Adaptive Capacity for Responding to Climate Variability and Change in Estuarine Fisheries of the Rio de la Plata

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Adaptive Capacity for Responding to Climate Variability and Change in Estuarine Fisheries of the Rio de la Plata[1]

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Abstract

Key words: Climate variability and Change; adaptation strategies; Rio de la Plata estuary; Fisheries; Livelihood; scenarios

Climate and natural systems are changing in the Rio de la Plata basin over the last few decades, posing new threatens to multiple sectors associated with the estuarine waters. In a previous paper we assessed the vulnerability of some ecosystem functions and services focusing on ENSO-related variability and extremes. This paper primarily deals with the strategies of the artisanal fisheries fleet to cope with past and current variability (called Type-I adaptation). This fleet exploits fisheries within the estuarine front that moves river- and seaward driven by prevailing on- and offshore winds (E-SE and W-NW respectively) on synoptic to seasonal time-scales, and following river flow fluctuations on seasonal to inter-annual time-scales. The latter are partly associated with ENSO-related variability. Recent climatic trends and projections should result in the changes in location of the front and consequently of the spatial variability of fish distribution and recruitment of juveniles, and fishing grounds. Fishermen have shown to be resilient to stresses and perturbations within a wide coping range and have maintained the long-term productivity of resources up to 2002. However, they use to suffer heavy losses during strong ENSO years due to the change of location of the front. Land operation sites are placed within the typical front location where fishing grounds are accessible to the fleet. Fishing activity remained sustainable due to three main successful autonomous adaptation strategies based upon local knowledge: 1- seasonal migration; 2- change of fishing sites and 3- cautious fishing behavior and acceptance of some financial loss to avoiding risks. Nonetheless, evidence is that fishermen are not prepared to cope with climatic extremes and projected changes for the 2050s, i.e., an increase in river flow. Type-II adaptation (for climate change) should rely on planned adaptation strategies on the basis of adaptive management that will require a better interaction among stakeholders, real-time flow of information and early warning systems. The increase in public awareness associated with recent initiatives on climate issues and coastal zone management should be germinal to create a new behavioral scenario to cope with future changes.

Short title: **Climate Variability Adaptation of Estuarine Fisheries of the Rio de la Plata**

1. Introduction

The Rio de la Plata basin and estuary have been substantially influenced by human activities in recent decades and are vulnerable to climate extremes and changing precipitation patterns caused by climate change and variability (Camilloni and Barros, 2000; Nagy et al., 2002*a*; Nagy et al., 2006).

A self-sufficient artisanal fleet exploits fisheries at Pajas Blancas within the estuarine frontal system (Figure 1). The salt intrusion limit is located within two front lines: the Main Turbidity Front (MTF) and the Secondary Main Front (SMF) (Lappo et al., 2005; Severov et al., 2003; Nagy, G. J., et al., unpublished data). This feature sustains relevant ecological processes (nutrient assimilation, denitrification), services (CO_2 fixation, fish reproduction) and fisheries. The main resource is the croakers (Micropogonias furnieri), which migrates to the

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estuarine front to spawn at the bottom waters of the front from October to January. The spatial variability of the croakers and their recruitment strongly depends on the seasonal and interannual variability of river flow (Q_V), whereas fishing activity is limited by S/SE/SW winds (Norbis, 1995), with frequency patterns changing over the last few decades (Escobar et al., 2004).

The estuarine waters are subject to environmental changes (symptoms of eutrophication such as oxygen deficit and harmful algal blooms) associated with human activities at the watershed level and triggered by climatic stimuli, such as floods and droughts, which are partly associated with El Niño/Southern Oscillation (ENSO) variability on interannual timescale (Nagy et al. 2002*b*, 2006).

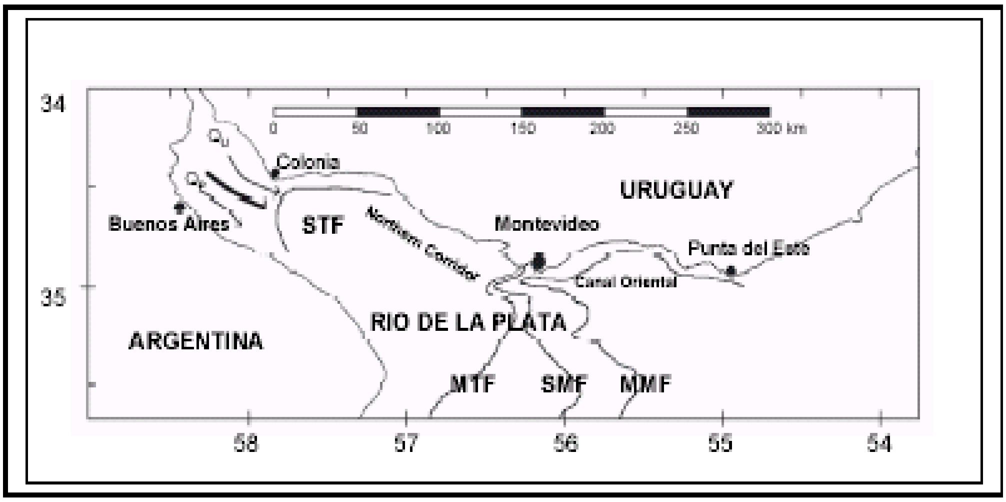

Figure 1. Sketch of the river flow corridors and fronts of the Rio de la Plata. Distance down-river from Colonia (DRC) is shown in kilometers. Estuarine frontal system is denoted by MTF and SMF. Composite image from Sea-WIFS satellite observations and in situ measurements on November 17, 2003.

Impacts, vulnerabilities, and risks associated with ENSO events in the studied area are summarized as follows: Strong El Niño (i.e., > 2.0 Sea Surface Temperature-SST 3,4) sustained for 3 or more months induces high rainfall and increased river flow. This increase in freshwater displaces the frontal system, where fishing grounds are placed, off and/or seaward of fishermen's land site. During strong La Niña (i.e., <2.0 SST 3,4), the front displaces off and/or riverward. Also, evidence is that wind climate, water temperature, symptoms of eutrophication, and the vertical structure of the frontal system change, all of which impact the availability of resources and water quality in addition to the accessibility and fishing cost-benefit issues (Nagy et al., 2006).

This paper primarily deals with the strategies of the artisanal fisheries fleet to cope with past and current variability (called Type-I adaptation).

2. Adaptation, Sustainable Livelihood and Local Knowledge

2.1 Categories of adaptation

We can think of two categories of adaptation. They might be called Type I and Type II (Burton, 2004). The former refers to past and current adaptation strategies without considering climate change. Most of the adaptation we do is still Type I. The latter is adaptation to climate change. Because of climate change risks, future scenarios and uncertainty have still not been factored into many development decisions, not much Type II adaptation has taken place.

2.2 What is adaptation?

Adaptation is the process by which stakeholders reduce the adverse effects of climate on their livelihood. This process involves any passive, reactive, or anticipatory adjustment of behavior and economic structure in order to increase sustainability and reduce vulnerability to climate change, variability, and weather/climate extremes (modified from Burton, 1996, 1997; Smit, 1993; Smit et al., 2000). An action is effective when it avoids a potential impact (Ionescu et al., 2005). Regarding the studied issues, adaptation occurs through two external physical processes: River flow and wind changes, and associated displacement of the frontal zone. Variations in the location of the main resource (Croakers) induce fishermen migration.

2.3 Sustainable livelihood and local knowledge

Sustainable livelihood of small-scale and subsistence fisheries is strongly associated with local and traditional knowledge, the way they organize themselves to manage natural resources, and the improvement of participatory processes and governance (Food and Agricultural Organisation -FAO-, 2000). Knowledge is at the heart of economic growth and sustainable development, understanding how people and societies acquire and use it—and why they sometimes fail to do so—is essential in improving people's lives, especially the lives of the poor. The fisheries sector is particularly rich in custom, tradition, and local knowledge, reflecting these in its communities, their established beliefs, and practices. The location and seasonality of fishing grounds and fishing are all facets of this knowledge fund. The proximity to the natural resource base has a dominating influence on the culture and thinking of the fishing community (FAO, 2000). Conservation and management decisions for fisheries should be based on the best scientific evidence available, also taking into account local knowledge of the resources and their habitat (FAO, 2000). Some of the characteristics of local knowledge (Studley, 1998), which are attributes of Pajas Blancas' fishermen community are *1*) it is linked to a specific place, *2*) it is dynamic in nature, and *3*) it belongs to a group of people who live in close contact with natural systems.

- Sustainable livelihood is a dynamic set of capabilities, assets, and activities required for a mean of living (DFID, 2000). The assets are human, physical, social, financial, and natural capitals. Livelihoods are considered to be sustainable when they (1) are resilient in the face of external shocks and stresses, (2) are not dependent upon external supports, and (3) maintain the long-term productivity of natural resources.

3. Goals and questions addressed

This paper deals with Type-I adaptation measures to climate variability and current environmental changes for subsistence fisheries associated with the estuarine frontal system of the Rio de la Plata. We put the emphasis on ENSO-related vulnerabilities analyzed in our previous paper on vulnerability (Nagy et al, 2006). We assume that historic responses to gradual socioeconomic or environmental conditions can serve as analogues for social adaptation to future climate change (Stockholm Environment Institute - SEI -, 2001; Easterling et al., 2004). Finally, we suggest Type II adaptation options based on Type I experiences and analogues, and future climate and environmental scenarios. Main questions addressed in this paper are the following:

1. Is the coastal fisheries Type I adaptation adequate to cope with current climate variability?
2. Is the plausible increase in temperature (i.e., +1–2° C), precipitation and river flow –

Q_V (~5–20%) by 2050 a threat to the sustainable livelihood of coastal fishermen?

3. Is the access to information and knowledge (generation, demand, information, and outreach) adequate to deal with Types I and II of adaptation?

4. Framework and Methods

4.1 Approach

Our approach is based upon SEI (2001) framework for a second-generation assessment of vulnerability and adaptation (Figure 2). This approach is based upon six concepts: (1) to determine what responses reduce risks?, (2) to investigate causes of vulnerability, (3) to take into account social causes of vulnerability, (4) to consider multiple stresses, (5) to use recent experiences as analogues and (6) to treat adaptation measures centrally.

Also, we took into account the FAO Report No. 639 on fisheries (FAO, 2000), our previous assessment of vulnerabilities (Nagy et al., 2006) within the context of the multilevel indicator "vulnerability to climate variability and change" (Moss, 1999), and a classical driver-Pressure-State-Response (d-PSIR) framework, which will be shown later in this section. Likewise, we assume that reducing vulnerability requires enhancement of adaptive capacity.

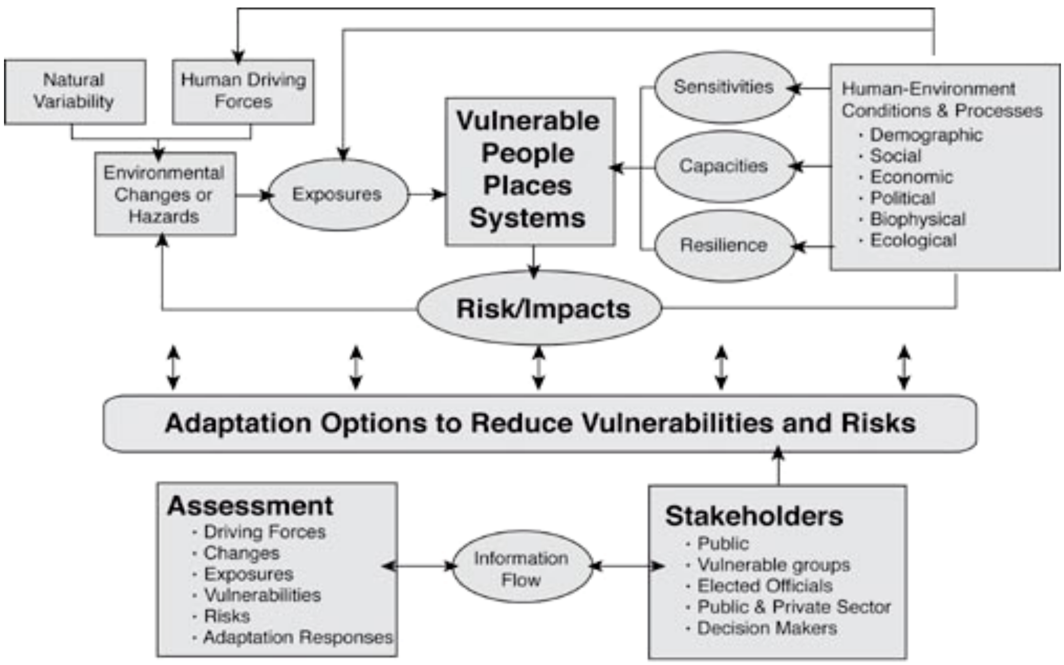

Figure 2. Vulnerability and adaptation framework (from SEI, 2001).

4.2 Methods

We used a combination of primary and secondary information (Pittaluga et al., 2005), including (1) in situ and remote observations to follow the location of the estuarine fronts (see Figure 1), (2) climate scenarios (global circulation models; see section 6 and Nagy et al., 2006), (3) expert judgment of authors (based upon primary and secondary information, indicators such as ENSO SST 3,4, salinity, fish yields, wind speed; see also Nagy et al., 2006), and (4) cost-benefit valuation of direct use of artisanal fisheries-fishing activity (Dixon and Huffschmidt, 1986;

Pearce and Turner, 1991; Nagy et al., 2006). Social vulnerability was assessed from secondary information (Hernández and Rossi, 2003; Norbis et al., 2005; Nagy et al., 2006).

5. Fishing Activity within the Estuarine Front and Sustainable Livelihood
5.1. Background of fishing activity

A self-sufficient artisanal fleet exploits fisheries within 5–7 miles off the Uruguayan coast at the Northern corridor close to the MTF front-line within the estuarine front of the Rio de la Plata. The main fishermen community is based at Pajas Blancas about 125 km down-river from Colonia (Figure 3). Fishing activity is carried out year-round, the peak being associated with croakers' migration to the estuarine front to spawn during spring and early summer (last September to January), accounting for more than 80% of annual catch. Usually, from January to September, many fishermen migrate to seaward fishing sites (i.e., San Luis, 225 km Down River Colonia) or look for alternative incomes.

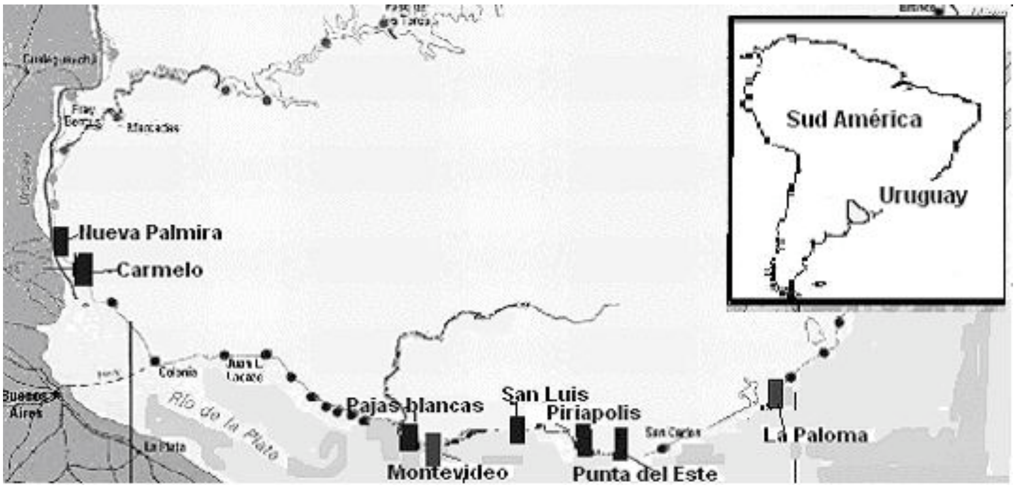

Figure 3. Location of main fishing sites of Uruguay.

First studies of Pajas Blancas' fishery were carried out from 1987 to 1989. During the 1988–1989 fishing period, both the length of the reproductive period and the number of captured fishes were less than in 1987–1988 and total catch was 60% less (Acuña et al., 1992). Norbis (1995) analyzed captures from the 1987–1988 fishing period and concluded that the catch was greater after southeast winds (postfrontal period), when north-northeast winds blow and diminished when south-southeast (S-SE) winds greater than 8 m/s or west-southwest winds, which oppose river discharge, prevailed. These studied fishing periods were characterized by moderate (1987–1988) and very low river discharge (1988–1989), especially of River Uruguay flow, the latter associated with the strong La Niña 1988. Usually, the percentage of River Uruguay flow increases with total freshwater inflow (Tables 1 and 2).

Table 1. Freshwater Inflow ($Q_P + Q_U$), River Uruguay Flow (Q_U) and Percentage of Q_U During the Fishing Periods 1987–1988 and 1988–1989

Freshwater Inflow (m3/s)	**November 1987–January 1988**	**November 1988–January 1989**
Total inflow (Q_V)	19,200	14,000
River Uruguay flow (Q_U)	2,900 (15%)	1,500 (11%)

Table 2. Average Yearly Freshwater Inflow (Q_V) and River Uruguay Flow (Q_U) During the Period 1990–1999 and the Extreme Years 2000 (La Niña) and 2002 (El Niño)

Year	Q_U (10^3 m^3/s)	Q_V (10^3 m^3/s)	Q_U %
1990–1999	5,6	26,0	21
2000	4,7	20,1	23
2002	9,2	26,8	35

5.2. Fishing activity within the estuarine frontal system: Impacts and risks

The estuarine frontal system displaces tens to two hundreds kilometers down- and up-ward as a function of seasonal to interannual river flow variability, onshore (S-SE) and offshore (W-NW) winds on weather development (1–10 days) and seasonal timescales (Framiñán and Brown, 1996; Severov et al., 2003, 2004; Nagy et al., 2006). Frequency patterns of these winds have changed over the last few decades, with an increase in onshore (E-SE) winds (Pshennikov et al., 2003; Escobar et al., 2004).

Flooding of River Uruguay (Q_U) occurs preferentially in the northern corridor (Figure 1) in October–November followed by low-water from December to February. Both of these events are triggered by El Niño (i.e., 1997 or 2002) and La Niña years (i.e., 1988 and 1999) respectively, when the frontal zone and fish resources were located far up river or downriver, respectively, from the land base resulting in an increase in fishing effort. Fishing effort is the ratio cost of navigation to the moving fishing ground to the benefits of catch.

Net income during strong ENSO years is reduced to about 40–70% (60% on an average) of long-term average (1988–2001) (Norbis et al., 2005; Nagy et al., 2006) mainly because of the shortened fishing peak period due to both the inaccessibility and size of fishes. Strong La Niña events such as 1988–1989 and 1999–2000 are severe shocks that pose a big threat to fishermen's adaptive capacity and sustainable livelihood (Norbis et al., 2005).

In addition to climatic and economic threats to fishermen's livelihood, the estuarine waters are subject to environmental changes, especially symptoms of eutrophication, which could alter the resources habitat, especially because of development of hypoxia (oxygen deficit) at bottom waters (Nagy et al., 2002*b*).

Until 2001–2002, fishermen had shown that they were resilient to stresses within a wide coping range and have maintained the long-term productivity of resources. However, they were partly dependent upon external support (they received some money in advance for fuel in exchange for future catch). According to the criteria of Pittaluga et al (2005) for poverty and vulnerability of livelihood systems the Pajas Blancas' fishermen community can be placed between moderately poor and self-sufficient groups.

We are developing a dynamic model of fishery livelihood for Santa Catalina fishing community (located close to Pajas Blancas) and analyzing its relationship with climate variability and environmental changes; a causal diagram loop is shown in Figure 4 to show all of the variables involved and their interactions without giving details.

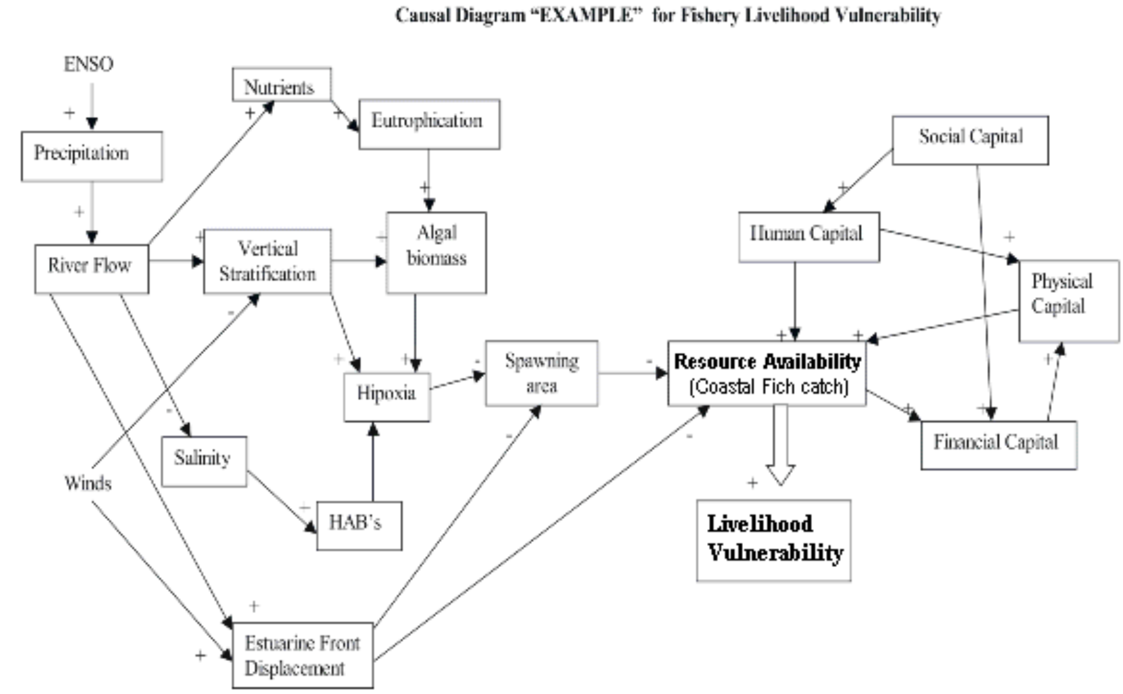

Figure 4. Causal diagram for fishery livelihood vulnerability.

6. Adaptation Strategies and Future Scenarios
6.1. Adaptation strategies and cost-benefit of fishing activities

Fishermen have acquired (local) knowledge of the interactions between environment and resources (as shown in Figure 4), as well as a mode of behavior, which have been the base of their adaptive capacity (human capital). Fishermen have developed three main adaptation strategies to cope with the increase in ENSO-related river flow variability and related locations of front lines, evolving from autonomous and reactive actions to planned private ones, without any participation of public managers or local authorities. It seems reasonable to assume that the nature of decision making at the strategic level is less clear than for individual actions within a strategy (Downing et al., 2004):

1. Seasonality (seasonal migration)
2. Change of fishing site(s)
3. Cautious fishing behavior and acceptance of loss

In spite of human capital and good resources availability, fishermen remain vulnerable and have not the appropriated social and financial capital to cope with climate extremes (Nagy et al., 2006), whereas the physical and natural capital is threatened by economic losses during strong ENSO years and the increase in environmental and welfare economics changes, respectively.

Spatial changes along the coast reduce the ability of fishermen to catch in other conditions, increasing their vulnerability to the vicissitudes of life: relocating and finding employment outside of fisheries. However, fishermen do not notice fluctuations of resources until they perceive changes of availability as a consequence of river flow and/or winds. Thus, extreme events drive adaptive prevention of loss (Norbis, 2003). It is probable that the very low catch attributable to La Niña in 1988 induced autonomous behavioral changes.

Because of the spatial and temporal changes of the estuarine front and resource availability, as well as the increasing trend of river flows, many fishermen have migrated seasonally or definitively away from the front along the coast following resources in order to reduce their long-term vulnerability to hydroclimatic fluctuations and avoid bad catch years (Hernández and Rossi, 2003; Norbis et al., 2005).

Aside from these two seasonal and climate-induced migration strategies, fishermen have learned that a cautious behavior to avoid weather-related risks reduced their vulnerability (Nagy et al., 2006). Usually, they do not risk fishing for at least one day after the occurrence of nonfavorable wind conditions. However, Norbis (1995) demonstrated that fish are often available and fishermen lose up to 20% of good fishing days, and that this cautious practice could be modified.

Adaptation is a risk-management strategy that is not free of cost (Easterling et al., 2004). Evidence is that fishermen could afford residual loss after reactive and planned adaptation measures made up to 2002 (Norbis et al., 2005; Nagy et al., 2006). A key question for future research is: Are adaptation benefits from avoiding damage losses equal or greater than adaptation costs and loss of benefits? The fishing period 2002–2003 illustrates fishermen's options. This period was very bad because of three constraints and impacts:

- the seaward displacement of the estuarine front (up to 150–200 km DRC) because of increased river flow (due to a moderate to strong El Niño event);
- the increase in the frequency of unfavorable (SE) winds to fish (Nagy et al., 2006; Nagy, G. J., et al., unpublished data; Norbis et al., 2005);
- the deterioration of socioeconomic conditions (very strong regional economic crisis during 2001–2003 that affected welfare economics index, increase in fuel price, and lack of alternative incomes).

Thus, many fishermen took a risk fishing under unfavorable conditions (SE winds), which ultimately resulted in a maladaptation practice (Norbis et al., 2005; Nagy et al, 2006). Fish yields were very bad because of the increased cost of navigation, shortening the fishing period, reducing the number of good fishing days, and reducing the availability of resources, all of which forced many fishermen to migrate to eastern sites such as San Luis before January.

Was this failure of human capital an anticipation of future difficulties to adapt (Type-II adaptation) to increasing changes? It seems that fishermen need to adopt further adaptation strategies in case of climate variability and change, as well as increases in nonclimate stresses.

Pathways of response of fishermen to combined climate change, ENSO-related variability, and human drivers of environmental changes are shown in Figure 5.

6.2 Future climate and environmental scenarios

To examine whether the increase in temperature, precipitation, and river flow (Q_V) pose a threat to the sustainable livelihood of coastal fishermen, we used recent experiences as analogues, as well as projections from current literature. In order to estimate the future climate scenarios and the climate simulations with global climate models (GCMs) in the southeastern South America region, we selected two available runs from Intergovernmental Panel for Climate Change (IPCC) Distribution Data Center, using the IPCC socioeconomic Special Report on Emissions Scenarios (SRES) and projections from current literature (Nagy et al., 2006). The A2 and B2 scenarios describe a future (i.e., 2050) characterized by a globalized world with high emissions and a regionalized world with low emissions. They correspond to middle-high and middle-low views of future emissions, respectively.

The selected models were HadCM3 (UK) and ECHAM4/OPYC3 (Germany), which have acceptable agreement with the observed sea level pressure field. These models are able to represent the position and intensity of the pressure systems, both on monthly and annual bases (Bidegain and Camilloni, 2004; Nagy et al., 2006).

DRIVERS

CLIMATE CHANGE and ENSO VARIABILITY + ECONOMIC and POPULATION GROWTH

↑ Air Temperature — Land Misuse / Cover Change

↑ Precipitation — ↑ Nutrient Point Sources

↑ RIVER FLOW

⇓

IMPACTS

HYDROLOGIC ENVIRONMENT

↑ Water temperature
↑ Freshwater volume
↓ Salinity ↑ Vertical Stratification
Δ Displacement of the Estuarine Front
↑ Nutrient Non-Point Sources

HUMAN SYSTEM

Change of fisheries accessibility
↓ Fish catch /economic benefit

. ⇓

STATE

Environmental Changes (symptoms of eutrophication)
↑ Algal Biomass (chlorophyll-*a*)
↓ Dissolved Oxygen (Hypoxia)
↑ Harmful Algal Blooms
Δ Ecosystem metabolism (Production - Destruction of Organic Matter*)*

. . ⇓

RESPONSE and ADAPTATION

AUTONOMOUS ADJUSTMENTS
Salinity / oxygen changes
Fish Migration

ANTICIPATORY MEASURES
Adaptation Control Information System

⇓

Fishermen Migration
(both fishing activity and settlements from Western Montevideo to San Luis)
enhancement of appropriated weather / climate forecasting for fishermen
increase in the number of (good) fishing days
increase in Catch
amelioration of legal and institutional conditions of fishermen communities
partial reduction of vulnerability

Figure 5. Pathways of driver-Pressure-State-Impact-Response of fishermen (human system) and eutrophication (natural system) to combined climate change, ENSO-related variability, and human drivers.

Observed climate fields indicate that both models underestimate precipitation within the Rio de la Plata basin. Nevertheless, monthly and annual temperature fields show that, in general, both models have acceptable agreement with the observed fields.

Future regional climate scenarios for precipitation and temperature were constructed for 2050 and 2080s with HADCM3 model forced by the SRES A2 socioeconomic scenario.

Current climate and future scenarios for the Rio de la Plata basin (2050) and estuary suggest a change in precipitation within the range +5% to +20% and in temperature from +1 to +2°C, whereas during the last few decades, these changes have been +20 to 25% for precipitation and +0.5 to +0.8°C for temperature, as well as +25 to 40% for river flow. Trends for Q_{Vs} are very difficult to be estimated because of both the uncertainty of regional human drivers and because of the varied regional scenarios from different GCMs.

Under a future scenario in which stream flow remains similar or slightly lower (i.e., 0% to –10%), we do not expect a significant increase in current environmental stresses on the estuarine system (which are already moderately high) with the exception of nutrient inputs (a pressure indicator for eutrophication). Our concern is about a future scenario where Q_V increases within the range ~10–25%, together with projected temperature increases and economic and population growth, for which significant impacts are expected in the estuarine system.

Considering the fact that seasonal temperature, precipitation and stream flow cycles are not superposed, any changes should modify seasonal circulation, stratification and estuarine front location, inducing further environmental shifts with a probable increase in the degree and occurrence of symptoms of eutrophication such as hypoxia (oxygen deficit) at bottom waters and harmful algal blooms (Nagy et al., 2002*a*,*b*; 2006).

6.3. Scenarios of sustainability and future adaptation

A model of fishing activity was developed during this study based upon direct use costs estimated from secondary information (observed data during the fishing period 1998–1999). We assume, on the basis of climatic conditions and seasonal yield compared with long-term yields and income figures that the studied year is a typical one and allows fishermen to be sustainable. These figures are 923 fishing navigations in 64 days with an average catch of 22 boxes. The model considered 640 navigations (10 boats per navigation/day) and an average catch of 20 boxes per navigation/day. Usually, fishing period lasts 2–5 months, average favorable fishing days is 15–16 days/month, and total number of boats is about 31 (Norbis et al., 2005; Nagy et al., 2006).

Figure 6 shows the comparison between observed versus modeled total accumulated boxes. Up to about fifty fishing navigations, modeled capture is greater than observed capture, whereas for navigations greater than fifty observed ones are greater. For instance, for sixty-four navigations (1998–1999), the increase in capture should be about 60%, which should allow fishermen to recover both the investment capital and losses during bad years.

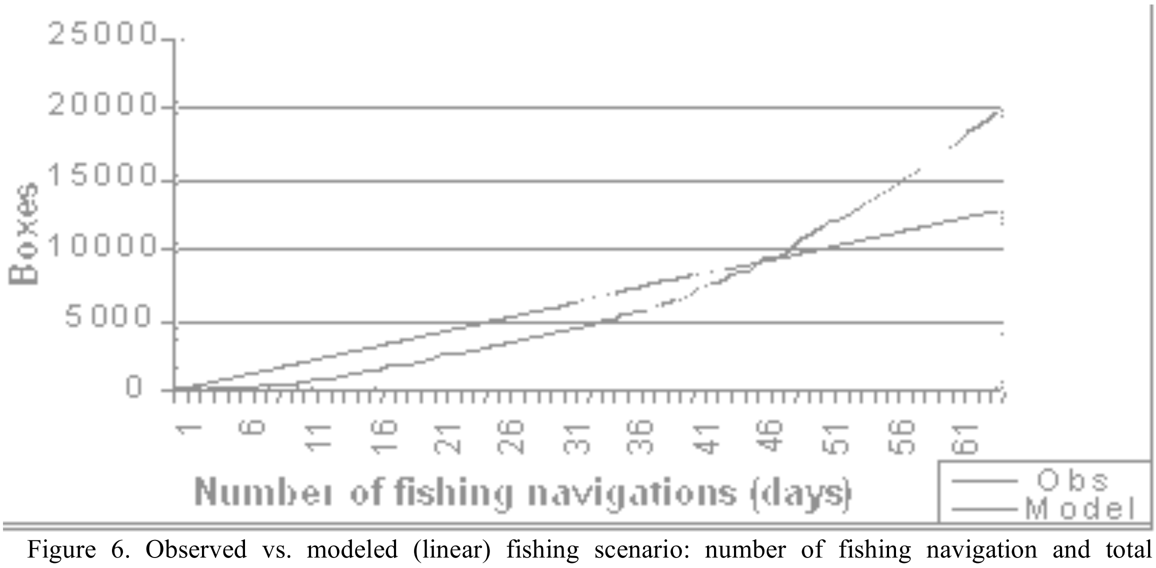

Figure 6. Observed vs. modeled (linear) fishing scenario: number of fishing navigation and total accumulated boxes.

It must be noted that average boxes and navigation days are not independent because usually a few number of leading fishermen decide to navigate and are followed by others, and this number should increase if adaptation measures were taken.

The model, which takes into account cautious numbers of catch per day (20 boxes), suggest that an increase in the number of fishing navigations is a key factor. Thus, because neither weather nor climate conditions can be managed, only real-time forecasting and communication with fishermen, which should allow to increase the number of navigations under favorable fishing conditions, seem to be a wise and low-cost adaptation practice. For this, an increase in security of navigation and good relation with the Coast Guard and the Directorate of Aquatic Resources are needed.

Regarding *questions 1* and *2*: Is the coastal fisheries Type I adaptation adequate to cope with current climate variability? Yes, it is adequate to cope with current variability, but it is not enough to cope with Type II adaptation needs associated with future climate variability and changes, and nonclimate changes.

7. Adaptation Control Information System and Access to Knowledge and Information

There is no system of planned adaptation measures, but the aforementioned autonomous actions. The last two decades have been characterized by increasing trends in means and variability of river flow and temperature, changes in front location and salinity, and resource availability. These environmental factors have led to an increase in interannual fluctuations of fish yields and fishermen's income. All of these facts have imposed new challenges and threats to subsistence fishermen. If no changes in behavior and policy are made, the adaptation will continue on a business as usual (BAU) trajectory, and coastal fisheries are likely to be unsustainable under projected increase in climate variability, environmental changes, and economic recession. Past and analogous experiences show that under severe climatic pressures, fishermen are strongly impacted and reactive measures have poor results, independently of socioeconomic and institutional constraints and actions. Because of uncertainty, management strategies should be periodically revised and adapted to the dynamic conditions of the stock, environment, and resource users, as well as to changes in the intertemporal preferences of the fishing sector. That is to say, fishermen and policy makers need to adopt an adaptive management strategy.

We suggest the best approach is to develop an adaptive management strategy supported by an Adaptation Control Information System (Figure 7), which should prioritize:

- generation and access to knowledge and information on weather and climate forecasts, fishery resources, frontal dynamics (satellite data-based), and water quality;
- education, learning processes and participatory processes; and
- early warning systems.

Local and scientific knowledge are shared between managers, institutions in charge of observations, scientists, and fishermen, and there is a lack of interaction and trust between all of them. Furthermore, some coastal observations have been discontinued in Uruguay (i.e., daily salinity in several sites).

Knowledge is accumulated through observation, monitoring, and analysis, which degrades if the data collection system collapses, if literacy and education levels diminish, or if basic societal infrastructure diminishes (Easterling et al., 2004). States should assign priority to undertake research and data collection in order to improve scientific knowledge of fisheries (FAO, 2000).

Adaptation measures will only be effective if education, the generation and access to information and communications among stakeholders (fishermen, managers, local authorities and scientists) are improved. Neither the acquired scientific and local knowledge nor the

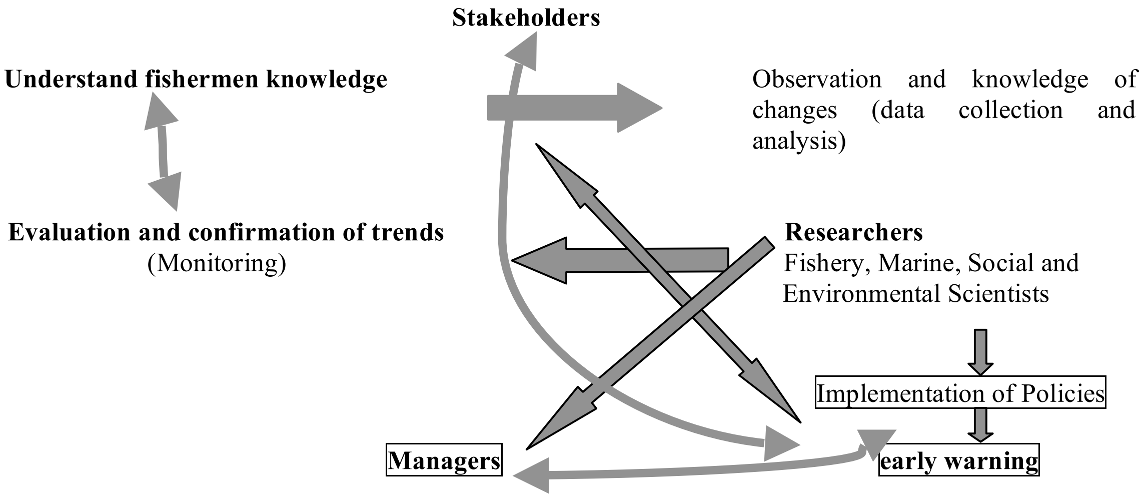

Figure 7. Hierarchical procedure of the Adaptation Control Information System–ACIS (modified from Norbis, 2003).

improvement of early warning systems will be enough until fishermen are able to make an effective use of it. An important constraint is the failure of fit between time and space scales between institutions responsible for management and actors (Norbis, 2003).

Regarding question 3: Is the access to information and knowledge (generation, demand, information, and outreach) adequate to deal with Types I and II of adaptation? Fishermen using wise fishing practices have had an adaptive potential that has proven to be sufficient to cope with past climate and nonclimate scenarios and that they neither depend on the flow of information from managers and scientists nor demand it. However, empirical evidence suggests that if BAU economic scenarios continue, it seems likely that current adaptation will not be sufficient under increased climate constraints.

Translation of climate scenarios and forecasting to advise appropriate action are not simple matters. Most of the success will depend on the adaptive potential of stakeholders, that is to say the ability to innovate and create new strategies and actions outside the actor's customary network (Downing et al., 2004).

One example of a negative experience was the lack of an adaptive response of stakeholders and the failure to use human capital during the fishing period 2002–2003, revealing a loss of resilience. On the other hand, the increases in capacity building, participatory processes, and public awareness associated with current and future research projects and the National Communications to the United Nations Framework for Climate Change, should be germinal to create a new behavioral scenario to cope with climate variability and change, and environmental changes, not only for subsistence fisheries, but also for climate change issues in coastal zone management initiatives.

8. Summary and Conclusions

As a consequence of impacts, vulnerabilities and risks associated with ENSO events and environmental changes in the studied area, especially those related to the location of the frontal system—where croakers reproduce—and the physical and economical accessibility of boats to fishing grounds, two main approaches have been taken:

1- Analysis of past/analogue experiences in both climate and nonclimate constraints, vulnerabilities, and impacts.

2- Development of future climate and environmental scenarios based upon recent experiences as analogues, projections from current literature, and GCMs for the Rio de la Plata basin (SRES A2 and B2 for 2050).

Past experiences indicate that subsistence fishermen have successfully adopted three main autonomous adaptation options summarized as follows: (1) seasonal migration along the coast following the resources associated with frontal displacement; (2) change of fishing site(s) seaward of the frontal system, and (3) cautious fishing behavior under nonfavorable wind conditions and acceptance of income loss.

However, in spite of these wise Type-I adaptation practices, fishermen remain highly vulnerable to severe weather and climatic conditions and should be unsustainable under increasing climate variability and environmental changes.

Projected scenarios for 2050 will increase vulnerabilities of the artisanal fisheries, which should be heavily impacted.

Current level of uncertainty about near-future climatic change and socioeconomic trends does not seem to be the main constraint to adaptation, but the lack of both access to information and knowledge, as well as public awareness about the impacts of current climate variability and extremes. This statement could be extended for the coastal zone as a whole.

Education and training, participatory processes, dialogue, and communication between stakeholders are needed to implement effective measures to take advantage of generation of knowledge and information, forecasting, and early warning systems.

ENSO events are recurrent, and once the first indicators are known (i.e., SST 3,4) anticipatory adaptation measures should start (i.e., real-time communication and early warning).

Adaptive management should emphasize the integration of local and scientific knowledge, training, enhancement of data collection systems, weather and climate forecasting, and real-time communication to users (fishermen, Coast Guard).

As a consequence of research on recent severe ENSO events and the National Communications to the UNFCC, public awareness has been increased and new regulations on practices and plans have been planned in several sectors in order to adapt to the new climate variability conditions.

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