climate stimuli (in our case: temperature). Government agencies that have the intention of directing adaptation actions are the main operators concerned with targeting the impacts of CC. The two most relevant agencies are the Ministry of Agriculture, Food and Fisheries (SAGARPA) and the Ministry of the Environment (SEMARNAT). On the one hand, SAGARPA cooperates with the UN Food and Agriculture Organization (FAO) in the Strategic Project for Food Security (PESA, its acronym in Spanish), which focuses chiefly on poor rural communities. However, PESA does not directly address CC issues. Furthermore, the Commission on Fisheries (CONAPESCA), which is within the SAGARPA structure, has the function of establishing fisheries regulations. To date, no specific actions or programs have been aimed at adapting the fishery sector to CC. On the other hand, SEMARNAT has recently been leading actions and proposals in response to CC. One example is the Program on CC (PECC), which gives guidelines for mitigation and adaptation to CC. However, to date, adaptation actions have been rather neglected, as most of the attention has been placed on measuring vulnerability and promoting mitigation, mostly in the energy sector. The receptors of actions by SAGARPA and SEMARNAT are, in our case, both the fisheries sector and the consumers of seafood products. However, specific adaptation actions for the fisheries sector are still lacking. This could be, in part, a consequence of the lack of coordination among the Mexican ministries.

Next we will discuss two types of adaptation actions concerning CC and food security in the Mexican fisheries sector: one is directly related to adapting the fishery sector to CC and the other is focused on alleviating food insecurity.

a) Adaptation Actions for the Mexican Fishery Sector

According to the conceptual framework developed by Eisenack and Stecker (2012), adaptation actions related to the fishery sector are defined as indirect, facilitating, and explicit adaptations. They are indirect because the receptor (i.e. the fishery sector) and the exposure unit (i.e. the catch landings value) are different. They are facilitating because the operator (CONAPESCA) acts to change something for other actors (i.e. fishers). They are explicit because the target of the adaptation is a direct impact of CC (i.e. the loss of value in catch landings).

With respect to adaptation policies, there are actions that need to be taken for the Mexican fishing sector. It should first be acknowledged that the big problem with fisheries facing CC scenarios is that negative effects will be exacerbated by poor management. In other words, already ill-managed fisheries will be the most vulnerable in the short term (Allison et al. 2009; Daw et al. 2009; Hall et al. 2013; McIlgorm et al. 2010). Thus, some of the adaptation actions that need to be implemented in order to cope with CC impacts are the same for any depleted fishery. The recommendations are focused on ecosystem-based management (e.g. marine reserves and stock rebuilding) and fishing effort control (Hughes et al. 2012; Sumaila et al. 2011). Therefore, the major step for an adaptation policy in the fisheries sector is to address the current problems of overfishing and ecosystem degradation (Brander 2007; Perry et al. 2010). Lluch-Cota (2004) also recommends more investment devoted to understanding the relation between CC and the Mexican fishery sector.

Daw et al. (2009: 139) point out that specific adaptation actions for reduced fisheries productivity and profitability include access to higher-value markets, increasing the fishing effort (not for overexploited fisheries), reducing th ecosts, and discontinuing fishery activities to replace them with other livelihoods/investments. In the case of Mexico, however, the implementation of such actions has been awkward. On the one hand, instead of focusing on added-value markets for fish products, the Mexican Government is looking for new species to exploit in order to substitute depleted stocks. On the other hand, fuel subsidies directed at alleviating variable costs, which are what Mexican agencies offer (e.g. SAGARPA), work in the wrong direction because such subsidies foster the overexploitation of fish stocks (Sumaila et al. 2010) and furthermore generate CC emissions (Tyedmers et al. 2005). For example, our variable FINANCING was significant for shrimp fisheries, reflecting the fact that subsidies and soft credits have presumably helped to maintain the fishing effort, so that shrimp production has been sustained over the years thanks, in part, to fuel subsidies.

Discontinuing fishery activities or diversifying fishers' livelihoods is not an easy task in Mexico. For example, artisanal fishers will not be able to cope with the changing distribution of certain species due to their lack of capital-intensive fishing methods (Guzman-Amaya et al. 2010). In fact, livelihoods that depend on fisheries will suffer the most in poorer regions, resulting in reduced production opportunities, damage to productive assets, and decreased ability to plan livelihood activities (Badjeck et al. 2010; Daw et al. 2009; Delgado et al. 2003). Thus, migration from coastal zones may be expected, rather than specific adaptation actions (Guzman-Amaya et al. 2010). For further discussion of specific adaptations to climate impacts for fisheries, see Daw et al. (2009), Dulvy et al. (2010), Grafton (2010), Hanna (2010), Johnson and Welch (2010), and Rice and Garcia (2011).

b) Adaptation Actions for Food Security

Adaptation actions related to food security, according to Eisenack and Stecker (2012), are indirect, facilitating, and implicit. In other words, government actions (e.g. PESA) are in fact directed toward alleviating poverty in the short term rather than specifically dealing with direct CC impacts (i.e. an implicit adaptation target), since food insecurity is frequently linked to poverty levels in the fishery sector (Kent 1997).

A major concern is whether the protein content of fish products is diverted from poor people toward either more wealthy consumers or aquaculture feeds (Allison 2011; McClanahan et al. 2013). However, the question of how the effects of CC on fisheries will affect food security (and how to adapt if such is the case) remains unanswered (Rice and Garcia 2011). According to Garcia and Rosenberg (2010: 2876), CC will have minimal effects on the global contribution from fish to food security. In fact, the global fish catch has stabilized during the last decade (FAO 2012), but a closer look indicates that a number of fish stocks have collapsed (Worm et al. 2006). Thus, the global fish supply remains somewhat constant presumably due to species substitution, increasing fishing effort, and the expansion of fishing grounds, among other factors. Nevertheless, both consumers and producers will have to adapt to new species and market dynamics, as in the case of fishmeal (Merino et al. 2010), because the per capita fish product consumption is growing in both developing and developed countries (FAO 2012: 4). On a smaller scale, however, the effects of CC on food security and fisheries might be more evident in certain regions.

Although food availability is not a serious concern in Mexico, higher prices of basic foodstuff have severe consequences for poor people, especially in provinces such as Chiapas (CHIS), Guerrero (GUE), and Oaxaca (OAX) (Juarez and

Gonzalez 2010). These are the southernmost provinces, where the poverty levels are the highest in Mexico. With respect to our study, people employed in the shrimp industry will be affected by CC. In fact, CC is expected to increase the poverty levels in Mexico. A study by Fuente and Olivera (2013) predicts that this increase will be about 15.3% (without climate change) to 17.7% (with climate change) by 2030. A similar circumstance has been reported in West Africa by Lam et al. (2012). According to McClanahan et al. (2013), there is still a global need to integrate the issues of poverty and food security into fisheries and aquaculture policies.

Garcia and Rosenberg (2010) indicate that fisheries contribute to food security in either direct or indirect ways. In Mexico, sardines are consumed directly by domestic consumers, and indirectly as fishmeal for livestock. Sardines are, in fact, part of the basic basket, which is a standard measure employed by the government to measure the purchasing power among poor people. The recent trends of increasing prices and demand for fishmeal (and other fish products) around the globe once again raise the question of diverting protein to export markets (Delgado et al. 2003). Still, no direct links between sardine consumption among poor people and future trends of fishmeal exports have been investigated in Mexico. Export earnings, nevertheless, can help to alleviate food insecurity, provided that the local market and institutional mechanisms allow regional economic development (Allison 2011; McClanahan et al. 2013). For example, while shrimp in Mexico is mostly an export commodity, it indirectly contributes to domestic food security since money is earned in order to buy food. If shrimp production eventually decreases, fishers will target other species in order to compensate for their monetary losses. Because shrimp is a high-value fishery, a major risk of overexploitation of other fish stocks might lead to food security concerns in the mid and long term.

Finally, aquaculture is frequently evoked as an adaptation action for dealing with food insecurity (Ahmed and Lorica 2002; Allison 2011; Delgado et al. 2003; Rice and Garcia 2011). However, large aquaculture yields are often obtained by overfishing wild stocks that serve as food for cultivated species (Naylor et al. 2001). For instance, about 23% of the feeding content in shrimp farming worldwide is comprised of fishmeal, with this figure reaching as high as 50% in Thailand, which is the world’s major cultivated shrimp producer (Deutsch et al. 2007). In Mexico, shrimp farms still depend heavily on post-larvae harvesting from coastal lagoons and mangrove forests. In addition to the environmental problem, social conflicts arise between shrimp farmers and other coastal stakeholders (Thorpe et al. 2000). Tuna fish cage culture is just starting in Mexico, but it is expected to keep on growing. Tuna are carnivorous fish and are fed with smaller fish from wild stocks. At any rate, whether aquaculture is a solution or another factor of risk to food security will depend on the degree of sustainability with which it is carried out (McClanahan et al. 2013; Ruckelshaus et al. 2013). Therefore, the role of aquaculture as an option for food security remains ambiguous.

5 Conclusion

In conclusion, this analysis of scenarios by 2030 in coastal fisheries in Mexico suggests that the monetary impacts of CC will be differentiated. Thus, the shrimp fishery can be expected to present a decline in profits, which could be attributable to the temperature increase. However, poor management and degradation of coastal ecosystems could exacerbate this condition. In contrast, sardine fisheries may benefit. Nevertheless, the high variability of small pelagic fish restrains us from being overly optimistic about the role of sardine protein in alleviating food insecurity among the poor.

No specific actions for adaptation have been implemented in the Mexican fishery sector. Furthermore, the link between CC impacts on fish resources and food security remains ambiguous. More research is thus needed to understand how these differentiated outcomes could directly affect income, employment, profits, and, consequently, food security. There are also other questions that require answers: Which adaptation actions are needed in Mexico's fisheries sector? Who is responsible for implementing them? And how much will they cost?

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Appendix A: Province codes

Pacific coast	
BC	Baja California
BCS	Baja California Sur
SON	Sonora
SIN	Sinaloa
NAY	Nayarit
JAL	Jalisco
COL	Colima
MICH	Michoacan
GUE	Guerrero
OAX	Oaxaca
CHIS	Chiapas
Gulf of Mexico	
TAMPS	Tamaulipas
VER	Veracruz
TAB	Tabasco
CAMP	Campeche
YUC	Yucatan
QROO	Quintana Roo

Appendix B: Multicollinearity tests (regression: least squares)

Table B1: Variance inflation factors (VIF) for the Mexican shrimp and sardine fishery models.

	Shrimp		Sardine	
Variable	VIF	1/VIF	VIF	1/VIF
Temperature	1.24	0.808	1.10	0.912
Capital	1.70	0.588	2.10	0.476
Labor	1.30	0.770	1.58	0.632
Financing	1.32	0.759	1.40	0.716
Mean	1.39		1.54	

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