IVAN MACHADO MARTINS

Vulnerability to and perception of climate change among small-scale fishing communities from the South Brazil Bight

Thesis submitted to the Oceanographic Institute of the University of São Paulo, in partial fulfilment of the requirement for the degree of Doctor of Science, program of Oceanography, Biological Oceanography area

Supervisor: Prof. Dr. Maria de los Angeles Gasalla

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VERSÃO CORRIGIDA

Prof. Dr. ______________________________	Conceito ________
Prof. Dr. ______________________________	Conceito ________
Prof. Dr. ______________________________	Conceito ________

To my family,
in special to my grandfather
Teófilo (*in memoriam*)

AGRADECIMENTOS

(Acknowledgments, in portuguese)

À minha orientadora, Maria de los Angeles Gasalla, pela oportunidade de desenvolvimento deste projeto e pela orientação, confiança e incentivos, além de me proporcionar a participação no projeto GULLS.

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RESUMO

A pesca é uma das principais atividades extrativistas de recursos marinhos e constitui importante fonte de alimento, renda e modo de vida para milhões de pessoas ao redor do mundo. As comunidades pesqueiras são bastante susceptíveis às mudanças econômicas, sociais, naturais e também climáticas. Desta forma, as mudanças climáticas têm afetado o modo de vida das comunidades pesqueiras e seus impactos e consequências ainda são pouco explorados. Com isto, a presente tese buscou contribuir para um melhor entendimento dos impactos das mudanças climáticas em comunidades de pesca de pequena escala, usando a percepção e a vulnerabilidade como abordagens analíticas. A região alvo do estudo foi a costa Sudeste do Brasil, definida como a área da plataforma continental que se estende entre o Cabo Frio (RJ) e o Cabo de Santa Marta (SC). A região possui características únicas, pois situa-se na região mais urbanizada e industrializada do país, e abriga uma série de comunidades pesqueiras de pequena e grande escala. Com o intuito de representar a diversidade de comunidades pesqueiras da região, 8 comunidades com características distintas foram selecionadas: Itaipu (RJ), Ilha do Araújo (RJ), Enseada (SP), Bonete (SP), Boqueirão Sul (SP), Mandira (SP), Pontal de Leste (SP) e Praia do Porto (SC). Um total de 151 unidades familiares foram entrevistadas nas comunidades selecionadas no período de Novembro de 2014 a Setembro de 2016. No primeiro capítulo a abordagem etno-oceanográfica foi utilizada para investigar a percepção dos pescadores a respeito das mudanças no clima e nos oceanos e o impacto de tais mudanças no modo de vida dos pescadores. Os resultados encontrados mostram que os pescadores detectam mudanças no ambiente e que tais mudanças estão impactando positiva e negativamente os seus rendimentos e o modo de vida dos pescadores. No segundo capítulo foi utilizado uma abordagem ampla e multiescalar para avaliar e identificar os principais fatores que afetam a vulnerabilidade das comunidades pesqueiras às mudanças climáticas. Dentre os fatores temos a distância ao mercado e aos centros urbanos e a falta de suporte institucional que aumentam a vulnerabilidade; enquanto que organização comunitária, forte liderança, parceria com centros de pesquisa, gestão compartilhada e alternativas de modos de vida que reduzem a vulnerabilidade das comunidades. No terceiro capítulo a abordagem da vulnerabilidade foi novamente utilizada, mas desta vez em nível regional, através da comparação dos dados da costa Sudeste do Brasil com a costa sul da África do Sul. Entre os fatores que diferenciam as duas regiões estão a alta dependência da pesca, forte relação com a comunidade e falta de política pública voltada para a pesca de pequena escala que aumentam a vulnerabilidade das comunidades da costa Sudeste do Brasil; enquanto que participação no processo de tomada de decisão, posse de barcos e das licenças de pesca são fatores que reduzem a vulnerabilidade regional da costa Sudeste do Brasil. Desta forma, estes achados contribuem para melhor compreender o impacto das mudanças climáticas no modo de vida dos pescadores e nas comunidades pesqueiras, servindo de base para a elaboração de estratégias de adaptação às mudanças climáticas mais eficientes e de menor impacto social.

Palavras-chave: Vulnerabilidade. Mudanças climáticas. Percepção. Pesca pequena escala. Comunidades pesqueiras.

ABSTRACT

Fishing is one of the main extractive activities of marine resources and constitutes an important source of food, income and livelihood for millions of people around the world. Fishing communities are highly susceptible to economic, social, natural and climate changes. Climate change has affected the livelihoods of fishing communities, and the impacts and consequences are still poorly understood. Therefore, this thesis sought to provide a better understanding of the impacts of climate change on small-scale fishing communities, using an analytical approach focusing on perception and vulnerability. The study area was the South Brazil Bight region, defined as the continental shelf area that extends between Cabo Frio (RJ) and Cabo Santa Marta (SC). The region has unique characteristics, as it is located in the most urbanized and industrialized region of the country and has several small- and large-scale fishing communities. To represent the diversity of the fishing communities in the region, 8 communities with distinct characteristics were selected: Itaipu (RJ), Ilha do Araújo (RJ), Enseada (SP), Bonete (SP), Boqueirão Sul (SP), Mandira (SP), Pontal de Leste (SP) and Praia do Porto (SC). A total of 151 households were interviewed in the selected communities from November 2014 to September 2016. In the first chapter of this thesis, an ethno-oceanographic approach was applied to investigate fisher perceptions on climate and ocean changes and the impact of such changes on fisher livelihoods. The results show that fishers detected changes in the environment and that these changes are positively and negatively impacting their yields and livelihoods. In the second chapter, a cross-scale approach was used to assess and identify the key factors that affect the vulnerability of fishing communities to climate change. Among the vulnerability factors, the distance to the market and urban centers and the lack of institutional support increase fishing community vulnerability to climate change; community organization, strong leadership, partnership with researchers, co-management and livelihood diversification reduce the vulnerability of communities. In the third chapter, the vulnerability approach was used again but at the regional level, by comparing data from the South Brazil Bight with the southern Cape of South Africa. Among the factors that differentiate the two regions, a high dependence on fishing, a strong attachment to place, and the lack of policy focused on small-scale fisheries increase the vulnerability of the communities in the South Brazil Bight, while participation in the decision-making process, ownership of boats and fishing rights are factors that reduce the regional vulnerability of the South Brazil Bight. Therefore, these findings provide a better understanding of the impact of climate change on the livelihood of fishers and fishing communities and serve as a basis for the development of effective climate change adaptation strategies that have minimal social impacts.

Keywords: Vulnerability. Climate change. Perception. Small-scale fishery. Fishing communities

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LIST OF ABBREVIATIONS

BCLME	Benguela Current Large Marine Ecosystem
BRICS	Brazil, Russia, India, China and South Africa countries group
CIEC	Cananeia-Iguape estuarine complex
CO_2	Carbon dioxide
DAFF	Department of Agriculture, Forestry and Fisheries
FAO	Food and Agricultural Organization of the United Nations
GDP	Gross domestic product
GULLS	Global learning and understanding for local solutions: Reducing vulnerability of marine-dependent coastal communities
IUCN	International Union for Conservation of Nature
MER	Marine extractive reserve
MLRA	Marine Living Resources Act
MPA	Marine protected areas
PCA	Principal component analysis
pH	Potential of hydrogen
SACW	South Atlantic Central Water
SBB	South Brazil Bight
SNUC	National System of Marine Protected Areas
SSFP	South African small-scale fisheries policy
SST	Sea surface temperature
STC	Southern Cape

SUMMARY

GENERAL INTRODUCTION

1. GENERAL INTRODUCTION

Human societies as well as the ecosystems with which they interact are exposed to changes, stresses and threats related to climate change, a phenomenon that has increased with anthropogenic pressures on natural resources (IPCC, 2014). Climate changes are part of the geologic history of the Earth, but the rapid warming of the planet that has occurred over the past 150 years is what concerns most, because the warming has intensified over the past few decades due to the increase in greenhouse atmospheric gas concentrations, mainly carbon dioxide, generated by human activities (KARL; TRENBERTH, 2003). Climate change refers to any change in the climate over time whether due to natural variability or human activity (NOBRE, 2008), and it is also responsible for the increase in the surface temperature of the earth, which results in a warming planet (LOWRY, 1972). In relation to the increase of global atmospheric temperatures, the global average temperature warmed by 0.85°C over the 1880-2012 period (HARTMANN et al., 2013), with a projected increase of 2.6-4.8ºC by the end of this century if greenhouse gas concentrations do not stabilize within 10 years (COLLINS et al., 2013).

The effects of the global warming have already been observed in the ocean, with an increase in the relative mean sea level (RHEIN et al., 2013). Climate change is a phenomenon that will continue for several centuries, even if emissions and concentrations of greenhouse gases are reduced (NICHOLLS; CAZENAVE, 2010; HOEGH-GULDBERG; BRUNO, 2010). Coastal ecosystems are also susceptible to intense environmental changes, whether the changes are anthropogenic, such as deforestation, development in coastal areas, domestic pollution and industrial sewage, overfishing and tourism, or whether they are climatic, such as rising sea levels, increasing CO_2 concentrations and decreasing pH of sea water (DASGUPTA et al., 2009; LOVEJOY, 2010). The increase in CO_2 concentrations and in air and ocean temperatures will also lead to a series of other impacts, such as the intensification of storms, changes in precipitation and fresh water intake, increases in salt water intrusion into soils and coastal aquifers, acidification of oceans, and changes in the strength, direction, and behavior of marine currents (NICHOLLS; CAZENAVE, 2010; HOEGH-GULDBERG; BRUNO, 2010). These physical and chemical changes have different effects on natural and human systems, with likely increases in the existing risks of flooding, loss of wetlands (NICHOLLS, 2004), and flooding of populated and urbanized areas that will have significant economic impacts (ZHANG et al., 2004; WU et al., 2008).

Coastal ecosystems are one of the environments most impacted by global environmental changes, including climate change, and these impacts have led to consequences such as the loss of coastal habitats and changes in marine fauna (HASSAN; SCHOLES; ASH, 2005; BADJECK et al., 2010). Ocean biological productivity and nutrient cycles are severely affected by climate change, and these changes affect the marine food web (CHIN et al., 2010). Changes in the marine environment have also caused changes in the abundance and distribution of some fish species (HSIEH et al., 2009). Rising sea level temperatures compromise fish biology and modify the latitudinal distribution patterns of some species (HIDDINK; HOFSTEDE, 2008). Changes in the distribution and abundance of some marine fish species will have positive and negative impacts on fishing activities (ROESSIG et al., 2004). People and communities living in coastal regions are also increasingly exposed to environmental and climate changes, making them more susceptible to hazards (FORD et al., 2006), affecting the livelihoods of fishers and those who directly depend on fishing as a source of food (BADJECK et al., 2010).

Thus, the observed changes are affecting the livelihood of fishing communities, mainly those communities that have a greater dependence on marine resources for economic and food security and for the maintenance of their traditions and culture (GATTUSO et al., 2015). Fisheries remain a major source of food, income, and livelihood for millions of people across the world, particularly for those in developing countries (GARCIA et al., 2003). The coastal communities that rely on small-scale fisheries are often susceptible to a broad array of socio-economic and biophysical changes (BENNETT et al., 2014). Understanding the socioeconomic characteristics of fisheries is important for planning regulatory measures to improve resource and livelihood sustainability (BERKES et al., 2001).

Among the fishing activities practiced on the Brazilian coast, small-scale (or artisanal) fishing may be the fishing type most harmed by the environmental changes that affect coastal ecosystems. The activity is practiced in a variety of ecosystems that greatly influence the way fishing activities are organized. Sea currents, winds, tides, waves, coastal vegetation, fauna and flora, and particularly, ecological cycles are important elements that are taken into consideration by small-scale fishers in order to organize their activities (DIEGUES, 2006). Small-scale fishers employ a number of fishing strategies, using cast net, gill net, trawling, floating and fix fish trap, octopus pot, beach seine, line, pole and line, longline, manual collection and spearfishing to target a broad group of demersal fish, pelagic fish, rockfish, crustacean, cephalopods and shellfish species.

In small-scale fisheries, fishers often lack the infrastructure needed to adapt to climate change impacts, such as changes in migratory fish routes and distributions (SILVA, 2014). Socioeconomic factors such as low income, lack of access to quality health services and loss of fishing territories also increase the vulnerability of fishing communities (GASALLA; ABDALLAH; LEMOS, 2018; GASALLA; GANDINI, 2016). Since small-scale fisheries are susceptible to environmental changes, it is important to identify and assess the vulnerabilities of small-scale fishery systems, as well as to assess the resilience and adaptability of these systems in the face of climate events that may occur in the future.

Considering that future projections show increasing effects of climate change (IPCC, 2013) and that the Southern coast of Brazil is one of the global hotspots for ocean warming (HOBDAY et al., 2016), changes are expected in the behavior of the main target fish species and in the dynamics of the fishing fleets in the region, resulting in impacts on fisher livelihoods (GASALLA; ABDALLAH; LEMOS, 2018). Considering these factors, understanding fisher vulnerability to the effects of climate change is fundamental to the establishment of effective mitigation and adaptation plans and to the proper design of public policies (SAVACOOL et al., 2015; FUSSEL; KLEIN, 2006).

1.1 Vulnerability: concept and definition

The concept of vulnerability has become the focus of an increasing amount of academic and applied studies on global environmental change, marine observation, and fisheries (ADGER, 2006). The development of the concept of vulnerability is complex, and there are distinct approaches being developed and followed by various scholars. The term vulnerability, whose scientific use comes from the geography and research of natural disasters, has assumed an increasingly relevant position in different areas such as economics, anthropology, ecology, psychology, medicine, and engineering, among others (ADGER, 2006; EAKIN; LUERS, 2006; FUSSEL, 2007). The terminology has been used in many ways by various research communities, such as those concerned with food security, livelihoods, natural hazards, disaster risk management, public health, global environmental change, and climate change

(FUSSEL; KLEIN, 2006). In the 1990s, the vulnerability to natural systems approach became more widespread in the context of climate change research due to concern about the increasing occurrence of natural disasters, their impacts on the environment, and the processes of adaptation to these impacts (EAKIN; LUERS, 2006). During that time, the vulnerability of both natural and social systems, the risks to which the systems are exposed, and the complex human-environment interactions were increasingly explored by scientists and researchers from different disciplines (MARANDOLA Jr; HOGAN, 2006).

Each discipline has its own definition of vulnerability, which generally depends on the context and purpose of application (FUSSEL, 2007). Vulnerability from the perspective of natural systems varies according to its use, access to resources and susceptibility to changing conditions in the natural environment (YOUNG et al., 2010). Researchers addressing ecological vulnerability are concerned with what natural system are vulnerable, what consequences can be expected, and where and when impacts may occur (EAKIN; LUERS, 2006). However, social vulnerability is conceptualized as the exposure of individuals or groups of individuals to stress as a result of environmental and social changes (ADGER, 1999). The mechanism that stresses resulting from environmental and social changes affect human populations differ according to different cultures, levels of education, ages and socioeconomic levels (TEKA; VOGT, 2010).

While ecological vulnerability typically focuses on the study of natural systems and the flow of matter and energy from these systems, social vulnerability emphasizes the flow of information, social relations, and the cultural dimensions of social systems (FUSSEL; KLEIN, 2006; MARANDOLA Jr; HOGAN, 2006). Despite the conceptual differences of vulnerability, there is no definition of vulnerability more representative than in the scientific context (EAKIN; LUERS, 2006).

In this study, the (social) vulnerability was defined as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate vulnerability and extremes (ADGER, 2006; CINNER et al., 2013). Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (FUSSEL; KLEIN, 2006). In this context, vulnerability is typically measured as a function of sensitivity, exposure, and adaptive capacity of a system to climate change (MARSHALL et al., 2013; CINNER et al., 2013; CUTTER et al., 2003; O'BRIEN et al., 2004; ADGER;

EAKIN; WINKELS, 2009). Sensitivity is the degree to which a system is affected and will respond, either adversely or beneficially, by climate-related stimuli, and the effect may be direct or indirect (FUSSEL; KLEIN, 2006; ADGER, 2006; O'BRIEN et al., 2004, MCLAUGHLING; DIETZ, 2008). Exposure is the nature and degree to which a system is exposed to significant climatic variations or the extent to which a system experiences change (FUSSEL; KLEIN, 2006; ADGER, 2006; O'BRIEN et al., 2004; LUERS, 2005, MCLAUGHLING; DIETZ, 2008). Both the exposure and sensitivity of a system are shaped by structural, political, and institutional contexts (HELTBERG; SIEGEL; JORGENSEN, 2009) and are inherently interconnected, as the relative effect of exposing a system to change is dependent on its sensitivity (LUERS, 2005). Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (FUSSEL; KLEIN, 2006; ADGER; VICENT, 2005). The adaptive capacity of a system or society can be described as its ability to modify its characteristics or behavior to better cope with changes in external conditions (FUSSEL; KLEIN, 2006). In addition, it is the social, political, economic and cultural forces of a system that shape its adaptive capacity to disturbances (SMIT; WANDEL, 2006).

Fisher vulnerability studies attempt to promote the development of biodiversity conservation policies and fishing resources affected by climate change, thus seeking a greater resilience of the system (FRASER; MABEE; SLAYMAKER, 2003). It is necessary to comparatively understand each of the vulnerability categories and to analyze to what extent their subcomponents impact the livelihoods and adaptive capacity of communities and coastal ecosystems.

The effects of climate change on fishery resources and fisher livelihoods have not received the same attention in discussions on mitigation and adaptation policies compared to sectors such as agriculture (DULVY; ALLISON, 2009). This trend ignores the potential consequences of climate change on human populations that rely on resources that are already declining. Due to the complexity of the problems and the interactions between the social and ecological factors, there is a need for interdisciplinary research that considers factors at multiple scales. Considering that responses to the impacts of climate change will primarily consist of individual responses at the local scale, this multiscale perspective needs to be applied to the analysis of adaptive capacity at the community level (DOLAN; WALKER, 2004).

Vulnerability studies are central to this scenario, because they integrate biophysical threats with social, economic, political and ecological factors that make different groups vulnerable in different ways. Despite the recognition of the need for information on these processes at a local scale, studies on fisheries vulnerability to climate change are rare and generally address the problem at larger scales (ALLISON et al., 2009; BLASIAK et al., 2017). A major limitation of large-scale vulnerability analyses is the lack of detailed social and economic statistics on fishing industries and fisheries at a national scale. The problem is particularly acute for small-scale and subsistence fishers, who tend to be overlooked in national censuses or aggregated and hidden within the agricultural sector (SADOVY, 2005; ANDREW et al., 2007).

1.2 Broad context of the thesis

This study is part of a broader scientific research project that was proposed to study some marine dependent communities on the Brazilian coastline. This study is part of a multilateral international project under the Belmont Forum and G8 Research Councils Initiative. The project 'Global learning and understanding for local solutions: Reducing vulnerability of marine-dependent coastal communities' (GULLS) was designed to characterize, assess and predict the future of coastal-marine communities in rapidly warming marine hotspots (see HOBDAY et al., 2016). Within the project, an international group of scientists came together to define a collaborative framework of social vulnerability to climate change, and a survey instrument was developed (ASWANI et al., 2018). The goal of the framework was to collect robust, local-level, social vulnerability data that would provide a good understanding of the local-scale processes influencing community vulnerabilities while allowing for the data to be scaled up to regional, national, and global levels both to integrate with ecological and oceanographic models and to allow comparisons among hotspot countries and communities. However, there are some details specific to Brazil included in this project, and this thesis is a result of the combination of local and collaborative approaches developed to study fishing communities with respect to climate change.

1.3 Thesis structure

This thesis is the result of my original study that aims to provide a better understanding of the impacts of climate change on small-scale fisheries and fisher livelihoods, using an analytical approach focusing on perception and vulnerability. This thesis is organized into three chapters.

In the first chapter, fisher perceptions on climate and ocean changes were investigated using an ethno-oceanographic framework (GASALLA; DIEGUES, 2011). The goal of the chapter is to explore how fishers have perceived the changes in the climate and ocean and to understand how these changes have impacted their fishing activities and livelihoods. Fisher perceptions were cross-validated to the available scientific literature, and the uncorrelated changes were used to outline new research hypotheses that may add new drivers, scenarios or system responses to the regional knowledge. This chapter constitutes one of the first evaluations of fisher perceptions of climate and ocean changes in the South Brazil Bight (SBB) region and provides a new understanding of human-climate interactions.

In the second chapter, the vulnerability of SBB fishing communities to climate change is explored. A comprehensive range of indicators have been used to provide an in-depth understanding of the sensitivity, exposure, adaptive capacity and vulnerability of the communities using the vulnerability framework developed by the GULLS project (ASWANI et al., 2018). The goal of the chapter was to identify the key factors that are driving the vulnerability and adaptive capacity of the selected fishing communities. The chapter was the first regional assessment on social vulnerability to climate change, providing novel perspectives on the impacts of climate change on fishing communities and the pathways to more resilient systems.

In chapter three, rather than looking at vulnerability at the community level (as in chapter 2), vulnerability is explored at the regional level. In this chapter, SBB's fishing communities were compared to the fishing communities in the Southern Cape (STC) region of South Africa to explore the differences and similarities among the vulnerability factors between the regions. Qualitative and quantitative data were used to explore the factors that are positively and negatively influencing vulnerability in both regions. The chapter provides an insight into the regional vulnerability of both countries and supports the development of climate change mitigation plans.

This study seeks to clarify the understanding of the impacts of climate change on small-scale fishing communities by exploring the perceptions of fishers (Chapter 1) and the factors affecting vulnerability at the community level (Chapter 2) and at the regional level (Chapter 3).

FIRST CHAPTER [1]

[1] Manuscript accepted for publication in the Climatic Change journal

2. CHAPTER 1

Perceptions of climate and ocean change impacting the resources and livelihood of small-scale fishers in the South Brazil Bight

Abstract Coastal fishing communities are closely linked to the biological and ecological characteristics of exploited resources and the physical conditions associated with climate and ocean dynamics. Thus, the human populations that depend on fisheries are inherently exposed to climate variability and uncertainty. This study applied an ethno-oceanographic framework to investigate the perceptions of fishers on climate and ocean change to better understand the impacts of climate change on the coastal fishing communities of the South Brazil Bight. Seven coastal fishing communities that cover the regional diversity of the area were selected. Fishers were interviewed using a semi-structured questionnaire. The results suggest that fishers have detected climate-related changes in their environment, such as reduced rainfall, increased drought events, calmer sea conditions, increases in air and ocean temperatures, changes in wind patterns and shoreline erosion. The perceptions of the fishers were compared to the available scientific data, and correlations were found with rainfall, wind speed and air and ocean temperatures. New hypotheses were raised based on the perceptions of fishers about sea level, coastal currents and sea conditions, such as the hypothesis that the sea has become calmer. These perceived changes have positive and negative effects on the yields and livelihoods of fishers. The present work is the first evaluation of the perceptions of fishers on climate and ocean change and brings new understandings of climate-fishery-human interactions as well as provides inputs for future adaptation plans.

Keywords: Climate change; ethno-oceanography; small-scale fishers; perception; livelihood.

2.1 Introduction

The perceptions of fishers on the physical and biological aspects of the ocean can convey the intricate relationship that sea workers have with the natural environment and can help identify and understand the changes in those habitats (HUNTINGTON, 2000). With respect to climatic conditions and changes, fishers may provide details and local peculiarities that are often not detected by regional and global ocean models and may also supply information in areas where historical data are missing (GASALLA; DIEGUES, 2011). This local view can provide novel perspectives for scientific purposes and support the local stakeholders in developing climate change adaptation strategies, management actions and policies (ALLISON; BASSETT, 2015).

Climate variability and changes in the environment are experienced daily by fishers (JAHAN; AHSAN; FARQUE, 2015). The variability can be monitored by the simple act of going out to fish, which is strongly affected by climate and ocean conditions (FORD et al., 2006). In addition to detecting and perceiving climate regimes, fishers are also able to adapt and cope with new conditions (ZHANG et al., 2012). Local knowledge is particularly useful for understanding the feedbacks among environmental change, livelihoods, and coastal management and for characterizing social-ecological transformations (ANDRACHUK; ARMITAGE, 2015). The perceptions of fishers on the impacts of climate change on fisheries can also be used to identify the changes and patterns that are sometimes not detected by scientific research, which enhances the features of local management (BERKES; BERKES; FAST, 2007).

Changes in marine ecosystems due to climate change have been detected in many regions around the world (BELL et al., 2016). Those climate-related changes can have severe impacts on populations, coastal environments and livelihoods (ALLISON et al., 2009), particularly those in developing countries that are highly dependent on marine activities for food and economic security, as well as for the maintenance of traditional cultures (GATTUSO et al., 2015). It is by adapting to environmental changes and variability that fishers can develop technologies, knowledge and forms of social organization that enable the maintenance of their livelihoods (DAVIDSON-HUNT; BERKES, 2003). The individual and social memory can be accessed by studying the perceptions of fishers of the natural system.

The present study is the first analysis of the perceptions of climate and ocean changes of Brazilian coastal fishers. Other studies have explored the local knowledge on climate and environmental change, but these studies have focused on the inland ecosystems of Brazil and have mainly focused on the Amazon (PINHO et al., 2015) and Pantanal wetlands (SILVA; ALBERNAZ-SILVEIRA; NOGUEIRA, 2014). However, there is a clear lack of research addressing the impacts of climate change in coastal communities, and research on the impacts on the livelihood of those dependent on fishing is particularly lacking.

To fill that gap, the objectives of the present study were to understand how small-scale fishers perceive climate and ocean change and evaluate the impact of climate and ocean change on the fisheries and livelihoods across the South Brazil Bight (SBB) area. Our specific objectives were to understand the perception of fishers on changes in climate and ocean parameters, correlate those perceptions with the available ocean and climate literature, cross-validate the perceptions of the fishers or raise novel research hypotheses when no correlation is found, and analyze how the perceived changes impact the fisheries and livelihoods of the fishers. This study was conducted in this area mainly because the SBB is one of the global marine “hotspots” of ocean warming (HOBDAY; PECL, 2014). Those goals align with the recent calls for treating the hotspots as natural laboratories for observing, suggesting, and developing adaptation options and management strategies related to coastal communities and the fisheries sector (HOBDAY et al., 2016).

2.2 Methods

Given the diversity of the communities and environments along the SBB, the selection of traditional fishing communities sought to represent the diversity in the region. The selection criteria were based on the vulnerability aspects of the communities, as the data used in this study were collected in a survey administered as part of the Belmont Forum’s GULLS project (HOBDAY et al., 2016). A preliminary assessment of the communities was performed using information available from the literature and local archives. Seven traditional communities with different characteristics, such as population size, dependence on fishing, target species, tourism, remoteness, and infrastructure, were selected, which provided a comprehensive sample of the regional fishing communities (Figure 2.1; Table 2.1).

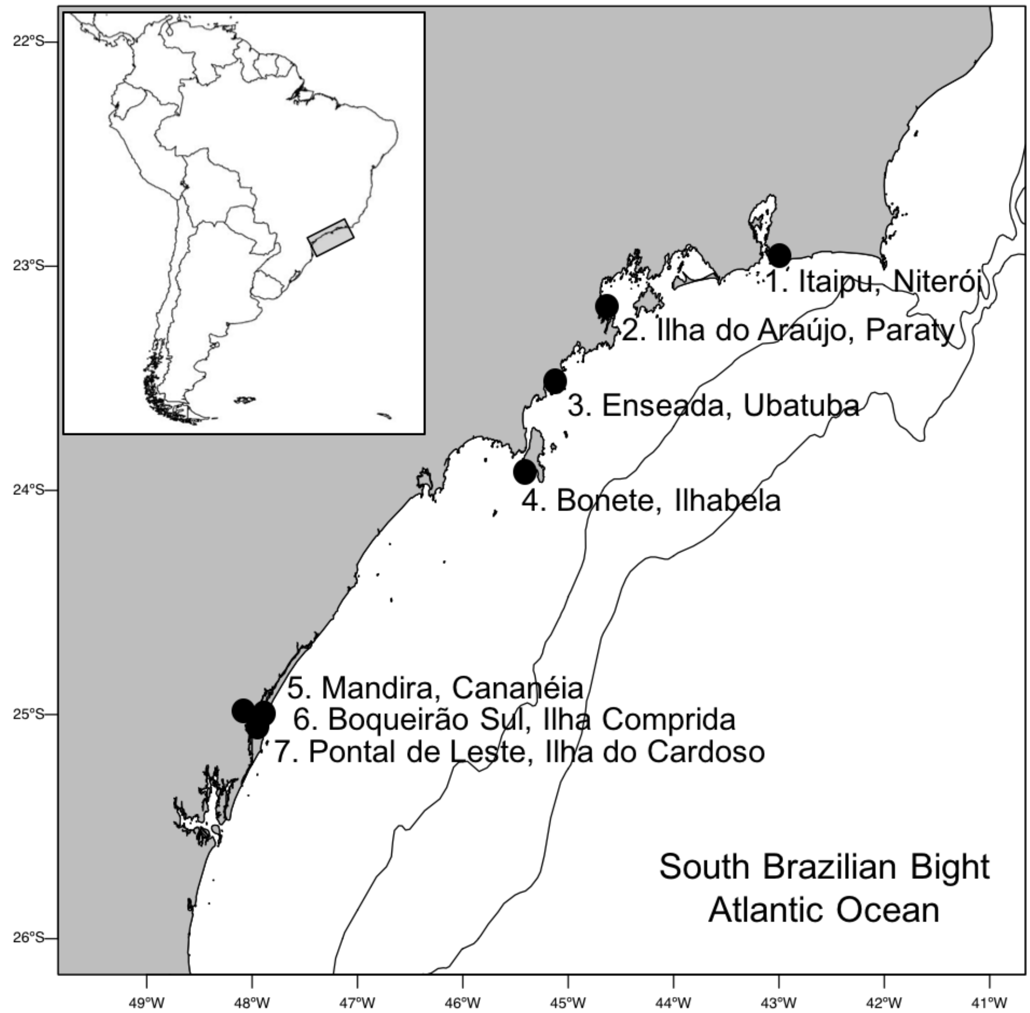

Figure 2.1 Map of the study area and location of surveyed sites (in dark gray, from 1 to 7: Itaipu, Ilha do Araújo, Enseada, Bonete, Mandira, Boqueirão Sul and Pontal de Leste fishing communities).

The ethno-oceanographic framework (GASALLA; DIEGUES, 2011, Appendix 1.1) was applied, focusing on the perceptions of fishers about climate and ocean changes. The framework combines bottom-up (people) and top-down (science) systems of knowledge to investigate climate change issues. The first step is to identify the climate change drivers affecting the area, which is followed by a survey that seeks to understand the perceptions of fishers about each driver. The next step is to analyze the perception of fishers and on each perceived change using a full revision of the ocean science literature to cross-validate the perceptions and drivers. The perceived changes that are not yet evidenced by scientific literature are used to outline new research hypotheses that may eventually add new drivers, scenarios or system responses to the regional knowledge.

Table 2.1 Summary information on the studied fishing communities (hh = household, MPA=Marine Protected Area, +++=high, ++=medium; +=low).

Community site	N⁰ hh sampled	Hh with fisher	Estimated total hh	Fishers hh coverage	Sampling period	Surveyed fishers' age range	Main fishing gear	Main target species
1. Itaipu	20	40	>300	50%	November, 1-15th, 2015	29-75	Gillnet, line and beach seine	*Micropogonias furnieri, Cynoscion* spp., *Trichiurus lepturus, Pomatomus saltatrix*
2. Ilha do Araújo	27	60	118	45%	December 1-20st, 2014	26-82	Trawl, line and gillnet	*Litopenaeus schmitti, Xiphopenaeus kroyeri*
3. Enseada	12	14	>300	86%	December 1-20st, 2014	38-84	Gillnet, mussel farming and floating fish trap	*Perna perna* farming and multspecies fishing
4. Bonete	20	25	100	80%	September 6-20th, 2015	24-75	Gillnet, line, jigging and floating fish trap	*Pomatomus saltatrix, Loligo* spp., *Epinephelus marginatus*
5. Mandira	18	20	22	90%	November 1-25th, 2014	25-64	Oyster extrativism	*Crassostrea* spp.
6. Boqueirão Sul	12	17	100	71%	November 1-25th, 2014	29-74	Gillnet	*Cynoscion* spp., *Micropogonias furnieri, Mugil liza*
7. Pontal de Leste	11	15	15	73%	November 1-25th, 2014	31-75	Gillnet	*Centropomus* spp., *Mugil liza, Macrodon ancylodon*

Table 2.1 Summary information on the studied fishing communities (hh = household, MPA=Marine Protected Area, +++=high, ++=medium; +=low). (*Continued*)

Community site	Population size	Degree of dependence on fishing	Involvement on tourism	Urbanization	isolation	Infrastructure	Fishing spots	Type of MPA
1. Itaipu	+++	+++	+	+++	+	++	Coastal, but exposed to wave and wind action	Extractive Reserve
2. Ilha do Araújo	+	+++	+	+	++	+	Coastal islands in a protected bay	Environmental Protection Area
3. Enseada	++	+	+++	++	+	++	Protected bay and surroundings	Environmental Protection Area
4. Bonete	+	+++	++	+	+++	+	Coastal, but exposed to wave and wind action	National Park and Environmental Protection Area
5. Mandira	+	+++	++	+	+++	+	Protected, inside the estuary	Extractive Reserve
6. Boqueirão Sul	+	++	+	+	++	+	Coastal, but exposed to wave and wind action	Environmental Protection Area
7. Pontal de Leste	+	+++	+	+	+++	+	Coastal, but exposed to wave and wind action	State Park and Environmental Protection Area

A total of 120 fishers from the seven selected communities were surveyed. The survey consisted of two groups of semi-structured questions. In the first group, the perceptions of changes in a set of parameters (sea level, rainfall, wind, air temperature, current strength, sea conditions, sea surface temperature (SST), and ocean column temperature) were explored. In response to any perceived change, a guided conversation was initiated to explore how that change was perceived and how it had or had not impacted the livelihood of the respondent. The second group focused on the occurrence of climate-related events (large storms, floods, droughts and shoreline changes) over the last five years. For each type of event, fishers were asked to state whether they had felt any direct impact at the community level. The survey protocol is further described in Appendix 1.2.

The interview data were grouped by community and parameter. The available climatic and ocean literature was searched and compared with the perceptions of the fishers. The comparisons were used to cross-validate the scenarios of change and eventually delineate new hypotheses, as proposed by the ethno-oceanographic framework (GASALLA; DIEGUES, 2011). No data were found in the literature on the sea conditions parameter that would allow for a correlation with the local perception. In that case, data on cold fronts were extracted from national reports, as Siegle and Calliari (2008) suggested these data as a factor to explain the local sea conditions (CLIMANALISE, 1986-2016). Data from the Iguape, Ubatuba and Rio de Janeiro municipalities were selected because of the proximities to the surveyed communities. The number of days per month with the occurrence of a cold front was plotted for the 1986-2016 period. Then, the trend in the cold front events was analyzed and fit by a linear regression model.

2.3 Results

2.3.1 Perceptions about climate and ocean change

Sea level changes were perceived in Itaipu, Ilha do Araújo, Boqueirão do Sul and Pontal de Leste, where some noted that the sea level had risen, while others said it had dropped (Figure 2.2a). Perceptions of reduced rainfall were unanimous in Boqueirão Sul and Bonete and shared by approximately three-quarters of fishers in Ilha do Araújo, Mandira and Pontal de Leste (Figure 2.2b). Fishers perceived that the wind had changed in recent years, but there was no clear pattern to the answers (Figure 2.2c). Most fishers from Itaipu, Ilha do Araújo, Bonete, Boqueirão Sul and

Mandira perceived an increase in atmospheric temperature, while approximately half of the fishers in Enseada and Pontal de Leste had the same perception (Figure 2.2d). A change in the coastal currents was perceived in only Boqueirão Sul, where one-quarter of the fishers said that the currents had decreased in strength (Figure 2.2e). The majority of fishers perceived that the sea is currently calmer than it was in the past. However, this perception was not shared by the fishers in Mandira, which is located within the Cananeia-Iguape estuarine complex (CIEC). Itaipu, Bonete and Boqueirão Sul are the communities that are most exposed to wave action, and they had the highest number of fishers that perceived that the sea is calmer (Figure 2.2f). The SST has increased according to the perceptions of the fishers. Most of the perceived increases were from the fishers from the southernmost communities, with more than half in Boqueirão Sul and Pontal de Leste (Figure 2.2g). Fishers from Ilha do Araújo and Enseada perceived a decrease in ocean column temperature, suggesting a possible stratification in these areas, with warm water on the surface and cold water at the bottom (Figure 2.2h).

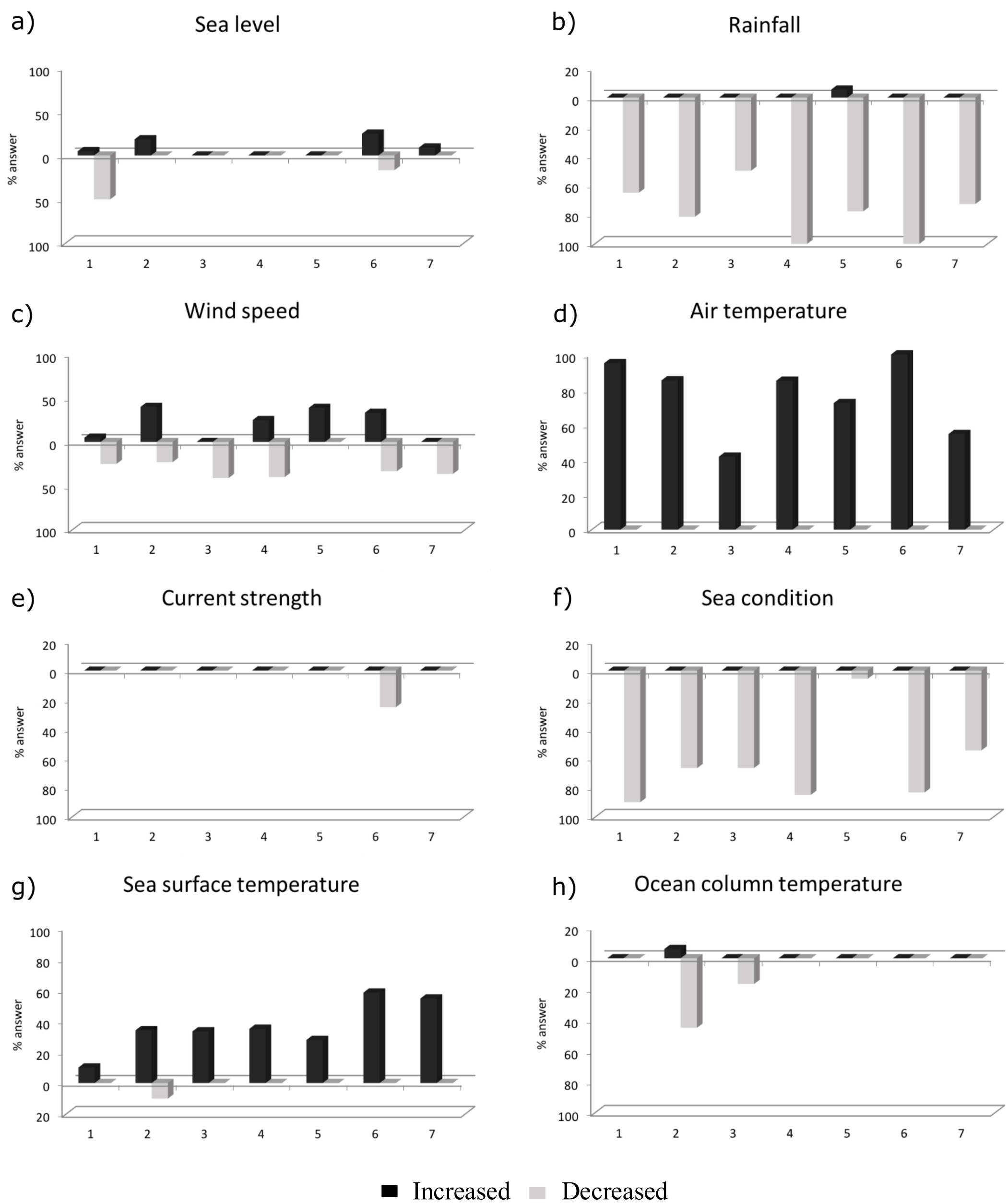

Figure 2.2 Fishers' perceptions in percentage of indications of increase or decrease in climate and ocean parameters by community site (X-axis: 1- Itaipu, 2- Ilha do Araújo, 3- Enseada, 4- Bonete, 5- Mandira, , 6- Boqueirão Sul and 7- Pontal de Leste).

The perceived changes have positively and negatively impacted the livelihoods of the fishers (Table 2.2). The positive impacts included a decrease in the number of days in which fishers could not go fishing due to rough seas and increased sea temperature, which can also be beneficial because it improves catches as well as the production of mussels, oysters and seaweed. On the other hand, if the water becomes too warm, the impact is negative, as it can hinder production and because greater care for fish conservation is required. Other negative impacts include the increase in erosive processes due to sea level rise and increased drought, which causes water shortages, catch reductions and crop losses. The changes in wind patterns and erosion debris carried by coastal currents, increased air temperature and decreased bottom temperature also have negative impacts on the livelihoods of fishers (Table 2.2).

Table 2.2 Fishers' description of impacts on livelihood due to changes in weather and ocean parameters.

Parameter	Livelihood impact	Impacts' direction
Sea Level	Increased the erosion process and jeopardized fishers' homes and access to the sea	NEGATIVE
Rainfall	Increased the number of drought events, which causes a shortage of water (consumption and home supply), reduction in catches and loss of crops	NEGATIVE
Wind speed	Changes in the traditional known weather patterns	NEGATIVE
Air temperature	Increased the costs of fish conservation (ice and more frequent landings)	NEGATIVE
Current strength	Trash carried by coastal currents damages gillnets and and therefore decreases the catch and increases the cost of fishing gear maintenance	NEGATIVE
Sea condition	Reduced the number of days that the fisher is not fishing due to the rough sea	POSITIVE
Sea surface temperature	Increased sea temperature improves fish, shrimp and squid catches and the production of mussels, oysters and seaweed	POSITIVE
	If the water becomes too warm it may kill the production and also require greater concern over fish conservation	NEGATIVE
Ocean column temperature	The catches decrease when the water is cold and when there is stratification in the water column	NEGATIVE

2.3.2 Occurrence of extreme events

Fishers from all communities recalled a large storm over the last five years, but the numbers of fishers affected were higher in Ilha do Araújo and Pontal de Leste (Figure 2.3a). Drought events were perceived by most fishers from all communities except Itaipu, and the direct impacts were higher in Boqueirão Sul and Pontal de Leste (Figure 2.3b). Shoreline changes were perceived by nearly all fishers in Boqueirão Sul and Pontal de Leste and by approximately half in Ilha do Araújo and Mandira, but fishers were directly affected in only Ilha do Araújo and Pontal de Leste (Figure 2.3c). Floods were reported in only the Bonete community, but they had not had a direct impact on any of the surveyed fishers despite the frequency (Figure 2.3d).

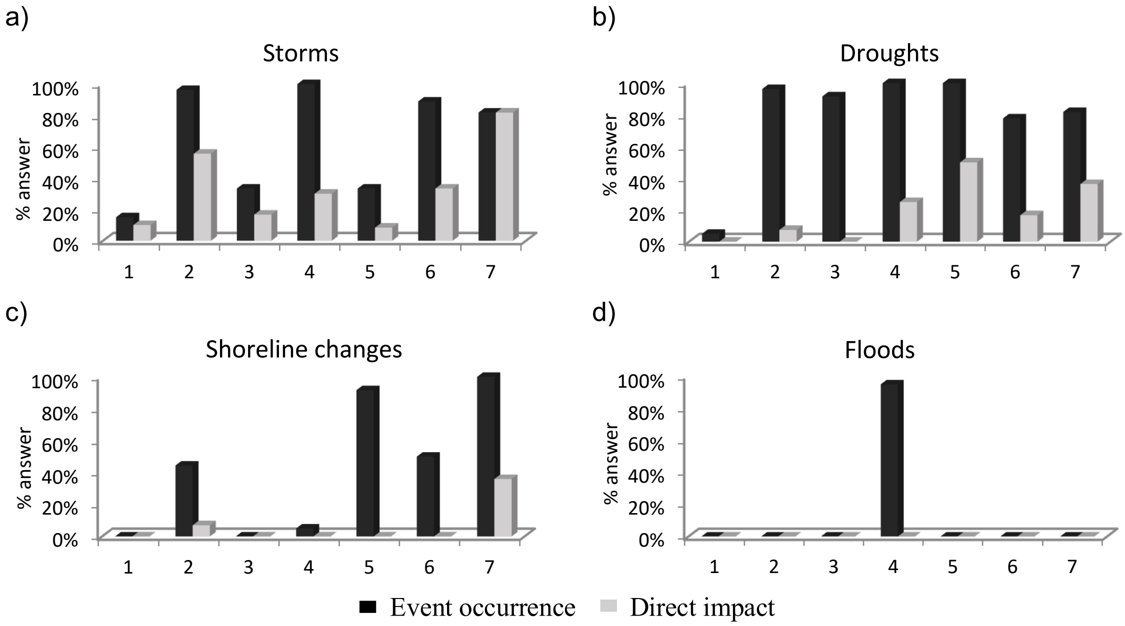

Figure 2.3 Fishers' perceptions of the occurrence of extreme events (black bars) and the perception of been direct impacted by the event (gray bars). X-axis: 1- Itaipu, 2- Ilha do Araújo, 3- Enseada, 4-Bonete, 5-Mandira, 6-Boqueirão Sul and 7- Pontal de Leste.

2.3.3 Environmental data

The perceptions of fishers about climate and ocean change were compared with scientific data, and correspondences were not found for all perceptions (Table 2.3). The scientific data show that the sea level has increased, but this was not perceived by all fishers. The perceptions of fishers of calmer seas and decreases in wind intensities and coastal currents did not correspond to the published data. Other factors such as rainfall, air temperature and ocean temperature were found to correspond with the scientific data.

Table 2.3 Average fishers' perception of change in weather and ocean parameters and correspondent published data.

Parameter	Fishers' perception	Record from published information
Sea Level	Increased: 8%	Global: The global mean sea level has raised 19 (17 to 21) cm between the period of 1901-2010 (RHEIN et al., 2013).
	Decreased: 10%	Regional: Along the Brazilian coast the estimated increase in sea level is 40cm/century (MESQUITA, 2003; HARARI et al., 2013).
Rainfall	Increased: 1% Decreased: 78%	The southeastern has been suffering with rainfall deficit since the late 90s. The 2013/2014 and 2014/2015 summers had an exceptional deficit of rainfall when compared to other summer since 1961/62 (COELHO et al., 2015; SETH et al., 2015).
Wind	Increased: 20% Decreased: 28%	The global warming scenarios suggest the probability of more tropical cyclones as hurricane Catarina in the South Atlantic (PEZZA et al., 2005). Windstorm has been the main cause for the shipwreck involving small vessels in south and southeastern regions of Brazil (FUENTES et al., 2013).
Atmospheric temperature	Increased 76%	Global: The global average temperature has increased 0.85°C since 1880 (HARTMANN et al., 2013). Regional: Surface temperatures have increased by 0.75°C over the past 50 years in Brazil (MARENGO et al., 2009).
Coastal currents	Decreased: 4%	No information
Sea condition	Decreased: 65%	No differences in the amount of extreme events in last thirty years in southern Brazil (MACHADO et al., 2010). There was an increase in the frequency of storm surge events in the last decades in Santos city (Alfredini et al., 2014).
Sea surface temperature	Decreased: 1%	The data from sea surface temperature indicate a change of 0.53°C from 1982-2006 (Belkin, 2009).
	Increased: 36%	South Brazil is one of the 24 global marine hotspots that are experiencing ocean warming at a rate faster than 90% of the rest of the oceans (HOBDAY; PECL, 2014).
Ocean column temperature	Decreased: 9% Increased: 1%	Increase in stratification is projected and it tends to slow ocean carbon uptake, oxygen level and nutrient supply to the surface, reducing the maximum size of fish and the fishery potential yield (ROY et al., 2011; GATTUSO et al., 2015).

The historical cold front data indicate a declining trend in the number of days with cold fronts per month, despite the low explanation of the model due to the high monthly variability (Figure 2.4). Nevertheless, the decreasing number of cold fronts in the last decade reinforces the decreasing trend of the event in the analyzed period.

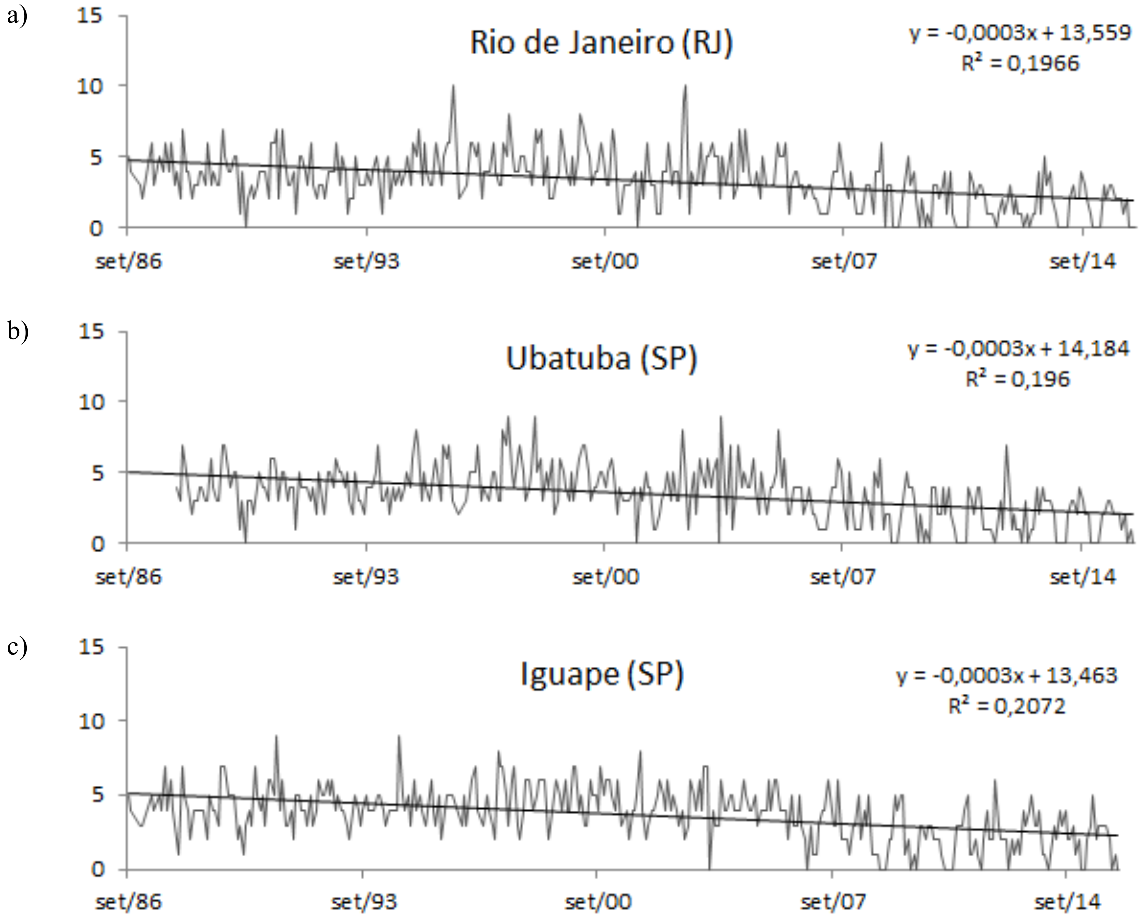

Figure 2.4 Monthly history of the occurrence of days with cold fronts in the coastal cities of (a) Rio de Janeiro, (b) Ubatuba e (c) Iguape in the period of September 1986 to April 2016. Source: Bulletin of Monitoring and Climate Analysis (Climanalise) published by CPTEC/INPE.

2.4 Discussion

2.4.1 Sea level rise and shoreline changes

The global sea level rose by an average of 19 cm between 1901 and 2010 (CHURCH et al., 2013). Along the Brazilian coastline, the relative sea level is increasing at a rate of 40 cm/century (HARARI; FRANÇA; CAMARGO, 2014). Even so, a rise in sea level was poorly perceived by the surveyed fishers. The low perception can be explained by the fact that the fishers experience the daily tidal fluctuations, and the annual rate of increase is a slow process that is not fast enough to draw their attention to the fact.

The communities with fishers that perceive sea level rise are the same communities that are facing shoreline changes caused by erosion. The erosion process has been well studied on Comprida and Cardoso Islands, where the Boqueirão Sul and Pontal de Leste communities are located. Both islands are very sensitive to erosion due to their sedimentary compositions and low average altitudes

(ANGULO; SOUZA; MULLER, 2009), but human activities have also influenced the erosion processes in the area (MAHIQUES et al., 2009). The data show that erosion does not have a direct relation to sea level rise, but our results show that fishers indirectly construct this relation, despite knowing the natural and anthropogenic influences in the process. Fishers are concerned because sea level rise can increase the exposure of their communities to erosion, which can affect their homes and livelihoods. The same concern was found in other places, such as Bangladesh, where fishers had to relocate their houses several times due to rising sea levels and other climate-related factors (RAHMAN; SCHMIDLIN, 2014).

There is no evidence in the literature to support the perception of fishers that the sea level is decreasing. The perception in Itaipu is that there are currently greater stretches of sand than in the past. This perception seems to be related to the local sediment dynamics and not to sea level change. In the 1970s, a channel was built, and this permanently connected the Itaipu lagoon with the sea, which may have changed the coastal dynamics of the region and increased the stretches of sand on the beach, which is a hypothesis that needs to be investigated by future work. In Boqueirão Sul, fishers perceived a decrease in the maximum limit that the sea reaches during storms. This perception may be related to a decrease in the intensity of the storm surge, and this hypothesis is discussed in the next topic.

The sea level is projected to rise by up to 98 cm by the end of the century (CHURCH et al., 2013), and the low number of fishers that perceive the phenomenon draws attention to the need for a discussion on the causes and projected consequences of sea level rise. Rising sea levels will have consequences other than erosion (e.g., saltwater intrusion, increased flooding and decline in mangroves) that will compromise the ecological functions of coastal areas and affect fish production (NICHOLLS; CAZENAVE, 2010). Fishers need to be aware of the risks and be included in the adaptation plan for coastal zones, as participation by fishers has the potential to minimize conflicts and reduce costs during the adaptation process (SHELTON, 2014).

2.4.2 Rainfall and drought-flood events

The perceptions of fishers about rainfall reduction can be explained by recent scientific observations that showed that São Paulo state has been suffering from a rainfall deficit since the late 1990s (COELHO; CARDOSO; FIRPO, 2015). The most recent summers in southeastern Brazil have suffered from exceptional rainfall deficits when compared to other summers since 1961. The reduction in rainfall can also be evidenced by a decrease in the frequency of cold fronts in the area, as cold fronts influence the intensity and distribution of rainfall throughout South America (CAVALCANTI et al., 2009).

The reduction in rainfall is one of the reasons for the perception of fishers of increased drought events. The shortage of water is of great concern to those communities that are not supplied by the public system (Ilha do Araújo, Bonete, Boqueirão Sul, Mandira and Pontal de Leste). In Bonete, the concerns about water shortages are even greater because the community power supply depends on a small generator linked to the local waterfall. During drought periods, energy production is impaired, requiring the use of a diesel generator and creating additional costs to the residents. The droughts generate an additional problem for those communities that rely on crops for income and food supply, as droughts generate additional costs associated with additional planting.

The fishers in the communities located in the CIEC (Boqueirão Sul, Mandira and Pontal de Leste) perceived that the droughts also affected the fishing industry. They perceived that during the long periods without rain, the catches decrease as the water becomes clearer. Fishers are not sure why the droughts affect fishing, but it may be related to changes in salinity and the nutrient supply, which affect the species distribution (PASSOS et al., 2013). A recent study conducted in the CIEC showed that the abundance of fish increased in the southern region of the estuary during the rainy season (CONTENTE, 2013), supporting the perception of the fishers that drought negatively affects catches.

Scientific observations have shown that during the rainy season, intense precipitation is becoming concentrated in only a few days (DUFEK; AMBRIZZI, 2007). These situations make flood events more frequent and intensify their impacts in areas that are already often flooded. This is the case in Bonete, where floods are common but do not have a direct impact on the fishers because their houses were built with the knowledge of the natural flood areas. However, the expected concentration of rainfall and municipal interest in urbanizing the community may increase the scale of floods and have an impact on the residents. In addition, the urbanization of the area will encourage real estate development in a traditional community that is already lacking in infrastructure and depends upon nature to maintain its livelihood.

The existing literature on the perceptions of traditional communities on flood and drought events in the Amazon shows that local people have a strong set of observations and practices that allow them to withstand the challenges during years of ‘normal’ variability, providing the social resilience required to cope with such events (MARU et al., 2014). However, the recent extreme events have taken them outside the range of conditions that can be handled by these practices (PINHO; MARENGO; SMITH, 2015). Thus, the resilience of the social system is diminished, and vulnerabilities are exacerbated. Similar results may be occurring with the SBB fishers, were climate change is reducing the resilience of the social system and limiting their ability to cope and adapt to the new scenarios.

2.4.3 Wind patterns

The small-scale fishers in Brazil are known to have good traditional knowledge of the natural cycles. It has been common for fishers to be guided by the behavior of winds, clouds and lunar cycles to perform their daily fishing (DIEGUES, 2006), but currently, they find difficulty in using this traditional technique, mainly due to the changes in the known wind patterns. An example given by fishers is that there is currently no longer an east wind, which is regarded as a wind for good weather and good fishing (BEZERRA et al., 2012).

The perception of wind decrease seems to be due to the decrease in the number of windstorms, which are becoming sporadic events. Moreover, the perception that the wind has increased seems to be related to the increase in the power of the windstorms. Most of the impacts associated with large storms are related to windstorms, including roof damage, falling trees, loss of fishing gear and shipwrecks. Shipwrecks often occur in the SBB region, and in most cases, the shipwrecks involve small vessels used in coastal fisheries. Fishers suggest that the causes of the shipwrecks are windstorms and strong waves. A recent study showed that strong wind was the main cause of the shipwrecks recorded along the Brazilian coast (FUENTES; BITENCOURT; FUENTES, 2013).

Hurricane Catarina over the western South Atlantic Ocean in 2004 marked the first hurricane recorded in the South Atlantic basin (McTAGGART-COWAN et al., 2006). Catarina caused deaths and millions of dollars of damage to the South Brazilian coast. The observed and predicted trends in climate change scenarios suggest that similar conditions could occur and increase the probability of more tropical cyclones in the region (PEZZA; SIMMONDS, 2005). These results suggest that extreme windstorm events may become more frequent and can cause major damage to the coastal populations.

2.4.4 Coastal currents

The fishers from only one community perceived changes in the ocean current, noting that it is weaker than in the past. The perception is related to the erosion debris from the mouth of the CIEC that is ending up on the beach and hindering fishing activities. When the outflow is strong, the debris goes offshore and does not reach the beach. The perception of the fishers seems not to be related to ocean currents, but to changes in the estuary outflows. There was no evidence of changes in the estuary outflows, but the frequent drought events in the region (COELHO; CARDOSO; FIRPO, 2015) may suggest a decrease in the number of streams flowing into the estuary. The link between rainfall reduction and the CIEC outflow is a new hypothesis that should be further investigated and related to the perceptions of the fishers.

2.4.5 Is the sea calmer?

Fishers perceived that the sea is currently calmer than it was in the past. The perception is that the storms are weaker, both in duration and intensity. Storm durations are related to the number of days without fish because of a storm, which was approximately 15-30 days in the past whereas this period does not currently exceed three days. The perception of storm intensity is based on the area flooded by the storm surge, which is lower than in the past. This situation seems to be seen positively as it allows for more frequent fishing, as the daily lives of the fishers are tuned to the weather and ocean conditions (GRANT; BERKES, 2007).

One way to investigate if the sea is calmer is to evaluate whether the frequency of storms has decreased. The only ocean scientific observation found was one evidencing an increase in the frequency of storm surge events over the last few decades in the city of Santos (ALFREDINI et al., 2014), which is in some disagreement with the perceptions of the fishers. The decrease in the number of cold fronts could mean a reduction in the number of storm surges and thus be one of the factors that led to the perception by the fishers that the sea is calmer. This hypothesis needs to be tested, as the decrease in storm surges is contrary to what is expected by climate change scenarios (VON STORCH, 2014). The understanding of the storm surge behavior is necessary for proper adaptation planning in the coastal areas and improvement of the projection of future events.

2.4.6 Air and ocean temperature

An increase in air temperature was perceived in all surveyed communities, and it was one of the factors drew the most attention from the fishers. Scientific observations of the global average temperature show a warming of 0.85°C over the period from 1880-2012 (HARTMANN et al., 2013). In Brazil, temperatures have increased by 0.75°C over the past 50 years (MARENGO et al., 2009). The models indicate rising temperatures as well as a reduction in the frequency of frost due to an increase in the minimum temperature in the SBB (CHOU et al., 2014). The perception of the fishers of temperature increases is based on the lack of cold days and frost, corroborating the findings in Chou et al. (2014).

Global warming is expected to increase the vertical stratification of the ocean, creating barriers to nutrient mixing between layers (ROY et al., 2011). Generally, an increase in stratification tends to slow ocean carbon uptake, reduce oxygen levels and decrease the supply of nutrients to the surface, reducing fish sizes and potential yields of fisheries (GATTUSO et al., 2015). Fishers perceived that catches decreased when the water column was stratified, and the projected increase of this process may be expected to reduce the fishing yields in the area.

In South Brazil, the SST increased by 0.53°C from 1982-2006 (BELKIN, 2009), and the region is one of the ocean warming hotspots (HOBDAY; PECL, 2014). According to fishers, the warm water is beneficial as it improves most of the catches and seafood production. Postuma and Gasalla (2010) confirmed the perceptions of fishers and found that squid fishing in the SBB is better in calm and warm water, but evidence related to other species was not found. However, water that is too warm becomes detrimental to marine farming production. In the Enseada community, for example, the warmer waters killed off the *Perna perna* production in the summer of 2010-2011. The shellfish producers from Cocanha beach along the São Paulo coastline also perceived that warm water is a major threat to their activities (SEIXAS et al., 2014). In the case of oyster production, the traditional management of *Crassostrea brasiliana* has allowed for the sustainable management of the resource in the Mandira community (MACHADO; FAGUNDES; HENRIQUE, 2015), but according to fishers, the production will be threatened by increased water temperatures, especially when added to rising atmospheric temperatures and long periods without rain. The optimal temperature to farm *P. perna* ranges between 22 and 26°C, and after that, the species begins to undergo physiological alterations (RESGALLA; BRASIL; SALOMAO, 2007). The best growth conditions for *C. brasiliana* occur at stable temperature and salinity conditions (PEREIRA et al., 2001), suggesting that extreme events such as drought and high temperatures can threaten the species. Only Itaipu fishers see the summer cold water as beneficial to fishing, probably due to the proximity of the community to the Cabo Frio upwelling, which increases the local productivity (COELHO-SOUZA et al., 2012).

The shifts in the distribution of marine species have been related to ocean warming with greater changes in distribution being evidenced (CHEUNG et al., 2010). A shift in species distribution due to climate change was not perceived by the surveyed fishers. The present concern of the fishers over the ocean temperature is related to a loss of yield and the fact that fish spoils more easily. However, the changes in the species distribution and catch composition need further investigation as this was not the focus of the paper. Moreover, distribution shifts could be an additional concern of the small-scale fishers in Brazil that was not detected in this study.

2.4.7 Applicability of perceptions by fishers

Communities that depend on small-scale fishing activities are inherently exposed to climate variability and uncertainty (ALLISON; ELLIS, 2001). The understandings of the effect of climate change on the livelihoods of fishers and fisher-environment relationships are of major importance to solve fishing conflicts that occur because of the climate and to ensure the future livelihoods of the communities (HOBDAY et al., 2015).

Traditional populations have a considerable ability to monitor variability and cope with this through adaptive cultural responses (GASALLA; DIEGUES, 2011). Local perceptions of climate change, as well as the associated adaptations made by the local populations, are fundamental for designing comprehensive and inclusive mitigation and adaptation plans both locally and nationally (ASWANI et al., 2015). In this context, understanding how climate change is understood by fishers, as presented here, is vital to the planning of an inclusive adaptation process (NURSEY-BRAY et al., 2012).

Climate-related changes are already impacting the livelihoods of people, particularly those in developing countries that are highly dependent on marine-related activities (GATTUSO et al., 2015). That is the case in the SBB fishing communities where some of the impacts to their livelihoods can be positive, such as calmer seas and the warmer ocean. As proposed by the ethno-oceanographic framework, these perceptions needed to be investigated in depth in future studies. However, our findings indicate that the perceptions of fishers present themselves as crucial and complementary information sources for the development of local/regional adaptation strategies, bringing a distinct and relevant point of view from the marine dependent communities to the decision makers. Therefore, the perceptions of fishers presented in this study have the potential to improve the description and interpretation of changes observed in recent decades, the associated impacts on livelihoods and coastal ecosystems and support the development of local adaptive strategies to climate change.

2.5 Conclusion

Our findings demonstrate that fishers have perceived climate and ocean changes, such as rainfall reduction, sea agitation, increased drought events, increased air and ocean temperatures and changes in wind patterns and the shoreline. The perceived changes have positive and negative impacts on the yields and livelihoods of fishers. New hypotheses were raised with respect to sea level, coastal currents and sea condition. These results reinforce the importance of fisher knowledge to identify peculiarities and local features that have not yet been detected by regional and global models, such as changes in cold fronts related to ocean conditions. Indeed, fishers proved to be an important social capital in climate and ocean monitoring, and the approach of this research illustrated how natural and social science research can be integrated and used by both policymakers and the broader society.

SECOND CHAPTER [2]

[2] Manuscript submitted to PlosOne

3. CHAPTER 2

Vulnerability of small-scale fishing communities to climate change in the south Brazil Bight

Abstract Small-scale fishing communities are often susceptible to climate change impacts especially due to the scale of their activities and limited spatial mobility at sea. Additional complex socioeconomic, demographic, and policy trends may also limit their adaptive capacity to cope with changes. Understanding the social vulnerabilities and community strategies to adapt to changes is crucial for the development of actions to enhance community conservation and survival. To identify the vulnerability and adaptation patterns to climate change among different coastal communities across a large marine ecosystem, a comprehensive multi-scale vulnerability framework was adopted. A total of 151 fishers were surveyed at the household level in eight carefully selected coastal fishing communities that represent the broad characteristics of regional livelihoods. Measurable indicators were used to assess the sensitivity, exposure, adaptive capacity, and vulnerability scores of each community. Our findings show that remoteness and lack of climate change-related institutional support increase vulnerability, while community organization, occurrence of strong leadership, partnership with research activities, community-based co-management and livelihood diversification reduce vulnerability. Overall, the key drivers that increase or decrease the vulnerability of fishing communities to climate change are components of adaptive capacity. Among the communities, Pontal de Leste, Ilha do Araújo and Boqueirão Sul showed the highest vulnerability to climate change, while Enseada, Mandira and Itaipu showed the lowest vulnerability. This assessment focuses on social vulnerability to climate change in regional fishing communities and provides a better understanding of climate change effects in coastal zones, local factors driving vulnerability and perspectives on more resilient and adaptable systems. Learning from comparisons may be applied to coastal regions elsewhere.

Keywords: Small-scale; fishing community; climate change; vulnerability; adaptation

3.1 Introduction

Climate change causes a progressive loss of productive capacity in some coastal and oceanic regions, with changes to the distribution, availability and production of fishery resources (BOOTH et al., 2018); acidification; sea-level rise and other impacts that often result in social and economic consequences (CHEUNG et al., 2010; GATTUSO et al., 2015; BRANDER et al., 2018). The impacts of climate change in marine ecosystems and coastal zones are predominantly felt by small-scale fishers, especially in developing countries (BADJECK et al., 2010). The limited spatial context and small scale of fisheries, as well as the complex socioeconomic, demographic, and policy trends associated with the activity, make them highly susceptible to environmental changes and reduce their adaptive capacity (MORTON, 2007). Assessing how fishing communities have been affected by anthropogenic stressors and their capacity to adapt is a necessary and important step to inform management initiatives, assist decision makers in weighing trade-offs and promote and increase resiliency of coastal communities (PERRY et al., 2010; CINNER et al., 2012). A set of different research frameworks has been developed to examine the vulnerability of small-scale fishers to environmental change (BADJECK et al., 2010; CINNER et al., 2012; MARSHALL et al., 2013; BENE, 2009; JACOB et al., 2013), proposing general definitions of vulnerability and resilience as the degree to which a system is susceptible and unable to cope with the adverse effects of a disturbance (ADGER, 2006; CINNER et al., 2013) and the ability to return to a functional state after a disturbance (BUCKLE, 2000), respectively. These concepts have been considered a continuum where vulnerable communities are generally less resilient and need additional resources to recover from a disturbance (JACOB et al., 2013).

In the context of environmental change, vulnerability is typically measured as a function of sensitivity, exposure, and adaptive capacity (MARSHALL et al., 2013; CINNER et al., 2013). Sensitivity is the state of susceptibility to harm from perturbations or long-term trends (ADGER, 2006). The sensitivity of socio-ecological system is usually defined as the intrinsic degree to which economic, political, cultural and institutional factors are likely to be influenced by extrinsic stresses or hazards (ALLISON et al., 2009). For example, social systems are more likely to be sensitive to climate change if they are highly dependent on a climate-vulnerable natural resource (CINNER et al., 2013). Exposure is the degree to which a system is stressed by climatic events and environmental conditions such as the magnitude, frequency, and duration of a climatic event (ADGER, 2006; CUTTER, 1996). In a practical sense, exposure is the extent to which a region, resource, or community experiences change (CINNER et al., 2012). For fishing communities, exposure captures how much of the resource they depend on will be affected by an environmental change (CINNER et al., 2013). Adaptive capacity is a latent characteristic that reflects people's ability to anticipate and respond to changes and to minimize, cope with, and recover from the consequences of change (ADGER; VICENT, 2005; GALLOPIN, 2006). For example, people with low adaptive capacity may have difficulty adapting to change or taking advantage of the opportunities created by changes in the availability of ecosystem goods and services stimulated by climate change or changes in management (CINNER et al., 2012; CINNER et al., 2013).

There are no single measures of exposure, sensitivity, or adaptive capacity; rather, their interpretation and analysis depend on the scale of the study and available data. However, understanding the vulnerabilities of fishing communities and their strategies to cope with and adapt to climate change is crucial to the development of policies and operational rules that can preserve the livelihoods of these communities and their social-ecological systems (KALIKOSKI; NETO; ALMUDI, 2010). Actions geared towards reducing vulnerability to climate change should generally be focused on reducing sensitivity, altering exposure, and increasing adaptive capacity of coastal communities, as well as on the spatial and temporal scales where these actions should be implemented (ADGER; ARNELL; TOMPKINS, 2005; CINNER et al., 2012). Another key step in addressing the effects of climate change will be to develop clear management objectives that reconcile competing goals and consider multiple objectives, such as conservation-based, biological, economic, social, cultural, and political objectives of marine social-ecological systems (PERRY et al., 2010).

In Brazil, both small- and large-scale fishers play a strategic role in the diet and economy of coastal populations, and they face many pressures that impact marine resources and livelihoods, and consequently, they need to adapt to environmental changes (BELL et al., 2016; GASALLA; GANDINI, 2016; CASTRO; MARTINS; HANAZAKI, 2016). In terms of climate changes perceived by Brazilian fishers in coastal areas, some changes have been documented, such as decreases in rainfall, increases in drought events, calmer sea conditions, increases in air and ocean temperatures, changes in wind patterns and shoreline erosion (MARTINS; GASALLA, 2018). These changes have positive and negative effects on the future catches of resources due to both abundance and distribution changes (GASALLA et al., 2018; CHEUNG et al., 2010). Off South Brazil and Uruguay, the ocean temperature is warming faster than in most other parts of the world (HOBDAY; PECL, 2014), and the effects of ocean warming are expected to be particularly strong in this region (POPOVA et al., 2016). Consequently, the effects of warming are already being observed, and social adaptations to these changes are paramount.

Moreover, understanding the vulnerabilities of fishing communities to climate change and their capacity to adapt is urgently needed (ALLISON et al., 2009). Nevertheless, fishing communities vulnerability to climate change has not been properly identified and evaluated in coastal Brazil. A few studies focusing on coastal fishing communities in southern Brazil found that vulnerability varies among communities and households, mainly due to the differences in their dependence on fishing, the distribution of assets and the level of participation in community organizations (FARACO, 2012), and vulnerability varies because the knowledge of small-scale fishers contributes to reducing that vulnerability and adapting to changes (SILVA, 2014). Both of these previous studies helped to understand some effects of climate change on fishing communities. Although, they do not present an understanding of which are the positive and negative drivers behind regional social vulnerability. Addressing these drivers, can be useful to collaboratively build the adaptation pathways that would increase coastal community resilience.

Within this context, the present study aims to explore the similarities and differences in social vulnerability and adaptation patterns among distinct coastal fishing communities of the SBB and provide an in-depth understanding of the local processes influencing community vulnerability to climate change and novel learning mechanisms that can be applied to other coastal regions. Our goal was to better understand how climate changes are impacting the vulnerability of small-scale fisher communities and their capacity to adapt, since fishing is important to the diet, economy and culture of these populations.

3.1.1 Study area and fishing communities

The SBB is defined as the area of the continental shelf of southeastern Brazil extending from Cabo Frio (23°S; 42°W) to Cabo Santa Marta (28.5°S; 48.6°W) (CASTRO; MIRANDA, 1998). The region is adjacent to the most industrialized and urbanized coastal zone in the country. In the SBB, isobaths run almost parallel to the coastline, and the oceanographic features include the occurrence of meso-scale eddies from the Brazil Current, intrusion of the South Atlantic Central Water, and seasonal upwelling (SILVEIRA et al., 2000). These features boost the regional primary productivity and therefore some of the fisheries (GASALLA; ROSSI-WONGTSCHOWSKI, 2004).

The SBB region has a heterogeneous coastline with a diversity of ecosystems and social characteristics, sustaining a diversity of economic activities such as small- and large-scale fishing, tourism, shipping, and oil and gas exploration. The fishing industry in the SBB is one of the most developed industries in the country, contributing to approximately half of Brazil's commercial fishery yields and supporting important pelagic and demersal fisheries (MPA, 2011). Fishing communities are diverse and abundant, provide seafood and employment opportunities to the country and have been impacted by recent development as well as climate issues (MARTINS; GASALLA, 2018). In the small-scale fishing communities, fishing is practiced daily by most fishers and is characterized by traditional cultures, values, and behaviors strongly associated with nature (DIEGUES, 2008). The activity occurs in coastal and inland areas, with small boats or canoes and using equipment with very simple technology. The main challenges faced by the small-scale communities in the SBB to maintain their livelihoods are marginalization by large-scale fishing, poor market access, lack of working capital, low credit access, and pressure to diversify the basis of their livelihoods (HAQUE et al., 2015; YKUTA; GASALLA, 2014). The changes associated with climate will be additional impacts affecting the fish stocks and consequently the livelihoods of these marine-dependent coastal communities (BELL et al., 2016).

Given the diversity of the communities and environments along the SBB, eight small-scale fishing communities were selected to represent the diversity of the region in terms of population size, proportion of households with fishers, fishing gear, target species, isolation, and inclusion in protected areas and to provide a comprehensive sample of regional fishing communities (for more information see Martins and Gasalla, 2018; Chapter 1). The communities were (Figure 3.1) Itaipu, Ilha do Araújo, Enseada, Bonete, Mandira, Boqueirão Sul, Pontal de Leste and Praia do Porto. In the most northern area, the Itaipu community is 15 km from the city of Rio de Janeiro, outside of Guanabara Bay. Fishers struggle to maintain their traditional fishing activities amid the growing urbanization, and in 2013, the area was recognized as a marine extractive reserve (MER), which is a type of co-management protected area in Brazil (IUCN

Category VI, DUDLEY, 2008). Fishing is still an important source of income, as is tourism and service provision. Second, the Ilha do Araújo community is located on a coastal island in the Ilha Grande Bay in southern Rio de Janeiro State. Fishing is the main economic activity of the community, followed by service provision in vacation homes and chartering of boats for recreational fishing. The Enseada community is in the Flamengo Bay, Ubatuba region (state of São Paulo), with characteristics that facilitate tourism as its main economic activity. However, fishers keep their livelihoods closely linked to the sea, and fishing is a source of complementary income and cultural resistance. Bonete is an isolated community located on São Sebastião Island. Despite the recent increase in tourism, the community is recognized for its strong preservation of culture and livelihoods linked to nature. Fishing is still an important source of income, complemented by tourism. Access to the sea is along a small river and is heavily dependent on good weather and ocean conditions. Mandira is a “quilombola” community within the Cananeia-Iguape estuarine complex (CIEC), having been recognized as MER in 2002. The main economic activities are mangrove oyster management, crab extraction, fishing and community-based ecotourism, all of which are highly dependent on tide variations. The Boqueirão Sul community is in the Ilha Comprida region, with the only access being via ferry from the town of Cananeia. The region is a popular tourist destination in the summer. The beach is exposed to the open ocean with no shelter for boats or canoes, meaning they need to be pulled up onto the sand every day. Pontal de Leste is an isolated community located at the southern end of the Ilha do Cardoso State Park that can only be accessed by boat. The community has no electricity supply, meaning that solar panels and batteries are the only sources of power. Fishing is the main economic activity, occasionally supplemented by tourism. Lastly, the southernmost community is Praia do Porto, located in the small city of Imbituba in Santa Catarina State. Fishing is the main activity of the community that is divided by the Imbutiba Harbour, which provides employment for some of the fishers and results in conflicts within the community due to the interest in using the area for harbor expansion and its associated companies.

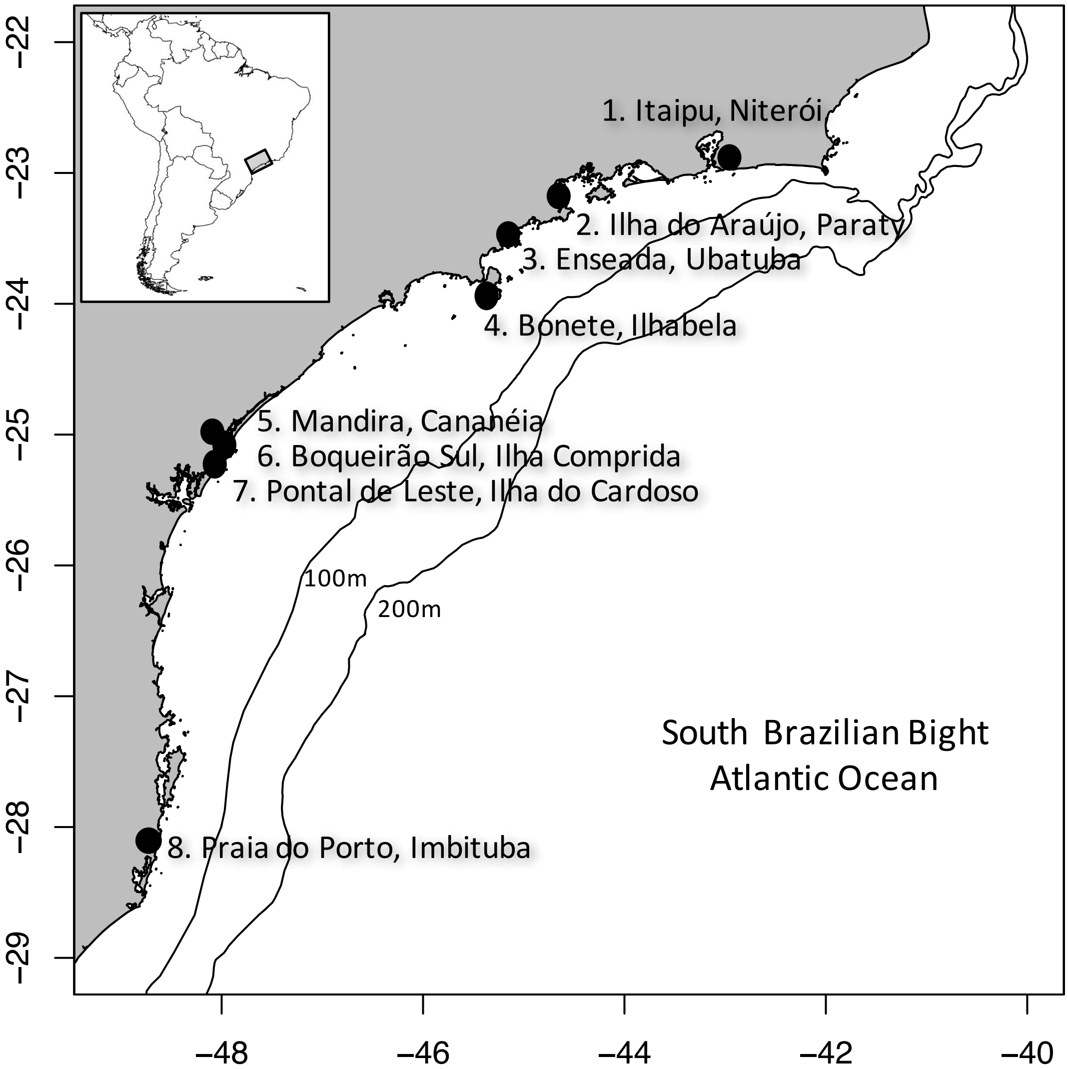

Figure 3.1 Map of the study area and location of surveyed sites. In dark gray, from 1 to 8: Itaipu, Ilha do Araújo, Enseada, Bonete, Mandira, Boqueirão Sul, Pontal de Leste and Praia do Porto fishing communities.

3.2 Methods

3.2.1 Social vulnerability framework

The framework used to evaluate coastal fishing community vulnerability to climate change has been developed to address different marine-dependent coastal communities in an internationally comparative effort across Southern Hemisphere coastal zones (ASWANI et al., 2018). The framework was proposed by a multilateral scientific team aiming at improving fishing community adaptation efforts by characterizing, assessing and predicting the future of coastal-marine resources and by co-developing adaptation options through the provision and sharing of knowledge across fast-warming marine hotspot regions (HOBDAY et al., 2016; POPOVA et al., 2016). A key component of the vulnerability framework is to collect rich, local-level, social vulnerability data to provide a detailed understanding of the local-scale processes influencing community vulnerabilities while allowing for the data to be scaled up to regional, country, and global levels. Here, the framework was used to understand the local process influencing the social vulnerability of coastal areas at a community level, but the same framework is also being used to scale up to regional and global analyses (ASWANI at el., 2018; Chapter 3). The framework consists of a four-step process that is described in the sections below (Figure 3.2).

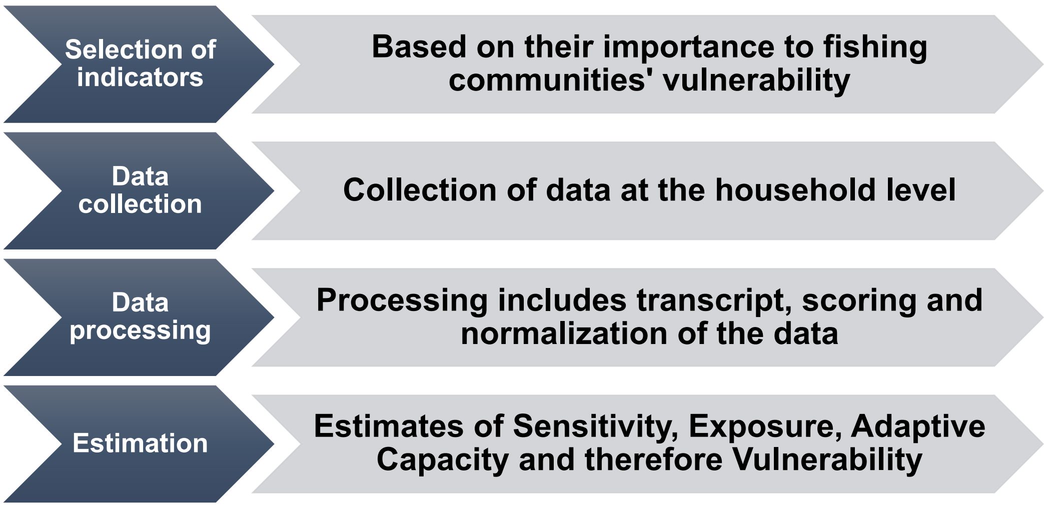

Figure 3.2 Methodological steps taken in this study (based on Aswani et al., 2018).

3.2.2 Selection of indicators

An in-depth literature review was used to identify relevant indicators to conduct the analysis of socio-economic vulnerability to climate change. The measurable indicators were used to assess the separate categories of vulnerability: sensitivity, exposure and adaptive capacity. The individual components within the sensitivity, exposure and adaptive capacity categories were then further expanded to provide more detailed descriptors. The original framework has a total of 255 indicators categorized into 90 subcomponents and 20 components (ASWANI et al., 2018). For the present study, a total of 160 indicators, 67 subcomponents and 20 components were selected and are described in Appendix 2.1. The selected indicators are those that best applied to the Brazilian coastal fishing communities and those that had quality data after sampled.

3.2.3 Data collection

After defining the indicators that make up the vulnerability analysis and that reflect the local culture and social context, the survey instrument was carefully constructed to translate the indicators into the questionnaire. The survey had previously been field tested in two other communities in the region. The questions that did not produce reliable data were identified during the field testing and subsequently improved or omitted. The final survey instrument has a mix of Likert scale, open, closed, binary (yes/no) and multiple choice questions.

Sampling occurred during two field periods, with the first in November-December 2014 and the second in September and November 2015. The unit of analysis was the household using a systematic approach. A total of 151 households that had regular interaction with the ocean were sampled face-to-face in the eight selected communities. The average length of the interview was 1.08 hours (0.35 to 2.35 hours).

3.2.4 Data processing

The full answers were recorded on a hard copy of the questionnaire and then copied into spreadsheet. The answers were coded and scored for each of the indicators according to the rationale, as describe in Appendix 2.1. As the survey consisted of different types of questions, the indicators were measured on different scales and were normalized to a value between 1 and 4 to allow for a consistent interpretation.

3.2.5 Estimation

A single quantitative vulnerability score was derived from the indicators and the metrics of the following equation (ALLISON et al., 2009; CINNER et al., 2012): Vulnerability = (Exposure + Sensitivity) – Adaptive capacity. This approach assumes that each index is equally important for overall vulnerability.

The scores for sensitivity, exposure, and adaptive capacity were plotted on a bubble plot to visualize the differences among the three key components of vulnerability. The sensitivity, adaptive capacity, exposure and vulnerability index were tested for normality using a Shapiro-Wilk test. As data were found to violate the criteria for normality, the non-parametric Kruskal-Wallis test (HOLLANDER; WOLFE, 1973; ZAR, 1996) was applied to test if there was a difference among communities. A post hoc pairwise comparison test was applied to determine which community was significantly different from the average (SIEGEL; CASTELLAN, 1988). All statistical tests were considered at a 0.05 level of significance. The sensitivity, exposure and adaptive capacity scores were also analyzed by a PCA to identify the influence of each indicator in the overall score of each category. The analyses and plots were performed using *devtools* (WICKHAM; CHANG, 2016), *pgirmess* (GIRAUDOUX, 2016), *plotly* (SIEVERT et al., 2016) and *ggbiplot* (VU, 2011) packages for the R program (R CORE TEAM, 2018).

3.3 Results

3.3.1 Sensitivity

The sensitivity category was composed of 36 indicators divided into four components. The social dependence on fishing component contained nine indicators, and based on these indicators, the community with the highest score was Itaipu, and the one with the lowest score was Enseada. For the historical and cultural dependence on fishing component, fifteen indicators were used; the community with the highest score was Ilha do Araújo, and the community with the lowest score was Boqueirão Sul. The economic dependence on fishing component was based on eight indicators; the community with the highest score was Itaipu, and the community with the lowest score was Bonete. For the economic dependence on other resources component, four indicators were used; the community with the highest score was Pontal de Leste, and the community with the lowest score was Enseada.

The PCA shows some overlap of data, but it can be observed that the sensitivity of Pontal de Leste and Bonete are mainly influenced by the economic dependence on other resources index, Itaipu is influenced by the economic dependence on fishing index and Mandira depends more on the historical and cultural dependence on fishing index (Figure 3.3). Other communities did not have a distribution pattern clearly associated with a specific index.

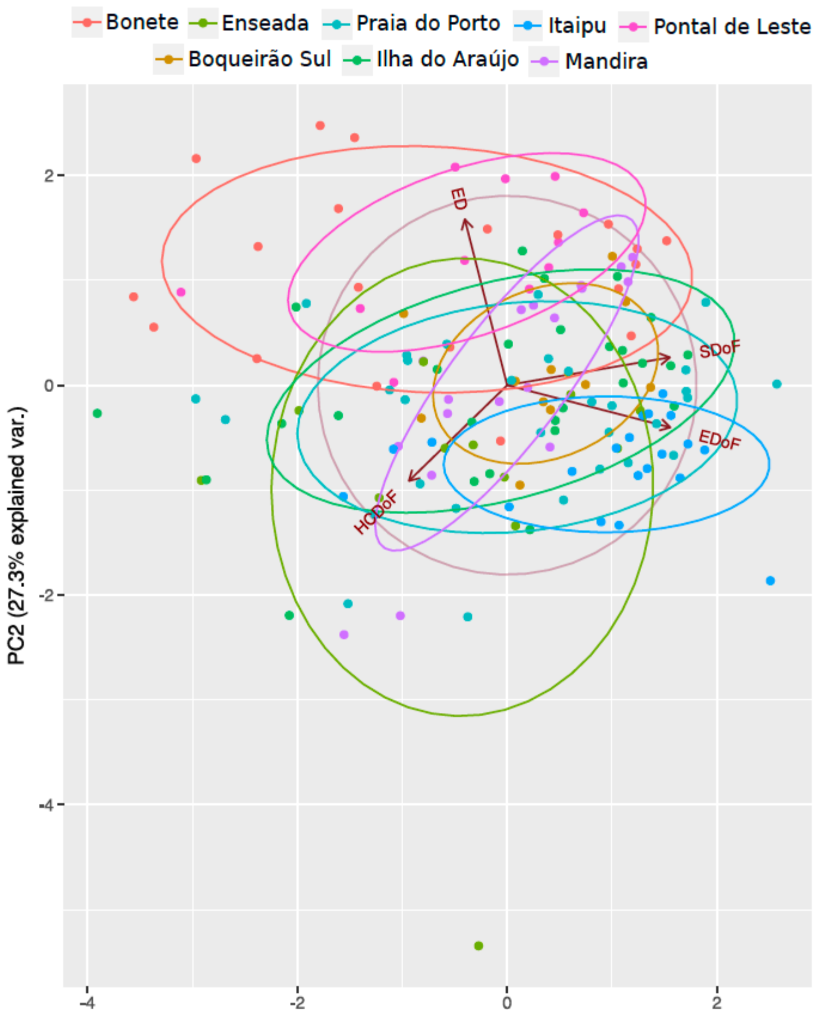

Figure 3.3 Principal component analysis of the sensitivity score category per community. Variables: SDoF (social dependence on fishing); HDoF (historical and cultural dependence on fishing); EDoF (economic dependence on fishing); ED (economic dependence on other resources).

The four components made up the final sensitivity category score, and the communities with the highest overall sensitivity were Pontal de Leste and Ilha do Araújo, while the community with the lowest was Enseada. The Kruskal Wallis test (p=0.0033) indicated that there was a difference in the sensitivity between communities (Figure 3.4a). The pairwise comparison test showed that the Enseada sensitivity index was significantly lower ($p<0.05$) compared to Ilha do Araújo, Mandira and Pontal de Leste (Table 3.1).

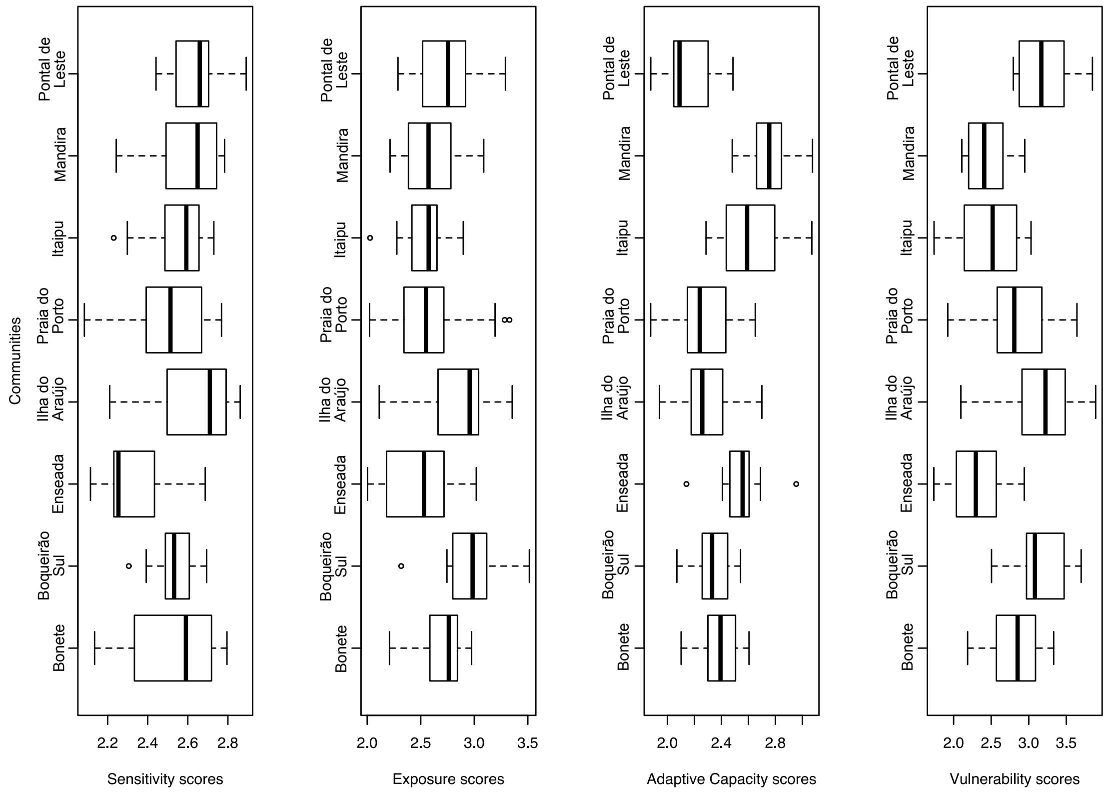

Figure 3.4 Scores of sensitivity (a), exposure (b), adaptive capacity (c) and vulnerability (d) per community. The solid black line represents medians; open boxes are 25% and 75% of the observations, bars indicate the range of durations, and dots the outliers.

Table 3.1 Pairwase comparison test for the vulnerability categories between communities, where the differences were significant (p <0.05). IT=Itaipu, IA=Ilha do Araújo, ES=Enseada, BN=Bonete, MD=Mandira, BS=Boqueirão Sul, PL=Pontal de Leste, and PP=Praia do Porto. S=Sensitivity, AC=Adaptive Capacity, E=Exposure, V=Vulnerability.

	IT	**IA**	**ES**	**BN**	**MD**	**BS**	**PL**	**PP**
IT								
IA	AC, E, V							
ES		S, AC, V						
BN								
MD		AC, V	S	AC				
BS	E, V		E, V		AC, E, V			
PL	AC, V		S, AC, V		AC, V			
PP	AC	E	AC, V		AC	E		

3.3.2 Exposure

For the exposure category, a total of 35 indicators were divided into four components. The environmental change component was based on eight indicators; the community with the highest score was Boqueirão Sul, and the community with the lowest score was Mandira. Two indicators were used for the institutional support component, and all communities had high scores. For the personal exposure component, twenty-one indicators were used; the community with highest exposure score was Pontal de Leste, and the community with the lowest score was Itaipu. For the attitude and perception component, four indicators were used; the community with the highest score was Itaipu, and the community with the lowest score was Pontal de Leste.

The PCA shows some segregation of communities, mainly associated with the personal exposure index (Figure 3.5). Itaipu and Enseada were disconnected from the other communities due to the low scores of the personal exposure index, while Pontal de Leste had the highest scores. Boqueirão Sul was also influenced by the personal exposure index but was also strongly influenced by the environmental change indexes. The other communities did not have a distribution pattern clearly associated with a specific index.

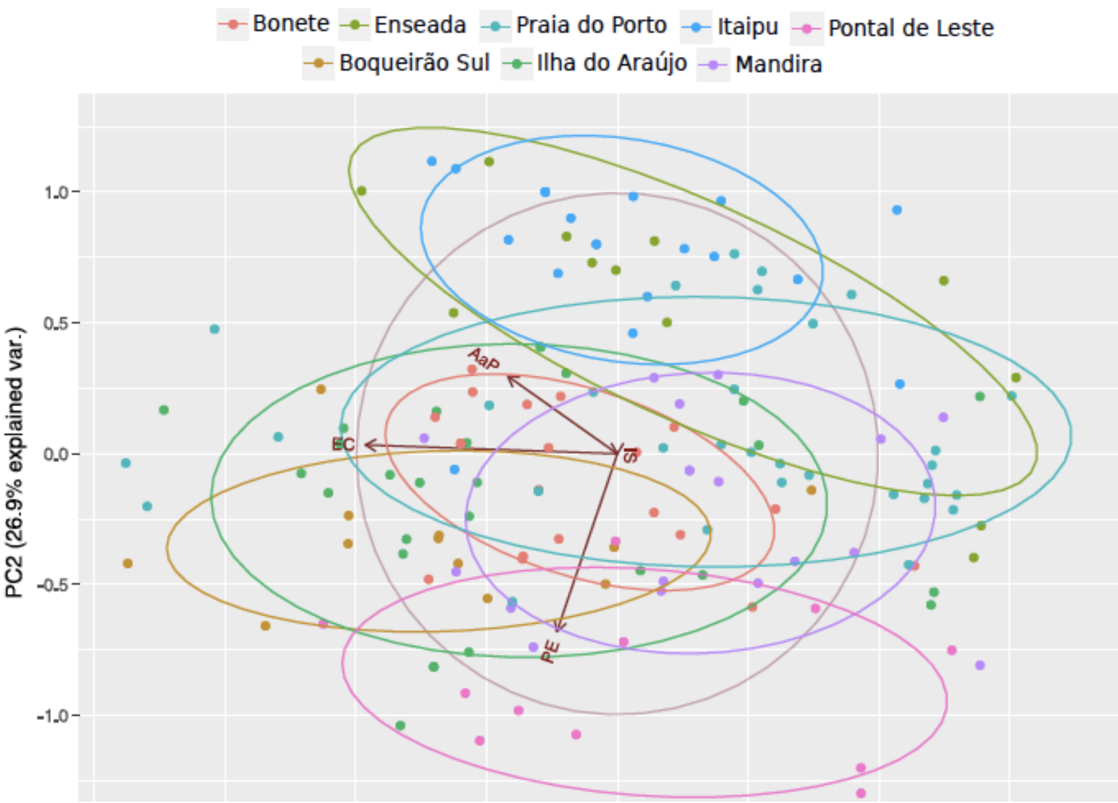

Figure 3.5 Principal component analysis of the exposure score category per community. Variables: EC (environmental change); IS (institutional support); PE (personal exposure); AaP (attitude and perception) indexes.

The final exposure score consisted of the four components. The community with the highest overall exposure was Boqueirão Sul, and the community with the lowest score was Enseada. The Kruskal Wallis test (p<0.0001) indicates that there is a difference in the exposure between communities (Figure 3.4b). The pairwise comparison test showed that the Boqueirão Sul exposure index was significantly higher ($p<0.05$) than that of Enseada, Praia do Porto, Itaipu and Mandira (Table 3.1). The Ilha do Araújo exposure index was also significantly higher ($p<0.05$) than that of Praia do Porto and Itaipu.

3.3.3 Adaptive Capacity

A total of 89 indicators categorized into 12 components made up the adaptive capacity category. The natural capital component was based on six indicators; the community with the highest score was Mandira, and the community with the lowest score was Ilha do Araújo. For the human capital component, eight indicators were used; the community with the highest score was Itaipu, and the community with the lowest score was Pontal de Leste. Nine indicators made up the social capital component; the community with the highest score was Mandira, and the community with the lowest score was Boqueirão Sul. Two indicators were used in the bridging social capital component; the community with the highest score was Itaipu, and the community with the lowest score was Pontal de Leste. For the physical capital component, eighteen indicators were used; and the community with the highest score was Itaipu, and the community with the lowest score was Pontal de Leste. For the financial capital component, eight indicators were used; and the community with highest score was Bonete, and the community with the lowest score was Pontal de Leste. For the personal flexibility component, nine indicators were used; the community with the highest score was Itaipu, and the community with the lowest score was Pontal de Leste. Four indicators were used for the attitude and perception component, and based on these indicators, the community with the highest score was Boqueirão Sul, and the community with the lowest score was Pontal de Leste. For the occupational flexibility component, seven indicators were used; the community with the highest score was Enseada, and the community with the lowest score was Pontal de Leste. The institutional support component was based on four indicators; the community with the highest score was Mandira, and the community with the lowest score was Bonete. Twelve indicators were used for the institutional flexibility component; the community with the highest score was Itaipu, and the community with the lowest score was Pontal de Leste. For the social dependence on fishing component, two indicators were used; the community with the highest score was Mandira, and the community with the lowest score was Pontal de Leste.

It is possible to recognize three groups, with some overlaps, in the PCA (Figure 3.6). One group contained only the Pontal de Leste community that was segregated from the other communities, and this group was mainly influenced by the lowest scores in the social dependence in fishing and occupational flexibility indexes. The second group contained Ilha do Araújo, Bonete, Boqueirão Sul and Praia do Porto and was influenced by the low scores in the overall indexes. The third group contained Mandira, Itaipu and Enseada, and as opposed to the second group, it had the highest adaptive capacity in the overall indexes.

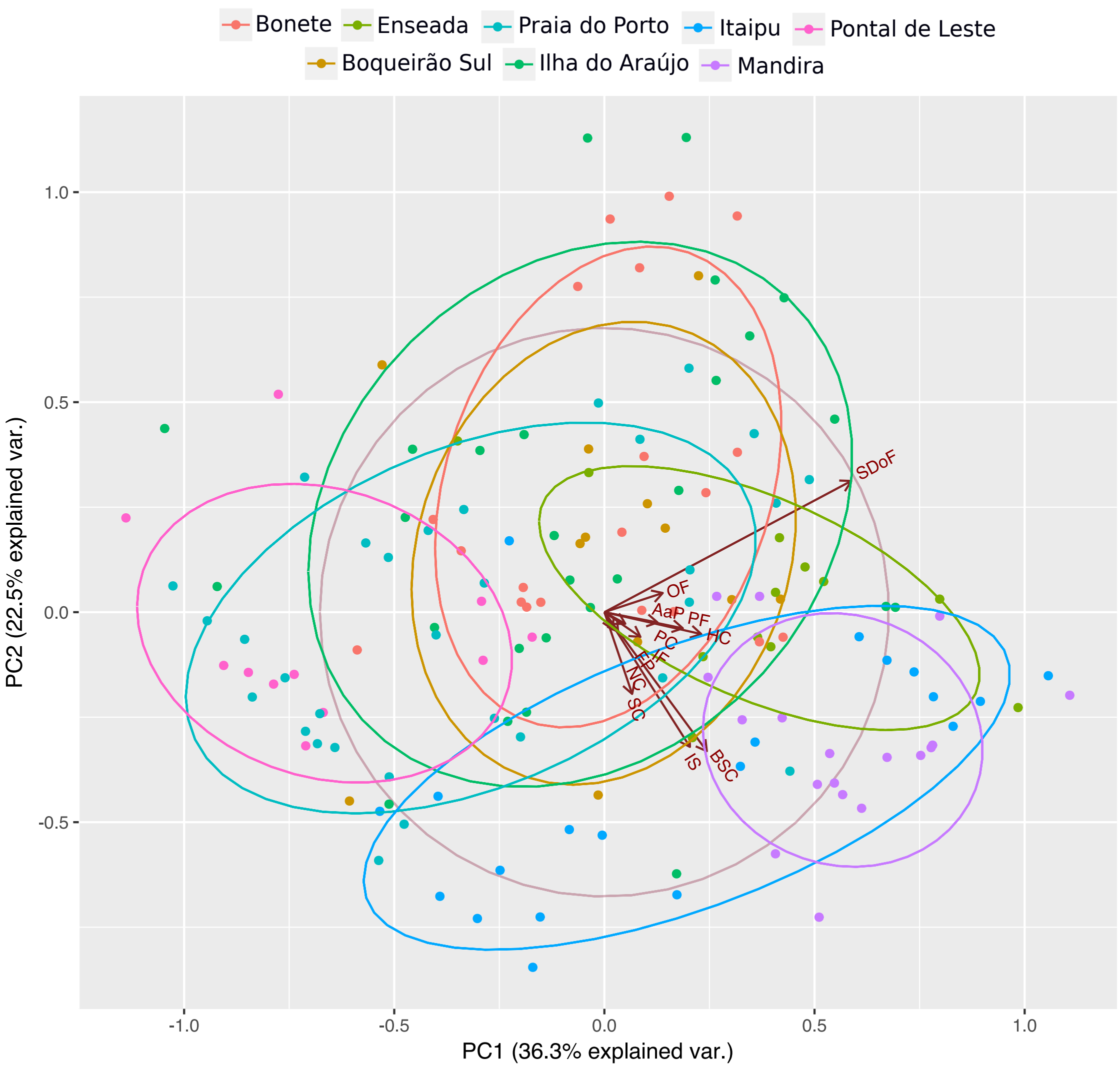

Figure 3.6 Principal component analysis of the adaptive capacity score category per community. Variables: NC (natural capital); HC (human capital); SC (social capital); BSC (bridging social capital); PC (physical capital); FC (financial capital); PF (personal flexibility); AaP (attitude and perception); OF (occupational flexibility); IS (institutional support); IF (institutional flexibility); SDoF (social dependence on fishing) indexes.

The final adaptive capacity score contained the twelve components; the community with the highest overall adaptive capacity was Mandira, and the community with the lowest overall adaptive capacity was Pontal de Leste. The Kruskal Wallis test ($p<0.0001$) indicated that there was a difference in the adaptive capacity between communities (Figure 3.4c). The pairwise comparison test shows that the Mandira adaptive capacity index was significantly higher ($p<0.05$) than those of Bonete, Boqueirão Sul, Ilha do Araújo, Praia do Porto and Pontal de Leste (Table 3.1). The Pontal de Leste adaptive capacity was also significantly higher ($p<0.05$) than the adaptive capacity of Itaipu and Enseada, while Ilha do Araújo and Praia do Porto had adaptive capacities that were significantly lower ($p<0.05$) than Enseada and Itaipu.

3.3.4 Vulnerability

The vulnerability score was based on 160 indicators split into sensitivity, exposure and adaptive capacity categories. The most vulnerable community was Pontal de Leste, followed by Ilha do Araújo, Boqueirão Sul, Bonete, Itaipu, Mandira and Enseada, and the least vulnerable was Praia do Porto. Pontal de Leste, Ilha do Araújo and Boqueirão Sul were the most vulnerable because they had the highest scores in all three categories: sensitivity, exposure and adaptive capacity. Bonete obtained intermediate values in the three categories and thus a moderate vulnerability score. Itaipu and Mandira had high sensitivity scores, but due to their highest adaptive capacity scores and low exposure scores, they were determined to have low vulnerability. Enseada had the lowest vulnerability score due its low sensitivity and exposure, and intermediate adaptive capacity score (Figure 3.7, Table 3.2). The Kruskal Wallis test ($p<0.0001$) indicated that there is a difference in the vulnerability between communities (Figure 3.4d). The pairwise comparison test showed that the vulnerability of Boqueirão Sul was significantly higher ($p<0.05$) than Enseada, Itaipu and Mandira (Table 3.1). The vulnerability of Enseada was also significantly lower ($p<0.05$) than that of Ilha do Araújo, Praia do Porto and Pontal de Leste. The vulnerability of Ilha do Araújo was also significantly higher ($p<0.05$) than that of Itaipu and Mandira. The vulnerability of Pontal de Leste was also significantly higher ($p<0.05$) than that of Itaipu and Mandira.

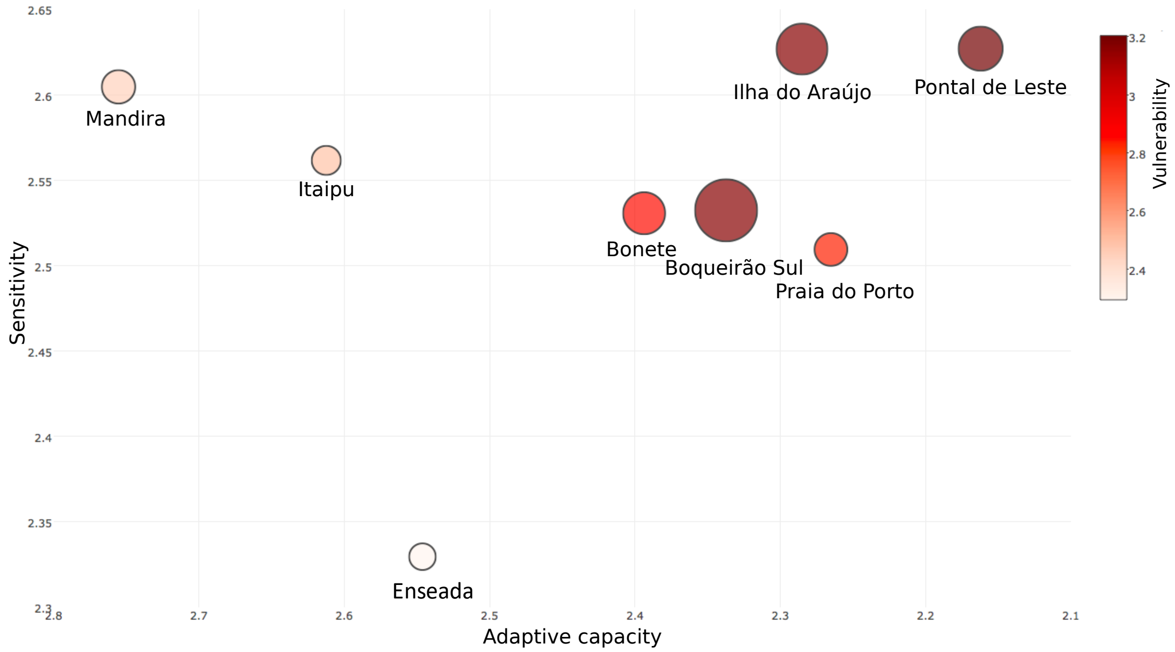

Figure 3.7 Vulnerability of fishing communities in South Brazil Bight to climate change. Adaptive capacity (x-axis) is plotted against Sensitivity (y-axis). The size of the bubble shows exposure. The colors represent the vulnerability score.

Table 3.2 Scores of each index and the cumulative score of sensitivity, exposure, adaptive capacity and vulnerability. Communities are ranked according to their cumulative vulnerability (1=most vulnerable, 7= least vulnerable). Scores are colored according to their value: green 1.00 – 1.74; yellow 1.75 – 2.49; orange 2.50 – 3.24; red 3.25 – 4.00). IT=Itaipu, IA=Ilha do Araújo, ES=Enseada, BN=Bonete, MD=Mandira, BS=Boqueirão Sul, PL=Pontal de Leste, and PP=Praia do Porto.

Categories	Component	BS	MD	PL	ES	IA	BN	IT	PP
	Social dependence on fishing	2,79	2,78	2,88	2,64	2,84	2,81	3,02	2.86
	Historical and cultural dependence on fishing	2,01	2,21	2,13	2,13	2,25	2,12	2,06	2.13
	Economic dependence on fishing	2,71	2,69	2,33	2,29	2,69	2,17	2,87	2.56
	Economic dependence on other resources	2,61	2,74	3,16	2,25	2,72	3,03	2,29	2.49
Sensitivity		**2,53**	**2,60**	**2,63**	**2,33**	**2,63**	**2,53**	**2,56**	**2.51**
	Natural capital	2,29	2,99	2,37	2,11	2,09	2,38	2,32	2.63
	Human capital	2,48	2,90	2,09	2,70	2,53	2,82	2,97	2.09
	Social capital	2,34	3,88	3,50	2,84	2,39	2,71	3,01	2.74
	Bridging social capital	1,25	1,81	1	1,79	1,30	1,10	2,02	1.42
	Physical capital	3,00	2,95	2,90	3,39	3,10	2,97	3,42	3.02
	Financial capital	2,75	2,73	2,59	2,62	2,60	2,78	2,77	2.70
	Personal flexibility	2,26	2,47	2,08	2,31	2,19	2,28	2,52	2.16
	Attitude and perception	3,37	3,10	2,68	3,02	3,04	3,15	3,22	2.86
	Occupational flexibility	1,79	2,02	1,76	2,38	1,92	2,37	2,05	1.90
	Institutional support	2,27	3,21	1,91	2,08	1,97	1,81	2,42	1.85
	Institutional flexibility	2,04	2,16	1,89	2,62	2,01	2,11	2,63	2.11
	Social dependence on fishing	2,21	2,83	1,18	2,67	2,28	2,25	1,97	1.69
Adaptive capacity		**2,34**	**2,76**	**2,16**	**2,55**	**2,28**	**2,39**	**2,61**	**2.26**
	Environmental change	2,78	1,85	2,06	1,94	2,54	2,39	2,29	1.76
	Institutional support	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4
	Personal exposure	2,43	2,15	2,75	1,43	2,20	2,05	1,20	1.93
	Attitude and perception	2,67	2,39	2,17	2,67	2,56	2,40	2,67	2.66
Exposure		**2,97**	**2,60**	**2,74**	**2,51**	**2,82**	**2,71**	**2,54**	**2.59**
Vulnerability		**3,17**	**2,45**	**3,20**	**2,29**	**3,17**	**2,85**	**2,49**	**2.83**
Vulnerability ranking		3	7	1	8	2	4	6	5

A scheme with the key drivers affecting the vulnerability of fishing communities to climate change was established, showing the effects of each driver on the final adaptive capacity of the group (Figure 3.8).

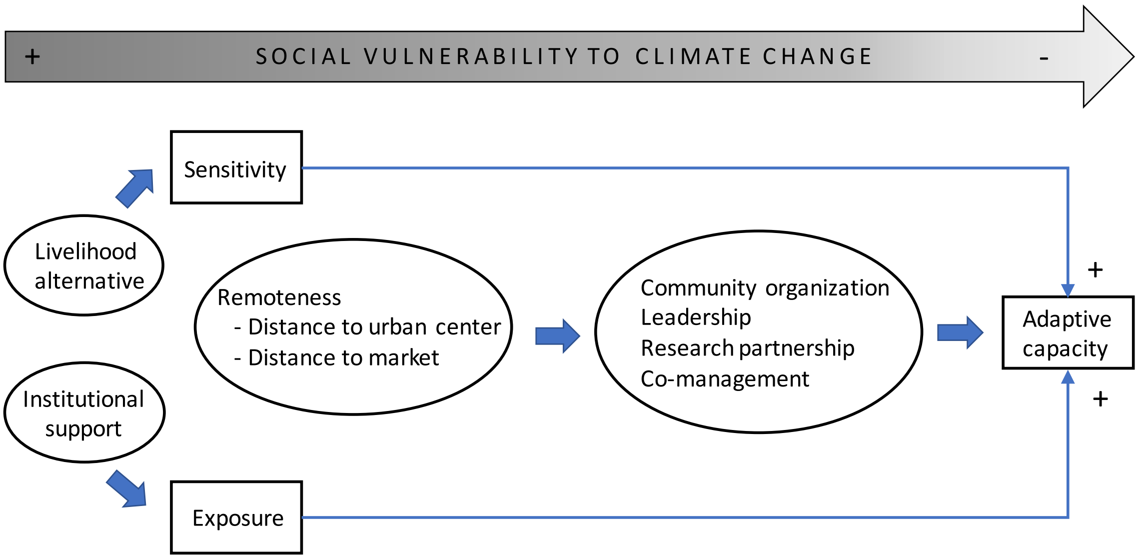

Figure 3.8 Key factors affecting the vulnerability to climate change in fishing communities of South Brazil Bight. Main drivers, in circles and vulnerability categories, in rectangles.

3.4 Discussion

3.4.1 Sensitivity drivers

Economic dependence on fishing is usually considered in isolation to express the sensitivity category in many vulnerability assessments, but in the framework used in this study the level of social, historical and cultural dependence were also considered, giving a broad overview of the sensitivities associated with climate change issues. The results show almost equal scores for seven of the eight fishing communities surveyed, with the Enseada community being the only different one. The low sensitivity score for Enseada is because the community members have diversified their livelihoods, reducing their economic dependence on fishing by adding mussel and seaweed farming and activities related to tourism. The diversification is a process by which households engage in multiple income generating activities, which is a strategy for spreading risk and reducing vulnerability (BRUGERE; HOLVOET; ALLISON, 2008). Finding other profitable activities and creating other sources of employment for the fishing communities under scenarios of collapsed fisheries and climate change are becoming a global challenge (PAULY, 2006). In our analysis, we indeed observed that livelihood diversification was an important factor driving a reduction in vulnerability.

Although there is diversification and a non-exclusive dependence on fishing, the Enseada community still has a strong link with the fishing tradition (NÉMETH, 2016), with it being practiced daily by all the interviewees.

The drivers for an increase in community sensitivity were the strong social, economic and cultural dependencies on fishing, mainly in Ilha do Araújo, Mandira and Pontal de Leste. The index of economic dependence on other resources is the main factor affecting the sensitivity of Pontal de Leste and Bonete, the most isolated communities and accessed only by the sea. The index considered the distance to the market to buy and sell goods, methods to obtain food, importance of food source and level of farming. Throughout the world, remote communities are often marginalized; therefore, these communities are among the most vulnerable to climate change impacts (MARU et al., 2014). The distance to market, which can express remoteness, is the factor that increases the sensitivity of the communities (CINNER; ASWANI, 2007) as it limits their ability to negotiate prices and avoid the use of middlemen to sell their catches (MERLIJN, 1989). In Pontal de Leste, the situation is worse, as it is a subsistence community and reliant on income from selling the fish. The strong dependence of these communities implies a concern in relation to food security, since their main source of income and food is threatened by climate change (GASALLA et al., 2018) and their access to markets, in addition to involving greater spending on transit, may also be impacted by the increase in storm surges predicted by climate change scenarios (VON STORCH, 2014). A similar situation is expected to be found in other isolated communities that also depend on the external market to buy and sell goods.

For the Itaipu community, its high economic dependence on fishing leads to its high sensitivity score, as changes in fishery resource availability are likely to have proportionally negative effects on the turnover of the activity. To ensure the survival of fishing and the maintenance of income related to fishing, the community fought for over 20 years for the creation of the Itaipu MER, established in 2013. The MER ensured community participation in the (in progress) construction of the management plan and the exclusive right to explore the area, which is facing the speculation from the real estate and the oil and gas industries.

3.4.2 Exposure drivers

Fisher personal exposure plays an important role in community exposure. The personal exposure component includes safety at sea, storms, floods, drought and shoreline change subcomponents. Of these subcomponents, shoreline change was the one with the main influence on the most exposed communities. The erosion process has been well documented in the communities exposed (ANGULO; SOUZA; MULLER, 2009) and has a direct impact on the livelihoods of local fishers, by jeopardizing their homes and their access to the sea (MARTINS; GASALLA, 2018). Other associated impacts of personal exposure are related to large storms, such as roof damage, falling trees, loss of fishing gear and shipwrecks. Shipwrecks occur with some frequency in the south and southeastern regions, as reported by the Itaipu, Araujo Island and Bonete communities over the past five years. Most of the shipwrecks recorded along the Brazilian coast were caused by strong winds and high waves, which were associated with large storms (FUENTES; BITENCOURT; FUENTES, 2013).

Another important driver of exposure to climate change that also affects the adaptive capacity of the communities is the distance to an urban center, with the closest communities being the less exposed, as they typically have better infrastructure and access to public services. This is the case of the Itaipu and Enseada communities, where in addition to being situated in urbanized areas, fisher houses are no longer adjacent to the sea, decreasing personal exposure to climate hazards. On the other hand, the communities most exposed are those that have poor infrastructure and that use the ocean as the main mode of transport. Due to the lack of infrastructure in these communities, they must use the ocean to go the close town to sell their fish catches and to buy food and basics needs. Using the ocean as the main mode of transport also means that good ocean and weather conditions are not only important to fishing activities but also to community mobility and survival. Based on climate change predictions, an increase in the frequency and intensity of the storms is expected (PEZZA; SIMMONDS, 2005; VON STORCH, 2014), which may increase community vulnerability.

The lack of institutional support related to climate change has drawn attention in the analysis, since it was the index for which all communities classified as highly exposed. None of the localities have institutions or government departments working with the community on climate change issues. This result does not mean that there are no institutions, mainly universities, researching climate change in the region, but shows that the communities are not aware of what is being researched and/or that the studies do not include the social component in their analyses. In addition to the need for clear government action on climate change mitigation, focusing on the fishing communities, the institutions and universities that are already researching the climate change issues need to improve communication and knowledge exchange with local communities (CVITANOVIC et al., 2015), better engage the social component of the ecosystem by using an interdisciplinary approach and innovative combinations of methods and data (OSTERBLOM et al., 2013; BENNETT et al., 2017), and encourage the participation of local communities in climate research to increase the capacity of these populations to cope and adapt to changes (NOP, 2016). These actions are mandatory to improve the understanding and knowledge of the climate change issues and therefore to contribute toward effective implementation of adaptation policies (MAKINDE, 2005).

3.4.3 Adaptive capacity drivers

Climate change tends to increase the social vulnerability of small-scale fishers, whose economic survival, habits, culture and livelihoods are strongly influenced by climate conditions. Adaptive capacity depends upon the availability of natural, human, social, physical, financial and institutional resources, as adaptive capacity can be measured as the ability people have to convert these resources into useful adaptation responses (BROOKS; ADGER, 2004; FOLKE et al., 2005; SMIT; WANDEL, 2006). An additional component of flexibility (personal, occupational and institutional) was incorporated into the framework used in this study to refine the measure of the potential of people and institutions to influence their current situation and adapt to future conditions (MARSHALL, 2010). The community with the highest adaptive capacity was Mandira, which had the greatest score in almost all the indexes. The high adaptive capacity of the community was driven by well-established community organization, proper management of the oyster resulting from a partnership between government, university and local knowledge (MACHADO; FAGUNDES; HENRIQUE, 2015), control of commercialization through a community cooperative (KEFALÁS, 2016), and the search for local income alternatives such as handcrafts and community-based tourism. On the other hand, Pontal de Leste had the lowest adaptive capacity, mainly due to its high dependence on fishing, inability to negotiate fish price due to its distance to the market and lack of electricity to store the fish, and absence of livelihood alternatives not related to fishing. The community has tried to diversify its income by having a community restaurant and renting rooms for tourism, but these activities are not yet representative as they are not part of the regional tourism route. The engagement of the community members into regional tourism councils is necessary to bring the community new employment opportunities even as local communities are faced with increasing responsibilities to provide for their own well-being and development (FLORA; FLORA, 1993). What can be done locally to improve local livelihoods and reduce community vulnerability is to adopt similar structures to those used by Mandira, with the commercialization of fish done in a communitarian way, with the development of community-based tourism and with a well representative community organization and strong leadership (HAQUE; DEB; MEDEIROS, 2009; GUTIERREZ; HILBORN; DEFEO, 2011).

Communities that are MER, as is the case of Mandira and Itaipu, are the communities with the highest adaptive capacities. MER is a type of community-based marine protected area in Brazil, with management decisions being taken at a local level. The marine MER in Brazil has been successful in granting territorial user rights for fisheries to small-scale fisher organizations and as a conservation strategy, despite some implementation problems (SANTOS; BRANNSTROM, 2015). The difference in the ability of MERs to stimulate a better social organization that other areas is based the local recognition of the relevant studies, the sustainable use of resources, and the reverse role of government, where it works as facilitator in the MER management, where stakeholders are able to influence and share control over the decisions affecting them (CHAMY, 2005; MOURA et al., 2009; SANTOS; BRANNSTROM, 2015). These characteristics increase the ability of a community to adapt to hazards, as well as reduce vulnerability.

The combination of community organization, representative leadership, scientific support, and bottom-up decision-making was the key for a higher adaptive capacity. The infrastructure and income alternatives are risky in all sampled communities, resulting in an overall low adaptive capacity. Livelihood diversification can increase the number of activities generating income and reduce the vulnerability of the community (BRUGERE; HOLVOET; ALLISON, 2008). The diversification of livelihoods is usually dependent on external investments in community enterprises and microcredit interventions (TORELL et al., 2017). However, Mandira proved that a strong leadership and community commitment can play a key role in the development of alternative livelihood options without dependence on external factors.

3.4.4 Overall vulnerability

The analysis presented here provides a foundation for addressing the similarities and differences in vulnerability and adaptation patterns among the SBB coastal communities, providing rich understanding of the local scale processes influencing community vulnerability and new learning mechanisms for other coastal regions. From a global aspect, developing countries, such as Brazil, are in the top half of the countries most vulnerable to climate change in terms of marine fisheries (BLASIAK et al., 2017). At the national level, Brazil is predicted to have high exposure and moderate sensitivity, adaptive capacity and vulnerability to the impacts of climate change on fisheries (ALLISON et al., 2009). At the local level, the social vulnerability assessment with fishing communities in the Parana coastline, southern Brazil, had similar results to ours, with the community infrastructure, household assets and level of participation in community organizations are driving the vulnerability (FARACO, 2012). While the study was carried out at Praia da Almada in Ubatuba, Southeast Brazil, it shows that among the alternatives sought by fishers to adapt to environmental and climatic changes and reduce their vulnerability is the search for alternative income and diversification of fishing grounds and species (SILVA, 2014). These data show that due to the absence of policies addressing the vulnerability issues, SBB fishers are dealing with the changes either through the traditional knowledge background or by representativeness and collectivity through community organizations to reduce their vulnerability. A global analysis shows the effects of strong leadership and community cohesion to the success of fishery management (GUTIERREZ; HILBORN; DEFEO, 2011), and here, we showed that these factors are also contributing to reduce the vulnerability to climate change by increasing the community adaptive capacity.

The socioeconomic vulnerabilities of coastal communities to climate change are typically related to the ongoing challenges of managing urbanization, pollution, sanitation and marginalization (CINNER et al., 2012). These factors are also influencing the communities of SBB, but we found that the remoteness, in terms of the distance to urban center and to market, as the main drivers negatively affecting the vulnerability in the region. The remote communities of SBB are the most vulnerable to climate change, as well as having the highest exposure and lowest adaptive capacity. Small-scale fishing communities located in remote areas tend to have limited or disadvantaged access to markets, and generally poor access to health, education and other social services (FAO, 2015). In addition to these factors, communities located on islands have geophysical characteristics, as low average altitude of Pontal de Leste and Boqueirão Sul (ANGULO; SOUZA; MULLER, 2009), that create inherent physical vulnerabilities to those locations. Socio-ecological stresses, such as habitat loss and degradation, overexploitation, pollution, human encroachment, and disease can harm biodiversity (KINGSFORD et al., 2009) and are adding to the social stresses faced by the communities as shown in this study to reduce the ability of socio-ecological systems to bounce back after shocks such as climate change (METCALF et al., 2015).

It is also important to note that although fishers are reasonably aware of the issue of climate change, with at least 80% of the respondents having heard of climate change, their responses show that they see it as a distant phenomenon, such as the melting of the polar glaciers, global warming or tsunamis and seaquakes, but they do not have knowledge on the impacts of such phenomena on daily activities at the local scale. Another important factor to note is that the climate issue is far from being a real concern for fishers, since the fishing has faced many other problems, such as overfishing, marginalization and struggles for territory (DIEGUES, 2006; HANAZAKI et al., 2013; GASALLA; GANDINI, 2016), making the “distant” climate issue not an issue that fishers are concerned with addressing at this time. This factor adds a new challenge, which is to make climate issues a concern to fishers, stakeholders and decision makers.

Small-scale fisheries are a category that have limited flexibility, opportunities, and capital to reinvest in alternative occupations, and these fisheries are losing fishing territory in coastal areas of Brazil (GASALLA; GANDINI, 2016). The ocean temperature is increasing quickly in southern Brazil due to climate change, and the expected effects are to be particularly strong in the region (HOBDAY; PECL, 2014; POPOVA et al., 2016). Some of the major commercial species from both small-scale and industrial fishing fleets have been classified as sensitive to climate impacts based on abundance, distribution, and phenology attributes (GASALLA et al., 2018). The effects of climate change are already being observed by the small-scale fishers, and climate change has affected their livelihoods (MARTINS; GASALLA, 2018). Within this context, the vulnerability of marine socio-ecological systems in the South Brazil Bight requires urgent actions that help to understand the aspects related to vulnerability and adaptive capacity and to address the impacts of climate change, as presented here.

The vulnerability framework used in this study was initially developed to allow across country and culture comparisons (ASWANI et al., 2018), but as the framework is based on a large database collected on at a local scale that is very detailed, the framework was highly refined for locally scaled vulnerability drivers. The criteria for selecting the communities that were designed to represent the diversity of characteristics in the region were also useful, since the criteria allow the extrapolation of the data found here to communities with similar characteristics.

3.5 Conclusion

The small-scale fishing communities in the South Brazil Bight are highly affected by climatic events as fishers have a strong dependence on natural resources for maintaining their livelihoods. This dependence makes all the communities in the region vulnerable to climate change in some way. Our findings show that the main factors that are driving the vulnerability of the small-scale fishing communities to climate change are the following:

- Community remoteness, as
    I. The distance to the market (to sell the catches or to buy food and basic needs) is the factor that increases sensitivity and decreases the adaptive capacity of the communities as it limits their ability to negotiate prices and avoid use of middlemen to sell their catches as most do not have the ability to stock or freeze fresh catch and because the simple act of buying food and basic needs involves high costs (financial and time) and in the vast majority of communities is dependent on good ocean and weather conditions.
    II. The distance to the urban center is also a factor that drives the vulnerability of small-scale fishing communities, as it increases the exposure and decreases the adaptive capacity of the communities to the effects of climate change. Some of the factors that increase the exposure are the lack of access to public services, such as access to basic sanitation, shops, public schools; availability of formal and informal jobs; and transport. In terms of transport, in addition to not having access to public services, which means community members need to use their own means to move to the nearest urban center, these communities depend

on a good ocean and weather conditions not only to fish but also for their own mobility.

- The lack of institutional support related to climate change is other factor that drive community vulnerability to climate change as the presence of institutions centered on climate change issues improves the adaptive capacity of the community and decreases the exposure to the climate-related hazard. There is a need to engage the government and the communities on climate issues, as well as a need for a clear policy arrangement for coastal populations, especially for the remote and most vulnerable communities. Research institutions also need to improve communication on the outcomes of their research to the public, as well as to work more closely with the communities, including the social aspects of their research plans.
- Livelihood diversification was an important driver decreasing the sensitivity of the Enseada community by decreasing their dependence on fishing and increasing the adaptive capacity of the Mandira community by bringing alternative income options. These drivers have positive effects as they decreased the vulnerability of both communities. The communitarian approach of Mandira and the attachment to the tourism activities in Enseada can serve as learning opportunities for other communities facing the same issue.
- A combination of factors such as a well-established community organization and recognized leadership, a partnership with the universities and researchers, and a community-based co-management of resources also increased community adaptive capacity and then decreased their vulnerability to climate change. The combination of these factors can all be found, at least partially, in Brazilian MERs.

The study presents a comprehensive assessment of social vulnerability to climate change in the SBB seeking to find the main drivers affecting the small-scale fishing communities. Our results show that adaptive capacity is what is driving the vulnerability, with the effects either on the positive or negative side. The findings provide new understanding of climate change effects in the region, perspectives to reduce the vulnerability, and learning to increase the adaptive capacity of the fishing communities.

THIRD CHAPTER

4. CHAPTER 3

Brazil-South Africa comparison on the vulnerability to climate change of fishing communities

Abstract Small-scale fisheries play crucial roles in the livelihoods, food security and income of millions of people in developing countries. These fisheries face similar challenges and constraints around the world, including marginalization, space competition with different economic sectors, unequal power relations and limited participation in decision-making processes. Other threats facing fishing communities include pollution, environmental degradation, climate change impacts, and natural and human-induced disasters. In addition to similar political and economic characteristics shared between Brazil and South Africa, the small-scale fishing sector in these countries also face similar climate stressors. Therefore, this study aims to compare aspects that guide the vulnerability of small-scale fishing communities under pressure from climate change in the Southern Cape in South Africa and the South Brazil Bight in Brazil. The utilized data were drawn from a global comparison database on the vulnerability of marine-dependent coastal communities to climate change. Here, subsets of similar questions were applied in Brazil and South Africa. The comparison was carried out using the final vulnerability scores of both countries to identify the differences and/or similarities between the fishing communities of Southern Cape and the South Brazil Bight. Highlighted differences found between the countries included participation in the decision-making process, ownership of the boats and fishing rights, and institutional support and mobility. The high dependence on fishing and attachment to place decreased the vulnerability of the Brazilian fishers; in contrast, the strong dependence on market forces to buy food threatened the food security of the South African fishers and, thus, increased their vulnerability. These findings provide noteworthy insights into the regional vulnerability of the small-scale fishing communities in both countries; additionally, the results support the development of local climate change mitigation plans and serve as learning mechanisms for similar communities that are likely to experience climate stressors in other regional locations.

Keywords: Small-scale; fisheries; climate change; vulnerability; management

4.1 Introduction

Fisheries in developing countries, including South Africa and Brazil, are under strong and increasing anthropogenic pressures that affect the social-ecological system of these areas (BENE et al., 2016). Specifically, small-scale fisheries play crucial roles as sources of livelihood, food security and income for millions of people in developing countries (GARCIA et al., 2003). While target species, vessel types, fishing methods and management approaches vary widely around the world, as well as within particular regions, resource use, community impact and policy issues are similar across the board (FAO, 2016). Additionally, there are many similarities in the constraints and challenges that apply to different regions of the world. According to the Small-Scale Fisheries Guidelines from the FAO (FAO, 2015), many small-scale fishing communities around the world continue to be marginalized, and their contributions to food security and nutrition, poverty eradication, equitable development and sustainable resource utilization—which benefits both them and others—are not fully realized.

Globally, in recent decades, the development of both the small- and large-scale fishery sectors has, in many cases, led to the overexploitation of resources and threatened habitats and ecosystems (PAULY; ZELLER, 2016). The traditional management practices of natural resources in small-scale fisheries that may have been in place for generations have changed as a result of non-participatory and increasingly centralized fisheries management systems, rapid technological developments, and demographic changes (BERKES et al., 2001). In many places, ongoing conflicts with large-scale fishing operations are problematic, resulting in increasingly high interdependence or competition between small-scale fisheries and other sectors. These other sectors, which may include tourism, aquaculture, agriculture, energy, mining, industry and infrastructure developments (PAULY, 2006), can often have stronger political or economic influences.

Other constraints faced by small-scale fisheries around the world include marginalization and poverty (NAYAK; OLIVEIRA; BERKES, 2014). These are multidimensional in nature and are not only caused by low incomes but also by factors that preclude the full enjoyment of human rights, including civil, political, economic, social and cultural rights. Small-scale fishing communities also tend to have limited or disadvantaged access to markets and poor access to health, education and other social services (MARU et al., 2014). Other characteristics include low levels of formal education and inadequate organizational structures. Available opportunities are limited, as small-scale fishing communities face a lack of alternative livelihoods, unemployed youth, and unhealthy and unsafe working conditions (BRUGERE; HOLVOET; ALLISON, 2008). Pollution, environmental degradation, climate change impacts, and natural and human-induced disasters add to the already described threats facing these small-scale fishing communities (ALLISON; ELLIS, 2001). All these factors make it difficult for small-scale fishers to make their voices heard, defend their human and tenure rights, and secure the sustainable use of the fishery resources on which they depend (FAO, 2015).

In the last two decades, South Africa and Brazil, together with Russia, China and India (i.e., the BRICS countries), have become increasingly important actors in the process of globalized trade. Of the BRICS countries, South Africa and Brazil experienced similar low growth in the early 1990s; however, their GDP growth rates accelerated in the 2000s (OECD, 2009). These positive outcomes were favored both by major macroeconomic policy reforms, which started in the early 1990s in both countries, and by significant productivity gains and rapid integration into the world economy; as a result, they received greater access to new technology, capital and financial markets (ARNAL; FORSTER, 2010). In the 1990s, Brazil changed its development strategy by opening the country's economy, reducing the role of the state and applying restrictive macroeconomic policies after the end of the military regime (i.e., 1964 to 1984); in contrast, in South Africa, the fall of apartheid and the general elections in 1994 marked a turning point away from the poor economic productivity trends observed before then (OECD, 2009).

South Africa and Brazil are both experiencing a relatively recent democracy. In Brazil, the process of democratization began in 1989 when the new constitution and the emergence of a presidential republic were consolidated. In South Africa, democracy started in 1994 after the end of the apartheid regime. What differentiates the pre-democracy period between the two countries is their access to fishing rights. Under the apartheid administration in South Africa, fishing rights were largely denied to any person who was not classified as "white", preventing the majority of the small-scale fishers from being allocated fishing rights (KLEINSCHMIDT; SAUER; BRITZ, 2003). As a result, historically disadvantaged individuals who had their fishing rights denied, began to work as crew members on small-scale fishing boats. In Brazil, although small-scale fishers had their fishing rights during the military regime, no policy was developed for the sector, which remained marginalized during this period. Despite the difference in fishing-rights access, the small-scale fishers were marginalized and forgotten in both countries, and only after the political liberalization were these groups able to express themselves more freely, particularly in defending their rights and their access to resources (ISAACS, 2011; DIEGUES, 2006).

In addition to marginalization and lack of policies, this sector also faces problems, such as poor market access, lack of working capital, pressure to diversify their primary livelihoods, tourism development and general economic changes, all of which threaten the resilience of small-scale fisher livelihoods (HANAZAKI et al., 2013; SOWMAN et al., 2013). Accordingly, small-scale fishing communities in both countries are characterized by high levels of poverty and unemployment, with few opportunities to earn an income outside of fishing; poor infrastructure; limited access to services; and a range of social problems that are associated with these conditions (DIEGUES, 2006; GLAVOVIC; BOONZAIER, 2007). The size of the fishing communities and the proportion of households involved in fishing activities are also similar between the two countries (ASWANI et al., 2018).

There are also similar climate stressors affecting South Africa and Brazil, as both countries are marine hotspots where the sea surface temperature is warming quickly (HOBDAY; PECL, 2014). These hotspots are expected to undergo the effects of climate change before; hence, they can serve as laboratories for understanding the impacts of climate change as well as for developing adaptation strategies. Vulnerability comparisons at different scales and between identified marine hotspots can provide accelerated learning mechanisms for communities likely to experience similar stressors and changes to their livelihoods in the future (HOBDAY et al., 2016).

Amidst the challenges and constraints faced by small-scale fishers in both countries, the present work aims to compare the aspects that influence the vulnerability of small-scale fishing communities in the Southern Cape (STC) in South Africa and in the South Brazil Bight (SBB) in Brazil. The underlying interpretation of vulnerability was centered around climate change issues; however, the individual indicators enabled the deeper interpretation of factors that affect the small-scale fishing communities as a whole. The interpretation and analysis of the drivers behind the vulnerability assessment are crucial for gaining understanding of the small-scale fishing sectors in these countries and, in turn, those in other emerging economies found worldwide.

4.1.1 Study area

In South Africa, the study focused on the STC small-scale commercial linefishery that operates in the inshore area of the Agulhas Bank (Figure 4.1). The area is part of the Benguela Current Large Marine Ecosystem (BCLME), an eastern boundary current system that sustains important fisheries for Angola, Namibia and South Africa. This highly variable ecosystem consists of four shelf subsystems, including the Agulhas Bank subsystem off the southern Cape coast (Hutchings et al., 2009; Jarre et al., 2015). In South Africa, the traditional linefishery is a boat-based, multiuser, multispecies and multiarea fishery that targets 50 commercially important fish species (GRIFFITHS, 2000; BLAMEY et al., 2015). A variety of anthropogenic and other stressors, including resource scarcity, poor socio-economic conditions and policy, and regulatory challenges, affect the inshore social-ecological system of the area. These stressors contribute towards increasing vulnerability to both global and local changes in the fishery system (ALLISON et al., 2009; BLASIAK et al., 2017). In the future, fishers will need to cope with and adapt to multi-scalar social and ecological changes (GAMMAGE; JARRE; MATHER, 2017), and communities will be required to enhance change response strategies to achieve resilience. The linefishery in the STC mainly harvests the silver kob (*Argyrosomus inodorus*) as their most economically viable and sustainable target species. Although other species, such as silvers/carpenters (*Argyrozona argyrozona*), red fish (such as red roman, *Chrysoblephus laticeps*) and sharks, are targeted in the absence of kob, these species are not profitable nor are they conducive to the long-term sustainability of livelihoods. Harvesting alternative species is a way to keep things 'ticking over,' as the high-value, slow-growing red fish are scarce, and fishers must travel approximately 30 km offshore to catch the relatively low-value silvers (GAMMAGE; JARRE; MATHER, 2017).

In Brazil, the SBB, defined as the area of the Brazilian Southeastern continental shelf that extends from Cabo Frio (23°S; 42°W) to Cabo Santa Marta (28.5°S; 48.6°W) (CASTRO; MIRANDA, 1998), is the most industrialized and urbanized coastal zone in the country (Figure 4.1). The region has a heterogeneous coastline with a diversity of ecosystems (i.e., rocky shores, sandy bays and estuaries). Oceanographic features include the occurrence of meso-scale eddies from the Brazil Current (to the east), the South Atlantic Central Water (SACW) intrusion, and seasonal upwelling (SILVEIRA et al., 2000). These features boost the regional primary productivity and, as a result, some fisheries (GASALLA; ROSSI-WONGTSCHOWSKI, 2004). Such characteristics make the SBB one of the most highly developed fishing industries in the country, contributing to about half of Brazil's commercial fishery yield and supporting important pelagic and demersal fisheries (MPA, 2011). Despite the representative large-scale fisheries, small-scale fishing still predominates in several traditional fishing communities along the coast. In such communities, fishing is practiced daily by most fishers and is characterized by traditional cultures, values and behaviors strongly associated with nature (DIEGUES, 2008). The fishing activity in these communities occurs in coastal and inland areas, with small-sized boats or canoes, and uses equipment that employs very simple technology. The infrastructure for landing, storage and commercialization of fish is very precarious (DIEGUES, 2006). In the SBB, the main challenges faced by small-scale communities in terms of maintaining their livelihoods are marginalization by large-scale fishing, poor market access, lack of working capital, low credit access and pressure to diversify the basis of their livelihoods (HAQUE et al., 2015; YKUTA; GASALLA, 2014). Changes associated with climate will act as additional impacts that affect the stocks and, consequently, the livelihoods of these marine-dependent coastal communities (BELL et al., 2016).

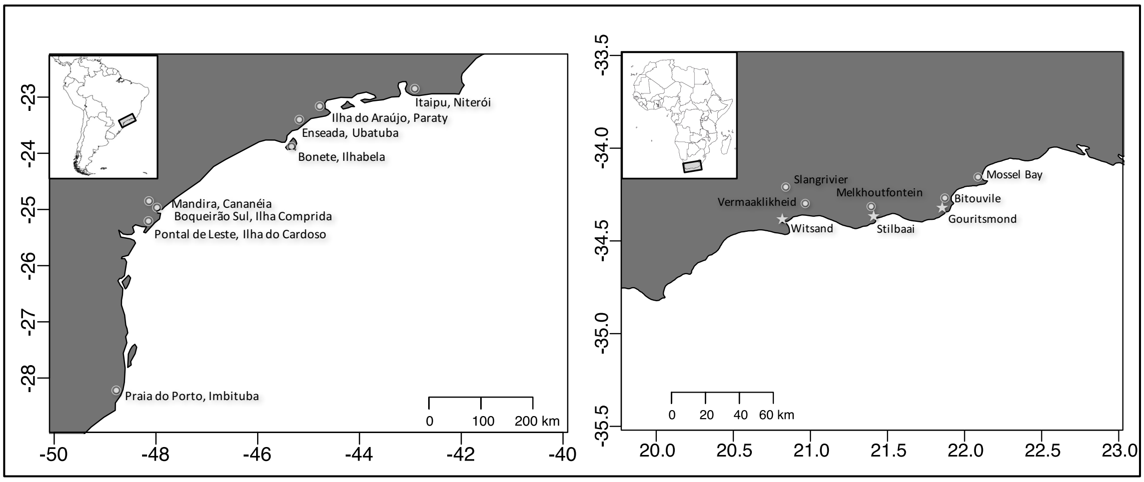

Figure 4.1 The sampled regions in the South Brazil Bight (left) and the southern Cape (right). The surveyed communities are shown by white dots. In the southern Cape, the stars represent the fishery harbors of the sampled communities.

4.2 Materials and Methods

The data used in this study were collected in a survey on the vulnerability of marine-dependent coastal communities to climate change, which was administered in countries with various levels of economic development as part of the Belmont Forum's GULLS project (ASWANI et al., 2018). The GULLS project was designed to characterize, assess and predict the future of coastal marine food resources in fast-warming marine hotspots (HOBDAY et al., 2016). A key component of this project was to collect rich, local-level, social vulnerability data that would provide a fine understanding of the local-scale processes influencing the vulnerability of communities while allowing for the data to be scaled up to regional, national, and global levels. The nature of the collected data allows for the integration with ecological and oceanographic models as well as for comparisons among hotspot communities and countries. For this study, we used data collected in Brazil and South Africa for a regional comparison of the SBB and STC fishing communities (Table 4.1). Specifically, our aim was to provide accelerated learning mechanisms for communities located in countries with similar characteristics that are likely to experience similar stressors and changes. In addition, the same database will be utilized for a cross-comparison at the national level as well as for a detailed local analysis of community-level vulnerability drivers in the SBB (Chapter 2) and STC (GAMMAGE et al., *in prep*).

The Brazilian survey consisted of 250 questions, and the South African survey consisted of 253 questions. For the purpose of this paper, a subset of similar questions (n=135) was applied in both countries. Of the 19 examined components, questions were divided into 57 subcomponents and then separated into the three vulnerability categories: sensitivity, exposure and adaptive capacity (Appendix 3.1). The final vulnerability score was derived from the three categories using the equation: [Vulnerability = (Exposure + Sensitivity) – Adaptive capacity] (ALLISON et al., 2009; CINNER et al., 2012).

The comparison occurred by using the final vulnerability scores of both countries to identify the differences and similarities between the fishing communities of the SBB and STC. These differences were then categorized into topics and discussed based on i) the GULLS survey information, ii) the additional complementary qualitative information collected in both countries, and iii) the available secondary data.

Table 4.1 Characterization of the sampled communities in Southern Cape (STC) and South Brazil Bight (SBB).

Region	Community	Sampling methods	Sampling size	Sampling period	Fishing methods	Main target species
STC	Slangrivier	Field survey	3	May, 26th-June 05th, 2015	Linefishery	*Argyrosomus inodorus, Argyrozona argyrozona*, *Chrysoblephus laticeps* and sharks
STC	Vermaaklikheid	Field survey	9	October, 17th - November 04th, 2014	Linefishery	*Argyrosomus inodorus, Argyrozona argyrozona*, *Chrysoblephus laticeps* and sharks
STC	Melkhoutfontein	Field survey	25	October, 13rd - November 04th, 2014	Linefishery	*Argyrosomus inodorus, Argyrozona argyrozona*, *Chrysoblephus laticeps* and sharks
STC	Bitouvile	Field survey	10	October, 21-30th, 2014	Linefishery	*Argyrosomus inodorus, Argyrozona argyrozona*, *Chrysoblephus laticeps* and sharks
STC	Mossel bay	Field survey	12	May, 27th - October, 15th, 2015	Linefishery	*Argyrosomus inodorus, Argyrozona argyrozona*, *Chrysoblephus laticeps* and sharks
SBB	Itaipu	Field survey	20	November, 1-15th, 2015	Gillnet, line and beach seine	*Micropogonias furnieri, Cynoscion* spp., *Trichiurus lepturus, Pomatomus saltatrix*
SBB	Ilha do Araújo	Field survey	27	December 1-20st, 2014	Trawl, line and gillnet	*Litopenaeus schmitti, Xiphopenaeus kroyeri*
SBB	Enseada	Field survey	12	December 1-20st, 2014	Gillnet, mussel farming and floating fish trap	*Perna perna* farming and multspecies fishing
SBB	Bonete	Field survey	20	September 6-20th, 2015	Gillnet, line, jigging and floating fish trap	*Pomatomus saltatrix, Loligo* spp., *Epinephelus marginatus*
SBB	Mandira	Field survey	18	November 1-25th, 2014	Oyster extrativism	*Crassostrea* spp.
SBB	Boqueirão Sul	Field survey	15	November 1-25th, 2014	Gillnet	*Cynoscion* spp., *Micropogonias furnieri, Mugil liza*
SBB	Pontal de Leste	Field survey	11	November 1-25th, 2014	Gillnet	*Centropomus* spp., *Mugil liza, Macrodon ancylodon*
SBB	Praia do Porto	Field survey	31	September, 02nd-14th, 2016	Gillnet, beach seine	*Micropogonias furnieri, Pomatomus saltatrix, Cynoscion* spp.

The statistical comparison consisted of a test to identify the differences and similarities in aspects of vulnerability for the SBB and STC fishing communities. To determine significant differences between countries, we first tested the normality of the data using the Shapiro-Wilk test (ROYSTON, 1982). The data that were normally distributed were tested using a two-sample Student's t-Test (MCDONALD, 2008). Data with non-normal distribution were tested using a nonparametric Wilcoxon test (BAUER, 1972). These tests were applied to the subcomponents, components, categories and vulnerability scores as described in Appendix 3.1. The analysis was performed using the *devtools* (WICKHAM; CHANG, 2016) package for the R program (R CORE TEAM, 2017).

4.3 Results

4.3.1 Vulnerability comparison

The STC fishing communities are more vulnerable to change in the marine environment than are the SBB fishing communities (t-test, $p=0.4121$, Figure 4.2); this was due to low adaptive capacity and high exposure scores, which were not compensated for by the relative low sensitivity. In the SBB communities, the high adaptive capacity and low exposure were enough to compensate for the high sensitivity associated with the strong dependence on fishing, which resulted in a lower vulnerability score.

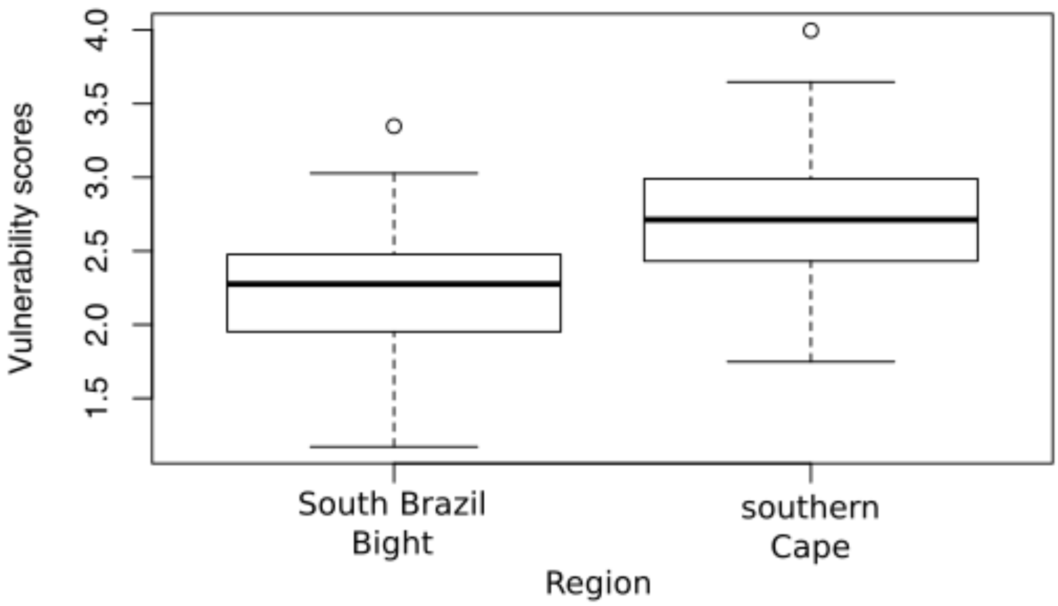

Figure 4.2 Vulnerability scores for the South Brazil Bight and southern Cape fishing communities. The vulnerability score of the southern Cape fishing communities is significantly higher (t-test, p=0.4121) than the vulnerability score of the South Brazil Bight fishing communities. The solid black lines represent medians; open boxes are 25% and 75% of the observations; bars indicate the range of durations; and dots represent the outliers.

4.3.2 Sensitivity comparison

In the marine environment, there was no difference between SSB and STC fishing communities (Wilcoxon test, p=0.05877, Figure 4.3). When scaling down to the component and subcomponent levels, differences emerge. In the social dependence on the fishing component, no difference was found between the SSB and STC communities (Wilcoxon test, p>0.05); however, in the subcomponents fishing frequency (Wilcoxon test, p=3.856e-09) and attachment to place (Wilcoxon test, p=0.0002689), the SBB fishing communities had higher sensitivity scores. In the subcomponent social dependence (Wilcoxon test, p=3.815e-06), the STC fishing communities had higher sensitivity scores. In the historical and cultural dependence on fishing components, the STC fishing communities had a higher sensitivity (t-test, p=<0.001); however, at the subcomponent level, the SBB fishing communities had higher scores in the cultural importance of fishing (Wilcoxon test, p=<0.001). The STC communities had higher social mobility scores (Wilcoxon test, p=<0.001). There was no difference between the SBB and STC fishing communities in the economic dependence on fishing component (Wilcoxon test, p>0.05); however, in the competition for fish subcomponent, the SBB fishing communities had a higher score (Wilcoxon test, p=1.633e-10). The competition for fish was based on the fishers' estimate of the number of fishers operating in the region. In the economic dependence on other resources component, there was no difference between the SBB and STC communities (Wilcoxon test, $p>0.05$), but when scaling down to the subcomponents levels, we can see that the STC communities had a higher sensitivity in terms of food source (Wilcoxon test, p=1.439e-10). This means that the STC fishers are more dependent on buying their food from formal markets, rather than supplementing their food intake with subsistence farming or eating part of their fish catch.

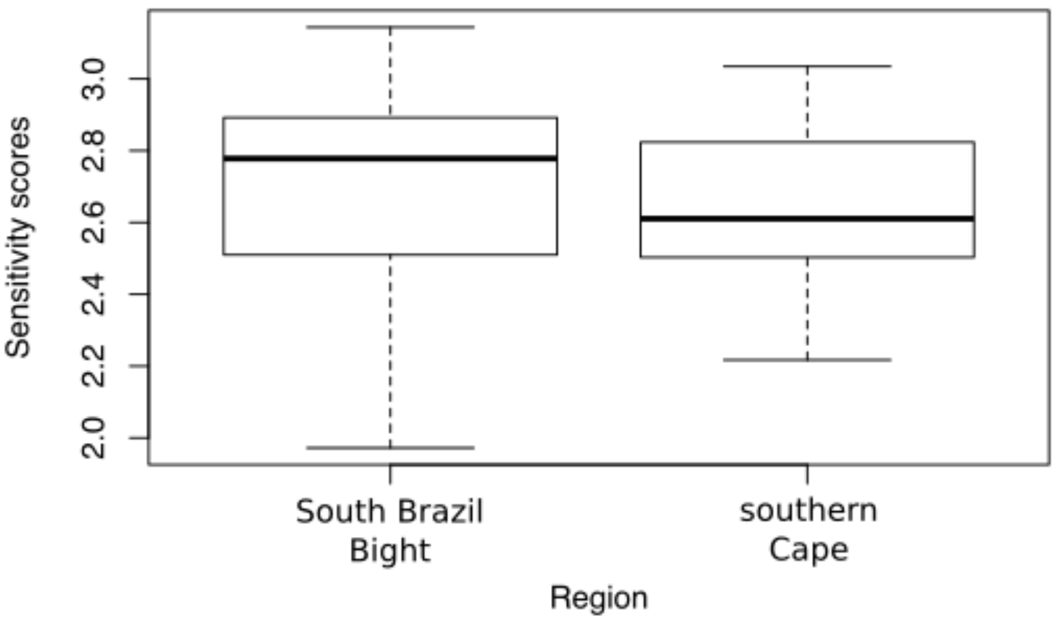

Figure 4.3 Sensitivity scores for the South Brazil Bight and southern Cape fishing communities. There is no significant difference between the southern Cape and South Brazil Bight fishing communities (Wilcoxon test, p=0.05877). The solid black lines represent medians; open boxes are 25% and 75% of the observations; bars indicate the range of durations; and dots represent the outliers.

4.3.3 Adaptive capacity comparison

The adaptive capacity of the SBB fishing communities was significantly higher than that of the STC communities (t-test, p=4.983e-14, Figure 4.4). When scaling down, it becomes apparent that the SBB communities did not have the highest scores for all components and subcomponents. Brazil had higher scores in the natural capital component (Wilcoxon test, p=1.107e-07) and in the changing resource base subcomponent (Wilcoxon test, p=1.107e-07). In the human capital, the SBB fishing communities had a higher score in the component level (Wilcoxon test, p=1.067e-05) but not across all subcomponents. The SBB communities had higher scores in the knowledge (Wilcoxon test, p< 2.2e-16) and labor (Wilcoxon test, p=3.576e-08) subcomponents, but the STC communities had higher scores in the education subcomponent (Wilcoxon test, $p=5.128e-13$). In terms of social capital, the SBB fishers had higher scores for this component (Wilcoxon test, $p=1.573e-11$) and for the following three subcomponents: decision making (Wilcoxon test, $p=4.781e-09$), leadership (Wilcoxon test, $p=0.001293$) and community cohesion (Wilcoxon test, $p< 2.2e-16$). The gender equity component had similarly high scores in both countries (Wilcoxon tests, $p>0.05$). In the bridging social capital component, which is based on the access to institutional safety and the information subcomponents, no difference was observed between the countries (Wilcoxon test, $p>0.05$). In general, both countries have weak relations with government departments and academic institutions related to fishing activities and disaster prevention. In terms of physical capital, the SBB communities had higher scores than did the STC fishing communities (t-test, $p=1.687e-15$). The higher physical capital of the SBB communities was related to a greater ownership of houses and boats. There was no difference between the SBB and STC fishing communities in the financial capital (Wilcoxon test, $p>0.05$) and personal flexibility (Wilcoxon test, $p>0.05$) component and subcomponent levels, respectively. The SBB fishing communities had higher scores in the attitude and perception component (Wilcoxon test, $p=0.001126$) due to their higher interest in the environment (Wilcoxon test, $p=3.328e-07$). The interest in the environment subcomponent consisted of the number of ideas held to ensure sustainability of the target fish. In the occupational flexibility component, the STC fishers had a better score than did the SBB fishers (Wilcoxon test, $p=1.875e-05$) due to their higher interest in having alternative employment to fishing as well as their willingness to move to a bigger town or community to work if necessary. In terms of the institutional support (Wilcoxon test, $p=1.81e-12$) and institutional flexibility (Wilcoxon test, $p=0.001095$) components, the STC communities had a higher score. The higher score of the STC communities in the institutional support is related to recent changes in the fishing policy and improved monitoring of the catches, which results in more reliable data being available to institutions.

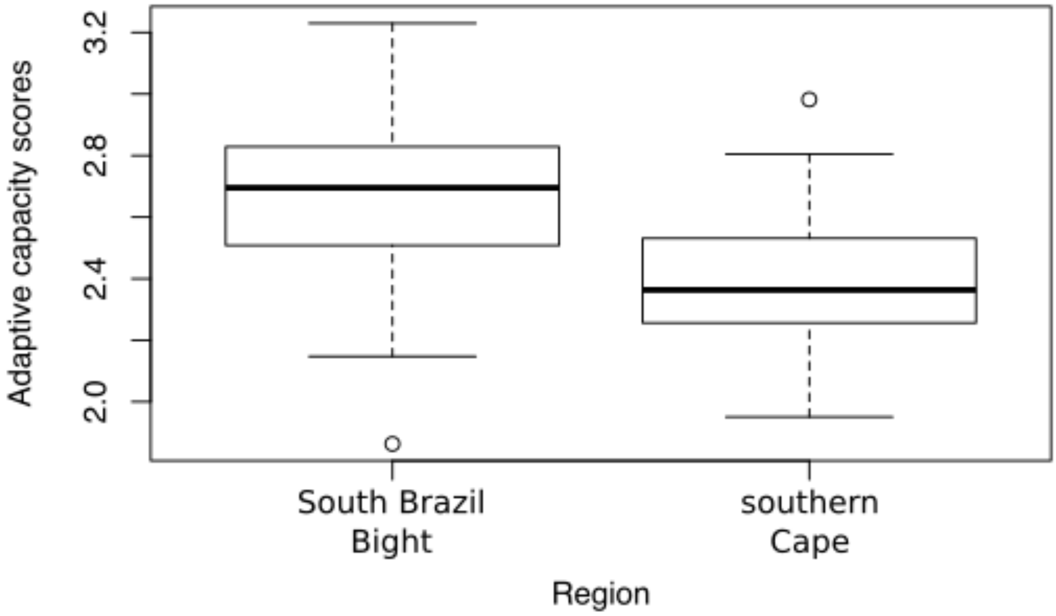

Figure 4.4 Adaptive capacity scores for the South Brazil Bight and southern Cape fishing communities. The adaptive capacity of the South Brazil Bight fishing communities is significantly higher (t-test, p=4.983e-14) than the adaptive capacity of the southern Cape fishing communities. The solid black lines represent medians; open boxes are 25% and 75% of the observations; bars indicate the range of durations; and dots represent the outliers.

4.3.4 Exposure comparison

Overall, the STC fishing communities had significantly higher exposure than those of the SBB communities (t-test, p=4.968e-07, Figure 4.5) and had experienced a greater environmental change (Wilcoxon test, p=3.798e-10) component. The institutional support, personal exposure and attitude and perception components (Wilcoxon tests, p<0.05) showed no differences between the STC and SBB scores (Wilcoxon tests, p>0.05).

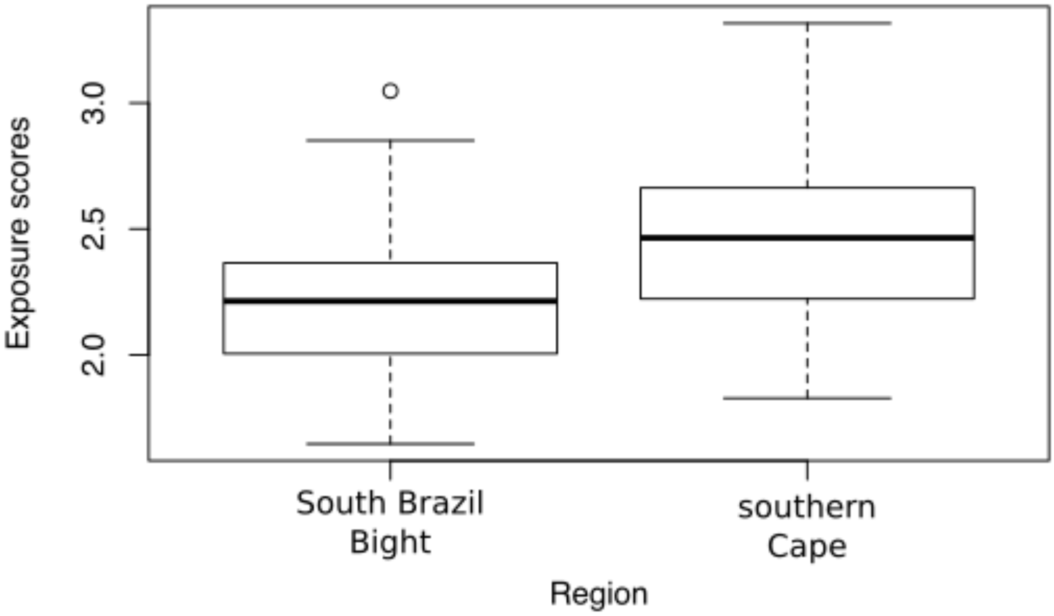

Figure 4.5 Exposure scores of the South Brazil Bight and southern Cape fishing communities. The exposure score of the southern Cape fishing communities is significantly higher (t-test, p=4.968e-07) than that of the South Brazil Bight fishing communities. The solid black lines represent medians; open boxes are 25% and 75% of the observations; bars indicate the range of durations; and dots represent the outliers.

4.3.5 Overarching comparison

The key differences and similarities found in the vulnerability aspects between the SSB and STC fishing communities were then divided into topics (Figure 4.6). All discussed differences were significantly different between the two countries. In Brazil, vulnerability decreased for the SSB fishing communities through participation in decision-making processes and fishing activity structure. Conversely, in the STC communities, vulnerability decreased through mobility and temporal working migration as well as through institutional support. Fishing activity structure increased vulnerability in the SSB communities of Brazil, and food security increased vulnerability in the STC communities of South Africa. The similarities between the countries were numerous and included social, economic and institutional themes (see Figure 4.6). These topics are further explained and interpreted in the discussion below.

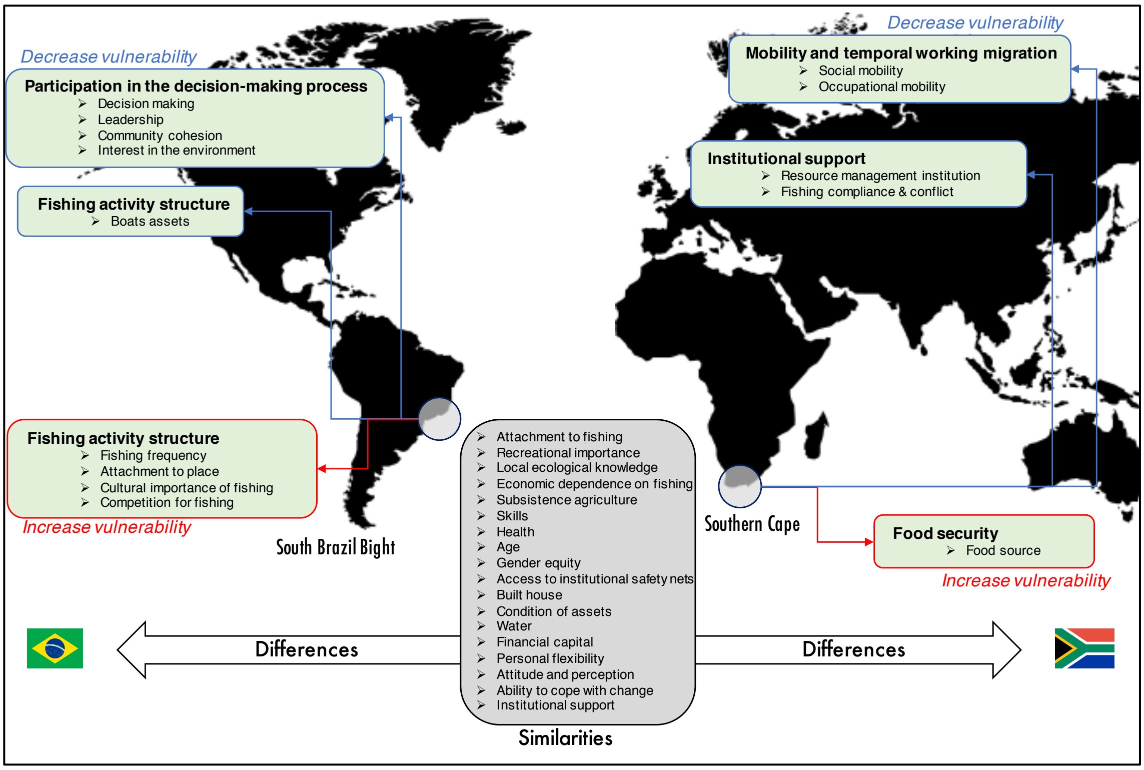

Figure 4.6 Factors influencing the differences and similarities between the South Brazil Bight and southern Cape fishing communities in the vulnerability to various aspects of climate change. All differences are statistically significant.

4.4. Discussion

4.4.1 Fishing activity structure

The factor that appears to be crucial in reducing the sensitivity to changes in the marine environment of the STC fishing communities is the way the fishing activity is organized in the South African region. The sampled STC fishers were mostly crew members who all participated in the small-scale commercial linefishery of the southern Cape. In this fishing sector, the skipper typically holds the fishing rights, addresses the supply chain, and decides when to fish (VISSER, 2015). The crew-skipper organization of the small-scale fisheries in the STC results in the marginalization of the crew members in the fishing sector (GAMMAGE; JARRE; MATHER, 2017). This is a result of the South African systematic exclusion and segregating policies that removes access to resources from small-scale fishers (SOWMAN et al., 2014). During apartheid, many of these fishing communities were dispossessed of both their lands adjacent to the coast and some (or all) of their traditional fishing rights to harvest marine resources (VAN SITTERT, 2002, 2003). As a consequence of the marginalization and removal of access to resources, the STC communities were socially and historically less dependent on fishing activities than were the SBB communities; consequently, the STC communities appeared to be less sensitive. In terms of vulnerability to the climate change framework, lower sensitivity is positive because it results in a lower vulnerability score. However, the low adaptive capacity of the STC fishers and the limited opportunities to create alternative strategies to face the effects of climate change has a substantial negative impact on the final vulnerability score.

In Brazil, the SSB fishers are the owners of their boats and have fishing rights, which gives them greater flexibility and power over fishing activities, resulting in a higher adaptive capacity. However, their relatively high dependence on fishing activities makes them more sensitive to changes in the marine environment.

4.4.2 Mobility and temporal working migration

The STC fishers have less attachment to place and greater social mobility through voicing their willingness to procure employment other than fishing; additionally, they have a willingness move to move to bigger towns to work if necessary. Although quantitative sample results show that STC fishers would be willing to move to another activity or town, the collected qualitative data and the literature indicate a strong connection to place and that any migration is temporary, with migrants having no plans to permanently move away from the community (GAMMAGE; JARRE; MATHER, 2017). This temporary mobility would involve only the fisher as an individual; in contrast, families would typically remain within their original community.

The handline crew regulations allow the STC fishers to have greater mobility than the rights holders and skippers, and they can move between areas to serve as crew members on different boats. However, recent work in the same region of South Africa shows that most of the crews indicated an unwillingness to pursue this strategy as it is not necessarily financially viable (GAMMAGE; JARRE; MATHER, 2017). This is largely due to the additional costs incurred, as the household and family at home need to be maintained, in addition to the fishers requiring temporary or alternative accommodation and purchasing extra food when they are fishing far away from their communities.

Social mobility is also limited by non-ownership of houses and boats by the previous generation (i.e., parents). However, despite the lack of ownership by the younger generation, the current linefishery regulation for crews should theoretically increase mobility to fish in other places or change to another job. Nevertheless, this mobility is hampered by financial constraints, family ties and community ties (i.e., attachment to place). Thus, the STC fishers display virtual mobility, although this is not necessarily used to their favor in practice.

On the other hand, Brazilian fishers have a strong connection with place, causing these fishers to reject the notion of engaging in alternative livelihood activities and an unwillingness to move within city limits. Preferred adaptation strategies for SSB fishers would occur without a total change of place or region. Their strong attachments to fishing and place make SSB fishers more sensitive not only compared to South Africa but also to other countries, such as India, Madagascar, Solomon Islands, and Australia (ASWANI et al., 2018). However, a considerable proportion of Brazilian fishers are involved with some alternative livelihood activities to supplement their income, albeit most of these activities are informal. Parallel activity is considered to be complementary and often contributes to higher earnings. Despite this, SSB fishers consider themselves as fishers above all and will not abandon their fishing activities (HANAZAKI et al., 2013). Trimble and Johnson (2013) also found that small-scale fishers from Paraty (Brazil) and Piriápolis (Uruguay) considered fishing as a way of life rather than just a job. The freedom of fishing and the inherent occupational satisfaction features prominently in the Brazilian fishers' attachment to fishing.

The SBB fishers also diversify their livelihoods into other fishery-related activities, such as mussel or seaweed farming, mangrove oyster and crab extraction, or just by widening the range of catch species and diversifying the fishing gears used (MACHADO; FAGUNDES; HENRIQUE, 2015; MARTINS; GASALLA, 2018). Other studies of Brazilian, Uruguayan and Cambodian fishing communities also found the same capacity of households to diversify their livelihoods into fishing or non-fishing activities (MARSCHKE; BERKES, 2007; TRIMBLE; JOHNSON, 2013). Flexibility of livelihood strategies plays a vital role in allowing fishers to address changes and challenges. Diverse (and often multiple) livelihood strategies result in greater adaptive capacity, which has a positive impact on reducing vulnerability.

4.4.3 Food security

Small-scale fisheries and aquaculture have been recognized as important opportunities to enhance household food security in developing countries, as the protein intake from fish can form an important contribution to human nutrition (KENT, 1997). The Kawarazuka and Bene (2010) review went further and showed that, in addition to the provision of protein, fish contribute to the nutritional security of poor households in developing countries in many ways. The first benefit of fish consumption is the direct nutritional contribution, as fish are rich in essential nutrients. The households that engaged in small-scale fisheries or aquaculture are, in theory, able to improve their own nutritional intakes by consuming some of the fish they catch. The second benefit is related to income, as increased purchasing power through the sale of fish is recognized as critical for households to be able to access other foods and improve their overall dietary intake. Finally, because the degree of control exercised by women over family income directly impacts household food security and nutritional outcomes, enhancing the economic status of women through their involvement in fishery-related activities (i.e., fish processing and trading) is also identified as another important pathway to improving household nutritional security (KAWARAZUKA; BENE, 2010).

The STC fishers are more dependent on markets and shops in obtaining food security, as the majority of their catch is sold, and very few fishers have access to subsistence gardens or livestock. The low access to fish for consumption as well as the lack of involvement with fish processing and trading limits the food sources of STC fishers (BRANCH et al., 2002; CLARK et al., 2002). The limitation of accessing diverse sources of food and protein, combined with the associated uncertainties related to climate change, expose the fragility of food security in this South African region.

Alternatively, the small-scale fishers of the SBB communities have historically practiced fishing activities, small-scale farming, hunting, and extracting plant resources in the Atlantic Forest (DIEGUES, 2002). However, in recent decades, the SBB coastline has undergone an intense process of urbanization and an intensification of tourism. Together, these factors have led local people to increase their participation in commerce-related activities and have even increased the rate of migration to urban centers (ADAMS, 2000). Reflecting on this scenario, new relationships have been established between the fishers and natural resources, and this involves changes in food acquisition and eating habits (HANAZAKI; BEGOSSI, 2000, 2003; HANAZAKI; ALVES; BEGOSSI, 2009; HANAZAKI et al., 2007, 2013; MACCORD; BEGOSSI, 2006; BEGOSSI et al., 2012; CASTRO et al., 2016). Nevertheless, the practice of subsistence agriculture or vegetable gardening is still central to many of the fishers' households along the SBB coast (GIRALDI; HANAZAKI, 2014), and the addition of possibly catching their own food also helps reduce their dependence on the food market. However, the ongoing transformations in the livelihoods of the SBB fishers have affected local food security, and the current dependence on the market as a food source is growing. This situation is more apparent for remote communities, as the distance and difficulty to accessing the market are some of the main drivers of vulnerability in the SBB fishing communities (Chapter 2).

4.4.4 Participation in the decision-making process

The STC fishers have lower participation in the local and regional decision-making processes; additionally, they hold the perception that their knowledge is not included in local natural resource management plans, which contrasts with the perception of the SBB fishers. The Marine Living Resources Act (MLRA) No 18 of 1998, i.e., the post-apartheid fisheries policy of which all South African fisheries are governed, strives to encompass the ideas of an ecosystem approach to fisheries management and related management approaches; however, it espouses a top-down management paradigm that does not seek to actively involve fishers in the decision-making process. There is also low confidence and access to local leadership, whether it be the local Department of Agriculture, Forestry and Fisheries (DAFF) representatives or the local municipal and political leadership (GAMMAGE, 2015). Finally, the biggest difference observed between the two countries is lower household participation in community organizations in the STC communities. The majority of the STC linefishers feel that they have long been, and continue to be, excluded from discussions surrounding policy, regulations and management strategies, all of which directly and pervasively affect their lives (GAMMAGE, 2015).

Delays in the allocation of fishing rights and repeated court challenges to the allocations that have been made (by those denied access to the resource and by those who felt that too much had been taken away from them) has resulted in the loss of confidence by the fishing industry in the ability of the government to implement the MLRA policy objectives or to bring stability back to the small-scale fishing sector in South Africa (SOWMAN et al., 2014). The small-scale fishers in South Africa have, until recently, been inadequately recognized and protected, and they have not been involved in fisheries management decisions that affect their lives (SOWMAN et al., 2013). The barriers to the greater involvement of fishers in decision-making processes revolve around institutional changes within the fisheries agencies and the lack of capacity to implement co-management; the failure to allocate rights to small-scale fishers; and the promised benefits of co-management failing to outweigh the costs (HAUCK, 2008; SCHELL, 2011). Furthermore, coordinated government support for initiatives that identify and develop supplemental or alternative livelihoods in poor and resource-stressed areas is lacking (MBATHA, 2011).

The MLRA attempts to address the issue of co-management or user participation in management and decision making as a means of improving management success (CADDY, 1999). Co-management is a partnership in which government authorities and users share responsibility for management (HARA, 2003). Its fundamental premise is that if people participate in decisions and gain ownership, they are more likely to comply with controls. In South Africa, the Sokhulu community served as a flagship community for the implementation of co-management in KwaZulu-Natal (HARRIS et al., 2003), where subsistence co-management committees that incorporate both community and management authority representatives have subsequently been formed for 27 communities in that province. Their charge is to determine sustainable catches, implement regulations and ensure monitoring of stocks and catches. The objectives and principles of the MLRA were to restructure the fishing industry to address historical imbalances and to achieve equity within all branches and groups of the fishing industry (KLEINSCHMIDT; SAUER; BRITZ, 2003). Despite the initial success observed in the Sokhulu community, the co-management of small-scale fisheries has failed to spread to other coastal provinces of South Africa (BRANCH; CLARCK, 2006).

In 2012, the new South African small-scale fisheries policy (SSFP), currently under implementation, again attempted to include fishers in the decision-making process and address the equal distribution of fishing rights (DAFF, 2012). Previous fishery management practices unintentionally marginalized traditional fishers in fishing communities around all four coastal provinces of South Africa. At the same time, it was recognized that the institution of fisheries management had to be restructured to become more of a cooperative governance arrangement that is appropriate for a modern democracy (KLEINSCHMIDT; SAUER; BRITZ, 2003). The SSFP is based on the establishment of community cooperatives, which will be managed by the local community associations; additionally, fishing rights will be allocated to the co-operative, of which identified small-scale fishers will be members. The successful implementation of the new policy will depend on strong community cohesion, the establishment of which is not always immediately apparent. Furthermore, joint efforts by government and fisheries organizations will be needed to ensure that the participating communities have the necessary infrastructure and capacity to harvest, process and market marine resources for the local, regional and, where possible, international markets (ISAACS, 2011). Without proper support that enables the co-operatives to work together while managing a business, the policy implementation will not be successful.

Although the SBB communities fared better with respect to participation in fisheries management, it is important to note that this does not necessarily imply that Brazilian fishers are fully involved and included in the decision-making process. There is a lengthy list of studies and local initiatives that strive for the inclusion of fishers in decision-making processes, as well as for equal access to resources in Brazil (e.g., MOURA et al., 2009; SEIXAS et al., 2011; MARTINS; MEDEIROS; HANAZAKI, 2014; GASALLA; CASTRO, 2016).

The positive results found here can be associated with the implementation of a National Systems of Marine Protected Areas (SNUC) policy in Brazil (established by Law 9985/2000). The SNUC policy assures the rights of local and traditional communities living in or nearby coastal zones, with the full consideration of, and the active participation by, the users of marine environmental resources in the management of the areas. Public participation is a legal requirement for studies and consultations prior to the creation of MPA, as well as after the establishment of an MPA through the consulting and decision-making boards, with the goal of ensuring resource user participation in area management. The SNUC policy objectives include promoting greater transparency and participation in the implementation of MPAs, which are achieved through governance mechanisms capable of ensuring effective participation in the creation and management of protected areas, particularly through the participation of local communities.

Even though the participation by local communities in local MPAs has increased, the SNUC policy is still flawed in terms of ensuring the rights of communities in decision-making processes, as well as in ensuring the proper management of the marine resources (SILVA et al., 2015). The major flaws in the SNUC policy implementation include poor inter-institutional coordination of coastal and ocean governance; institutional crises faced by the national government marine conservation agency; poor management within individual MPAs; problems with regional networks of marine protected areas; an overly bureaucratic management and administrative system; financial shortages that create structural problems; and a disconnect between MPA policy and its delivery (GERHARDINGER et al., 2011).

However, one specific type of MPA, as defined in the SNUC policy, addressed the issue of including the fishers in the decision-making processes; this was the MER. The aspects that characterize the superior way in which the MERs encourage participation in decision making is to stimulate better social organization by including representatives from local communities on management councils and to disseminate power to the local people through their ability to approve or reject management norms (MOURA et al., 2009). Two of eight SBB fishing communities surveyed in this study are MER and have resulted in greater involvement by SBB fishers in decision-making processes.

4.4.5 Institutional support

The STC fishing communities report better institutional support and flexibility, and consequently, they have lower vulnerability in this respect; however, this result may seem contradictory to what is reflected in the qualitative data and in other studies. The points that distinguish the STC communities from the SBB communities in terms of institutional support are (1) the small-scale fisheries policy has recently been reformulated to suit a new reality of fishing activities; (2) fisheries monitoring is more present and effective; and (3) fishing activities are better managed and enforced.

The new SSFP in South Africa is trying to address many aspects that drive the vulnerability of the STC fishing communities, such as the reallocation of fishing rights to the fishing communities; the community-based co-management approach of managing resources; providing job creation and livelihood opportunities by including local communities in the supply chain and related activities; and food security improvement and poverty alleviation by maximizing the access to the living marine resources. The South African government has prioritized the establishment of the SSFP since 2014, but implementation is still ongoing. The long implementation process has generated a great deal of uncertainty and mistrust within fishing communities over the policy itself and whether it will achieve its proposed goals. Therefore, it will be necessary to wait for the implementation of the new policy to see the results; however, having a small-scale fishing policy proposal is another major difference between South Africa and Brazil and was reflected in the responses of the STC fishers.

In Brazil, there is a need to improve institutional support, as it was the main negative aspect in the analysis. There is no longer any collection of catch statistics on behalf of the Brazilian management authority. Currently, there is no national standardized collection system in place (FREIRE et al., 2015). The most current information available on Brazilian catch landings are solely based on estimation models for the period between 2008-2011, yet there is no detail provided about catches and species (MPA, 2011). In the state of São Paulo, catches are being monitored despite the interruption at the national level, but the same efforts do not occur in all states. It is crucial for Brazil to resume its data collection system for all Brazilian fisheries. Catch landing data are essential for the proper implementation of fisheries policy and management, and the lack of data compromises the effectiveness or improvement of management.

Poor enforcement is another example of the lack of institutional support, and it constitutes one of the main complaints of fishers in Brazil, which is also one of the main reasons behind the MPAs lack of effectiveness (GERHARDINGER; CASTRO; SEIXAS, 2015). The SSB fishers noted that, in addition to inefficient enforcement, in most cases, enforcement is also unfair and not equally applied to all groups and sectors (SEIXAS et al., 2011). This situation also highlights the government's lack of support towards the fishing sector, as enforcement is a government imperative and one of the causes of conflict and mistrust in the role and ability of the Brazilian fisheries authority in managing the sector.

In terms of policies for small-scale fisheries, there is a lack of specific policy for the small-scale fisheries sector in Brazil. The SNUC policy, which was implemented in the 2000s, provided new perspectives of resource management and witnessed unprecedented growth in the implementation of co-managed reserves, especially in fisheries management, where local people play an increasingly important role in the decision-making process (LOPES; SILVANO; BEGOSSI, 2011). The SNUC policy was positive for the small-scale fishing sector but still struggled with effective application (SEIXAS et al., 2011). A specific policy for the small-scale fisheries sector, as it is being implemented in South Africa, still needs to be developed in Brazil. The recent world guidelines for small-scale fisheries warn of the need to incorporate new policies for small-scale fisheries into the legislation of regional and international instruments that govern small-scale fisheries (FAO, 2015); however, Brazil has not yet started to move in this direction.

4.5. Beyond the indicators

As demonstrated through the assessment of our vulnerability indicators, there are specific fishery and local coastal community aspects that drive the vulnerability of small-scale fishing communities at the local level and are unique to the specific contexts within South Africa and Brazil. Despite their differences, small-scale fishers and their communities also face similar challenges and constraints that are not bound by local contexts, including unequal power relations, lack of access to services and limited participation in decision-making processes, which may lead to unfavorable policies and practices within specific fisheries sectors and beyond (FAO, 2015).

4.5.1 Prominent common challenges

During the work carried out with the STC and SBB fishing communities, we observed that, despite the differences in the quantitative estimates of the vulnerability scores, both groups of fishers raised similar issues during the survey process. The issues were predominately based on the lack of clarity and understanding of the actions taken at the government level. Highlighted issues that were raised included ineffective management, poor or ineffective policy, unclear understanding of how policy will be implemented, and a general mistrust in the government actions. Previous work carried out in Brazil and South Africa also found similar constraints that have proven to be barriers in the management of resources in these regions (SOWMAN et al., 2013; TRIMBLE; ARAUJO; SEIXAS, 2014).

Regardless of organizational differences and the degree of involvement in decision-making, both the STC- and SBB-based fishing communities urgently demand clarity from the government in terms of actions and strategies for the fishing sector. The uncertainties generated by the lack of understanding in management actions create conflicts between different fishing sectors, general detachment from management, and non-compliance of proposed rules. The objectives, processes, procedures and intended outcomes need to be transparent and clearly defined, and should include the meaningful participation of fishers.

South Africa's new SSFP has attempted to respond and correct the problem over access to marine resources and many of the points discussed in this paper; however, the outcome will only be apparent in the upcoming years. In Brazil, the fishing sector has faced an institutional crisis with the recent ceasing of the Ministry of Fisheries, causing this department to be first transferred to the Ministry of Agriculture, Livestock and Food Supply, and then later moved to the Ministry of Industry, Foreign Trade and Services. Despite this institutional crisis and the lack of governmental support, the small-scale fisheries continue to supply local and regional markets, even under the innumerable pressures that the small-scale fishing communities have been suffering, owing to the expansion of the interests of the real-estate and tourism sectors, conservation policies, and environmental degradation (DIEGUES, 2006; GASALLA; CASTRO, 2016). In any case, further actions are required to ensure the maintenance of small-scale fishing activities and livelihoods for future generations.

4.5.2 Moving forward

The findings presented in this paper serve as a basis for providing options for enhancing the community adaptation pathways that are being developed or pursued by the small-scale fisheries in Brazil and South Africa. Furthermore, the findings also provide new insights into the regional vulnerability of both countries, and they serve as learning mechanisms for other communities that are likely to experience similar stressors.

GENERAL CONCLUSION

5. GENERAL CONCLUSION

This thesis presented the first systematic survey of the perception of fishers and the vulnerability of fishing communities in the SBB region with respect to climate change. The area is an important fishing region of Brazil and has several fishing communities that strongly depend on fishing from social, economic and cultural perspectives. Therefore, the heterogeneous sampling of communities based on their natural, social and management characteristics allows the data in this study to be extrapolated to other communities with similar characteristics.

The first chapter attempted to understand the perceptions of fishers on climate and ocean changes. In this regard, it was found that fishers have a good understanding of climate and ocean changes, such as reduced rainfall, increased drought events, calmer sea conditions, increases in air and ocean temperatures, changes in wind patterns and shoreline erosion. Fisher perceptions have also proved to be an important tool in identifying the changes that have had negative and positive effects on the livelihoods of fishing communities. The perceived changes have not only resulted in negative effects on fishing activities, as the increase in sea temperature and calmer seas have had a relatively positive effect on fisheries and fisher livelihoods. The perceived changes were cross-validated with the available scientific data, and those for which there were no correlations in the literature were used to raise new research hypotheses.

Fisher knowledge has also been proven to be a valuable source of scientific questions and new research hypotheses, thus providing new understandings on the phenomena related to climate change. The understanding of how fishers perceive changes in the climate and oceans and how such changes impact their livelihood are keys to building effective adaptation strategies with the least social impact on communities, fishing activities and fisher livelihoods.

To supplement the information obtained on fisher perceptions, the following chapters explored the factors influencing the vulnerability of fishing communities to climate change at local and regional levels. In the second chapter, fishing community vulnerabilities to climate change were explored at the local level, while in the third chapter, the factors influencing community vulnerability at the regional level were explored through a comparison with the STC communities in South Africa.

At both the local and regional levels, there are positive factors that reduced community vulnerability and negative factors that increased vulnerability. Among the factors that increased community vulnerability at the local level (Chapter 2), we found that the distance to markets and urban centers and the lack of institutional support increased community vulnerability. At a regional level (Chapter 3), a high dependence on fishing, a high attachment to place and a lack of specific policies for the small-scale fishery sectors are the factors that were most relevant. On the other hand, these results show the need to encourage strengthening and expanding actions that reduce vulnerability, such as community organization, strong leadership, research partnership, co-management and livelihood alternatives at the community level and participation in the decision-making processes, the ownership of boats and fishing rights at the regional level.

Thus, fishers' knowledge is an important source of information for understanding the vulnerability of fishing communities to climate change at local and regional levels. Understanding the positive and negative factors affecting the vulnerability of fishing communities, as shown in this study, can be used to support the construction of public policies that strengthen the positive aspects of vulnerability and disseminate this information to other communities and regions. On the other hand, this information can also be used to rectify and address the negative aspects of vulnerability.

This thesis presented the importance of fisher knowledge on the processes of understanding climate change, integrating local knowledge with scientific knowledge, and seeking a full understanding of climate phenomena and their impacts. The findings will be important to fishing management and adaptation to climate change. Local knowledge on climate change, as well as the associated adaptations made by local populations, is fundamental to designing comprehensive and inclusive mitigation and adaptation plans both locally and nationally.

In this context, understanding how climate change is understood by fishers and how it affects the vulnerability of communities, as presented here, is vital to the planning of an inclusive adaptation process. Therefore, our findings indicated that the perceptions of fishers and the vulnerability drivers are crucial and complementary sources of information for the development of local/regional adaptation strategies, providing a distinct and relevant perspectives from the marine dependent communities to the decision makers.

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APPENDIX

Appendix 1.1

Ethno-oceanography Approach (Gasalla and Diegues, 2011)

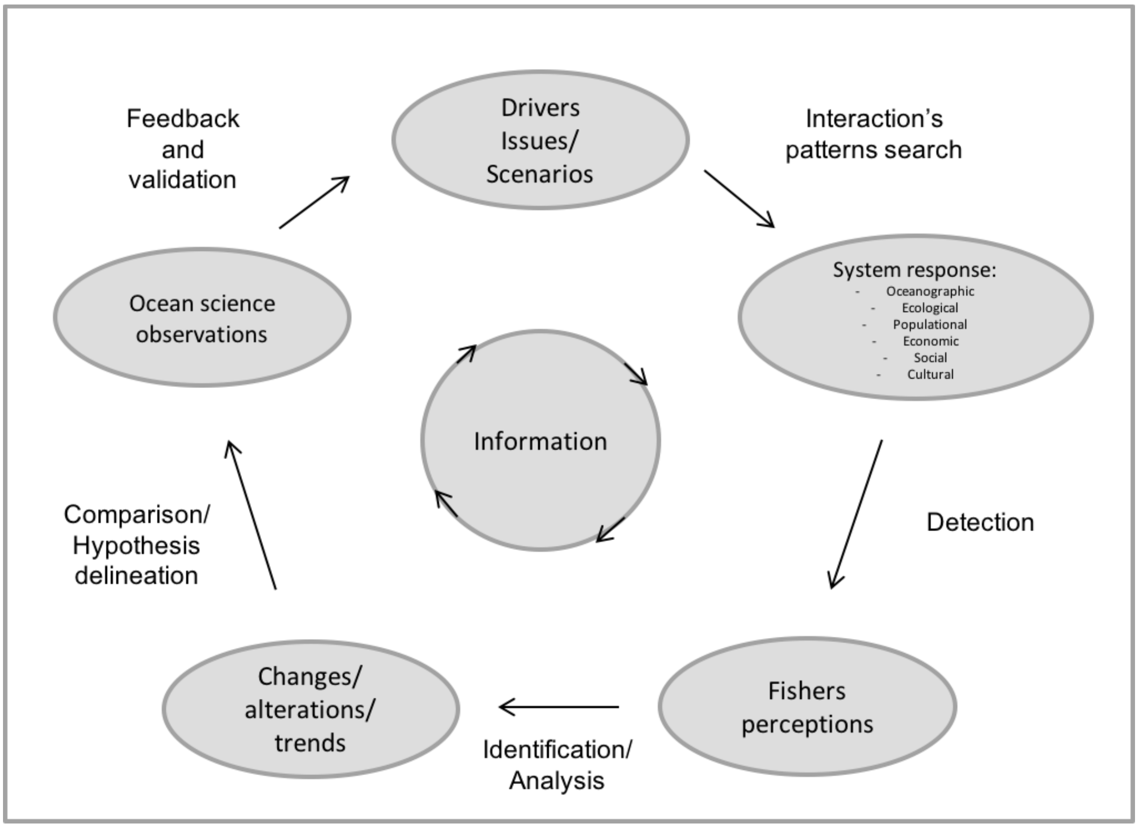

Fig. 2 The conceptual approach of the ethno-oceanography approach proposed by Gasalla and Diegues (2011).

A conceptual approach for ethno-oceanography as a feedback framework within a circular knowledge integration process is illustrated by Fig. 1. It includes linkages between bottom-up (fisher's knowledge-based) and top-down (science-based) knowledge. It summarizes important aspects of the dialogue between disciplines to find a resulted common epistemology. It deviates considerably from the established methods of traditional model building and analysis in oceanography as well as in maritime anthropology.

The process may start with the identification of issues, drivers or scenarios of change – e.g. ocean temperature. It is assumed that these issues can be related to their potential effects, and with a pattern-oriented search of systems response. The next step is the detection of fisher's knowledge or fishers' perception of change, and subsequently, the analysis and identification of trends of alteration or change. Defining new hypothesis can now be compared with ocean science observations with respect to its ability in pursuing a predefined set of hypotheses. The validation step initiates with new scenarios or drivers that can be examined beginning the sequence once again. The process can start at any step and represent the descriptions derived from the analyst, and the trends from data of various types, a distinct feature of the approach being the incorporation of fisher's knowledge and the subjective perception of users into the model building.

Reference:

Gasalla MA, Diegues ACS (2011) People's Seas: "Ethno-oceanography" as an Interdisciplinary Means to Approach Marine Ecosystem Change. In: Ommer R, Perry I, Cochrane KL, Cury P (ed) World Fisheries: A Social-Ecological Analysis. Wiley-Blackwell, pp 120-136.

Appendix 1.2

Fishers perception survey

➔ ***First group of questions***

Q1. Indicate if you have noticed an increase or decrease in any of the following parameters in the past 5 years:

Q.1.1 Sea level	( ) increase	( ) decrease	( ) not change
Q.1.2 Rainfall	( ) increase	( ) decrease	( ) not change
Q.1.3 Wind speed	( ) increase	( ) decrease	( ) not change
Q.1.4 Air temperature	( ) increase	( ) decrease	( ) not change
Q.1.5 Current strength	( ) increase	( ) decrease	( ) not change
Q.1.6 Rough seas	( ) increase	( ) decrease	( ) not change
Q.1.7 Sea surface temperature	( ) increase	( ) decrease	( ) not change
Q.1.8 Ocean temperature (water column below the surface)	( ) increase	( ) decrease	( ) not change

If change (increase or decrease) a guided conversation started in order to understand how that change was perceived and how it had or not impacted their livelihood. Some examples of the questions asked during the guided conversation are:

- How did you perceived that change?
- Could you explain how that change was?
- Has this same change already happened in the past (with the same amplitude/duration)?
- Can you describe how you perceived this change?
- Has that change been good or bad for you and for fishing?
- Did you have any impact/disturbance due to this change?
- How affected were you for this change?

➔ **Second group of questions**

Storms

Q2.1 Has there been a cyclone/large storm in the last 5 years in your area?
( ) yes( ) no

Q2.2 Were you directly impacted by the cyclone/large storm?
( ) yes( ) no

If yes, what was the impact? ____

Q2.3 How bad was the cyclone/large storm damage to your household?

____

Floods

Q3.1 Has there been a flood in the last 5 years in your area?
( ) yes( ) no

Q3.2 Were you directly impacted by the flood?
( ) yes( ) no

If yes, what was the impact? ____

Q3.3 How bad was the flood damage to your household?

____

Drought

Q3.1 Has there been a drought in the last 5 years in your area?
( ) yes( ) no

Q3.2 Were you directly impacted by the drought?
( ) yes( ) no

If yes, what was the impact? ____

Q3.3 How bad was the drought damage to your household?

____

Shoreline change

Q3.1 Have you noticed places in your area where the shoreline has been eroded by the sea?
( ) yes( ) no

Q3.2 Were you directly impacted by the shoreline change?
( ) yes( ) no

If yes, what was the impact? ____

Q3.3 How much of the beach has eroded in the last 5 years?

____

Q3.4 Have you notice any change in your livelihood as a result of shoreline change?

____

If notice a change in your livelihood, what was? ________________________

Appendix 2.1

Table. Rationale used to score the vulnerability indicators.

Category	Component	Sub-component	Indicator	Rationale	Question type	Question No.
Sensitivity	Social dependence on fishing	Frequency of fishing trips	Average number of days spent fishing per week	Higher frequency indicates a higher attachment to fishing and then greater sensitivity to change	Closed	1.2
		Attachment to place	Feeling of belonging to the community (4 point scale)	A greater feeling of belonging to the community indicates a higher attachment of place and therefore a higher social dependence on fishing	Likert scale	14.1
			Importance of friendships in the community	Important friendships indicate integration in the community and reasons to stay	Likert scale	14.4
		Attachment to fishing (occupation)	Degree of pride in telling others one is a fisher (4 point scale)	High levels of pride of being a fisher indicates a high attachment to fishing	Likert scale	16.4
			Level of interest in one's children becoming fishers (4 point scale)	Fishers who wish their children to also become fishers show high levels of attachment to the profession	Likert scale	16.6
			Fishing as main occupation	Fishing and main occupation indicates high level of dependence on fishing	Closed	1.1
		Recreational dependence	Regularity of recreational fishing	The more regular the recreational fishing activity the greater the dependence	Likert scale	15.2
		Social dependence	Level of dependence on other people and institutions	High levels of dependence on others to fish shows high direct social dependence of fishers on the community around them	MCQs	5.1
			Level of interaction on other people and institutions	High levels of interaction with others to fish shows high direct social dependence of fishers on the community around them	MCQs	5.2
	Historical & cultural dependence on fishing	Cultural importance of fishing	Length of time as a fisher	A longer involvement in the fishing sector means that it is likely that fishing is important to the participant. A change fish availability could mean that the impact for these long term participants are likely to be greater	Open	8.1
			Extent of ancestral involvement in fishing	If there is a large family tradition of fishing it is likely that culturally fishing is of great importance. A change in fishing activity (of fish abundance) might thus make these families more sensitive to change	Closed	8.3 & 8.4
			Concern regarding the continuation of fishing as a livelihood among the next generation	If people feel that the next generation might not be able to continue the tradition of fishing this means there is a lack of continuation of the importance of fishing and therefore a decreased dependency in the community in the future	Likert scale	19.2
		Local ecological knowledge	Inclusivity of local ecological knowledge within marine resource management planning	Incorporation of LEK can lead to better outcomes through potentially greater acceptance of management decisions more locally appropriate management. More LEK would suggest lower sensitivity.	Likert scale	19.1

Category	Component	Sub-component	Indicator	Rationale	Question type	Question No.
			Level of knowledge about marine environment	If people have greater knowledge of the marine environment this might mean they will notice change early or are able to make more informed decisions thus reducing sensitivity	Likert scale	20.1
			Importance to ensure LEK is passed on to younger generations	If greater importance is placed on passing knowledge down this means it is likely that the younger generation is better informed – reducing sensitivity	Likert scale	20.2
			Relative maintenance of LEK between generations (	As above - If LEK is maintained this means that it is likely that younger generations are more likely to make more informed decisions thus reducing sensitivity	Likert scale	20.3
		Social mobility	Difference in occupation from parents	Parents with higher education and greater income earning potential from their job would mean reduced sensitivity to the younger generation	Open	9.1
			Level of schooling of parents	Higher level of schooling of parent is more likely to be associated with higher schooling of offspring suggesting lower sensitivity	Open	9.2 & 9.3 (a)Father (b)Mother
			House ownership of parents vs interviewee	If house ownership of interviewee is different to the parents this suggest upward or downward mobility (but could simply be age related). Here it is interpreted as greater house ownership of interviewee reduces sensitivity	Closed	9.4
			Boat ownership of parents vs interviewee	As above – increasing ownership of younger generation means lower sensitivity	Closed	9.5
			Level of financial wellbeing compared to parents	As above – greater wellbeing compared to parents suggest upward mobility thus reducing sensitivity	Closed	9.6
	Economic dependence on fishing	Economic dependence	Contribution (%) of fisheries livelihoods to household income	A higher contribution of fishing to household income will mean that a change in fisheries resource is likely to have a negative effect	Open	1.8 & Income table
			Source of seafood consumed	Greater variety in the sources of seafood spreads the risk of food security being affected in the case of an adverse event	Open	6.2
			Possibility to feed family without fishing	If there are few feeding alternatives (besides fish) this means that families are more sensitive	Likert scale	17.2
			Turnover of business annually ($)	A higher turnover that is derived from fishing will mean that a change in fisheries resource availability is likely to have proportionally greater negative effect	Open	3.3
			Relative importance of fisheries to the HH	If there is a high dependence on fishing to the HH members it means than many people in the community will be affected by any potential negative impacts on the fishing resource	Survey	Livelihoods table
		Competition for fish	Perception of whether too many or too few fishers operate in the community (4 point scale)	If there are too many fishers this means the resource is more likely to be under higher pressure and the chance of environmental impact greater	Likert scale	18.1
			Perception of whether too many or too few fishers operate in the community (4 point scale)	If there are too many fishers this means the resource is more likely to be under higher pressure and the chance of environmental impact greater	Likert scale	18.2
			Degree of concern about illegal fishing levels locally (4 point scale)	If there is little concern about illegal fishing this means it is likely there is adequate monitoring and surveillance reducing the resource and thus any risk to future income from fishing	Likert scale	18.3

Category	Component	Sub-component	Indicator	Rationale	Question type	Question No.
	Economic dependence on other resources	Economic dependence on other resources	Location of store purchased food/goods	Greater distance to market will make households more sensitive (especially if subsistence and reliant on some income from trade at the market)	Open	4.1
			Relative contribution of different methods obtaining food	A greater diversity in the method used to obtain food would suggest a great number of options to fall back on in bad times.	Closed	4.2
			Relative importance of household's food source	If a household has better access to their own home grown food sources they are less exposed to changes in the price of food on the market. Greater self sufficiency leads to lower sensitivity	Closed	7.3
			Level of farming/subsistence activity	Households that operate a subsistence level are likely to be less affluent and have fewer resources to draw on in hard times. Greater subsistence would therefore mean greater sensitivity	Closed	7.5 -7.12 & Livelihoods table
Exposure	Environmental change	Sea level	Increase/ Decrease/ Same	Increase (Decrease) in sea level indicates high(low) exposure level	Closed	64.1
		Rain	Increase/ Decrease/ Same	Erratic rain leads to loss in fishing days indicating high exposure level /Increase in rain indicates high exposure	Closed	64.2
		Wind	Increase/ Decrease/ Same	Fluctuations in wind speed affects fishing operations leads to high exposure level	Closed	64.3
		Air temperature	Increase/ Decrease/ Same	Rising air temperature increases cost of living leading to high exposure level	Closed	64.4
		Current strength	Increase/ Decrease/ Same	Increase in current strength affects fish stock /ground indicates high exposure level	Closed	64.6
		Rough seas	Increase/ Decrease/ Same	Increase in the Intensity of rough sea affects the safety at sea indicates high exposure level	Closed	64.7
		Sea temperature	Increase/ Decrease/ Same(depth of fishing/area of fishing increase)	Increase in sea temperature affects fishing efforts (indicates high exposure level)	Closed	64.8
		Bottom temperature	Increase/ Decrease/ Same	Increase in bottom temperature (indicates high exposure level	Closed	64.9
	Institutional support	Climate change focused institutions	Presence of climate change centred institutions or government departments in the area/community	The presence of institutions or government departments improves the adaptation to change in the community and decrease the exposure	Closed	71.1
			Types of institutions working with community on climate change issues	As much types of institutions working with the community better the adaptation options to climate change issues and decrease the exposure	Closed & Open ended	71.2
	Personal exposure	Safety at sea	Preference for presence of other boats at sea while fishing (4 point scale)	Higher preference for the presence of other boats at sea while fishing indicate the need for getting support from fellow workers in identifying fishing ground and curbing eventualities at minimal level	Likert scale	63.1
		Storms	Occurrence of large storm in past 5 years (moment –adverse; long time – advantageous)	Occurrence of large storm indicates high personal exposure	Closed	66.1

Category	Component	Sub-component	Indicator	Rationale	Question type	Question No.
			Personally, directly impacted by storm	Incidence of personally impacted storms in terms of casualties /Fishing day loss indicates high personal exposure	Closed	66.2
			Degree of damage to household	Increased degree of damage to household due to storms in terms of destruction of assets/ coral reef indicates high personal exposure	Closed	66.3
			Action taken to prevent future large storm damage	Any mitigation and adaptation action taken to prevent future large storm damage indicates low personal exposure	Open	66.4
			Action taken to prevent future large storm damage	Any mitigation and adaptation action taken to prevent future large storm damage indicates low personal exposure	Open	66.5
		Floods	Household in area prone to flooding	Proneness of households to flooding increases destruction of assets leading to high personal exposure	Closed	67.1
			Occurrence of floods in past 5 years	Occurrence of flood increases destruction of assets leading to high personal exposure	Closed	67.2
			Personally, directly impacted by flood	Incidence of personally impacted flood increases casualties and maladies , destruction of assets leading to high personal exposure	Closed	67.3
			Degree of damage to household	Increased degree of damage to household due to flood indicates high personal exposure	Closed	67.4
			Action taken to prevent future flood damage	Any action taken to prevent future flood damage indicates low personal exposure	Open	67.5
			Action taken to prevent future flood damage	Any action taken to prevent future flood damage indicates low personal exposure	Open	67.6
		Drought	Occurrence of drought in past 5 years	Occurrence of drought limits livelihood options and acces to natural resources and indicates high personal exposure	Closed	68.1
			Personally, directly impacted by drought	Incidence of personally impacted drought limits livelihood options, creates food security concerns and indicates high personal exposure	Closed	68.2
			Degree of damage to household	Increased degree of damage to household limits livelihood options and due to drought indicates high personal exposure	Closed	68.3
			Action taken to prevent future drought damage	Any action taken to prevent future drought damage indicates low personal exposure	Open	68.4
			Action taken to prevent future drought damage	Any action taken to prevent future drought damage indicates low personal exposure	Open	68.5
		Shoreline changes	Occurrence of shoreline changes in past 5 years	Occurrence of shoreline changes indicates high personal exposure	Closed	69.1
			Observation of shoreline erosion by the sea locally	Incidence of shoreline erosion leads to infrastructure losses and reduced alternative options	Closed	69.2
			Degree of beach erosion over last 5 years	Incidence of beach erosion leads to infrastructure losses and reduced alternative options	Closed	69.3
			Impact of shoreline erosion on livelihood	Incidence of shoreline erosion leads to limitation in housing fishing assets	Closed	69.4

Category	Component	Sub-component	Indicator	Rationale	Question type	Question No.
	Attitude and perception	Attitude to change	Perceived level of risk to community from environmental change (4 point scale)	High level of risk perceived indicates a better capacity to anticipate and adapt to environmental change	Likert scale	32.1
			Degree of anxiety felt about environmental changes observed locally	High anxiety indicates community concerned about environmental change and will be more likely to take steps to adapt	Likert scale	32.3
		Perceptions of change	Degree of difficulty in finding/catching fish compared to the past	High difficult to catch fish indicates less capacity to adapt due to lower income	Likert scale	33.2
			Number of changes in marine species observed locally	High number of observed change indicates a better capacity to predict and adapt to change	Likert scale	33.3
Adaptive Capacity	Natural capital	Changing resource base	Observed changes in communities' marine resources during lifetime	Changes observed in communities' marine resource base usually indicates a decrease in natural capital	Closed	54.1
			Perception of changes in the local sea habitat	Higher levels of damage to the local sea habitat indicates a larger decrease in natural capital and AC	MCQ's	54.3
			Factors cause fish number declines locally	A higher number of factors of causes for fish declines indicate a decrease in natural capital and chronic, continuing causes of change decrease NC and AC to a greater extent than past, discrete causes of change	Open	54.4
			Perception of overharvesting of marine resources locally	Perceived overharvested marine resources indicates lower natural capital and AC	Closed	54.6
			Relative diversity of marine habitat locally (4 point scale)	Higher scores for the diversity of the marine habitat indicate higher natural capital and AC	Likert scale	62.1
			Perception of change in fish numbers in past 5 years (4 point scale)	The perception of increasing number of fish indicate higher natural capital and AC (and vice versa)	Likert scale	62.2
	Human capital	Local knowledge	Sources of fishing, weather and sea conditions information	The higher the level of knowledge concerning fishing and sea conditions the more likely to adapt and understand future changes	Open ended	37.1
		Knowledge	Possession of basic knowledge in environmental, marine, fishing or business knowledge	As much basic knowledge greater the ability to be successful in the fishing industry	Closed	41.1
		Education	Highest level of formal education attained	Higher the level of formal education better the ability to cope with change	Closed	39.1
		Labour	Degree of difficulty in finding alternative work if known as a fisher	As easier to finding alternative work better the chances to find another occupation in case of an impact reaches the fishing sector	Closed	42.1
		Skills	Possession of skill sets outside of fishing related activities	As much skills outside the fishing related activities less the dependence on fishing and better the capacity to find another occupation in case of an impact reaches the fishing sector	Closed	40.1
		Health	Presence of infirm or unwell person in household in the last year	The presence of infirm person in household reduce it adaptive capacity	Closed	38.1
			Presence of chronically ill person in the household	The presence of chronically ill person in household reduce it adaptive capacity	Closed	38.2
		Age	Direct - dependency -	Vulnerability increases with increase in age OR	Survey	household data

Category	Component	Sub-component	Indicator	Rationale	Question type	Question No.
				Increase in fishing experience (in years) improves the knowledge level eventually leading to decrease in vulnerability		
	Social capital	Decision making	Degree of involvement in community decision making (4 point scale)	As much involvement in the community decision greater interest in finding community and not individual solutions	Likert scale	56.1
			Degree of involvement in MPA management/decision making (4 point scale)	As much involvement in MPA management greater interest in protect the marine resources and activities	Likert scale	56.3
		Gender equity	Number of women in leadership roles in the community and positions	As much women in leadership greater the community equity and the diversity of opinions to deal with problems	Survey	36.1
			Equality of access and control over livelihoods and resources between men and women	Higher levels of equality indicate an equal distribution of power and access between men and women	Likert scale	58.1
		Leadership	Strength of community leadership	As much stronger the leadership greater it representation on the community	Likert scale	57.1
			Accessibility of community leadership	As much the access to the leader greater it representation on the community	Likert scale	57.4
		Social capital, networks and community cohesion	Main source of assistance when have financial, food or basic needs	The source of assistance can increase or decrease adaptive capacity. E.g. Family more helpful to adapt whereas loan sharks negative impact on adaptation due to high interest and debt traps. High values for safe sources of financial assistance, low values for unsafe/debt prone sources of assistance.	Closed	35.1
			Types of community organisations active in the community	The more community organizations that are active the more organised the community and the more likely to be able to organise and adapt to future change.	Survey	Comm data
			Types of community organisations actively participated in	As much community organizations the household participate greater the interest in finding solutions to problems	Survey	42.2
	Bridging social capital	Access to institutional safety nets and information	Number of governmental safety nets for fishers	As much governmental safety net the community has better will be the response in case disaster strikes the fishing activities	Likert scale	31.1
			Strength of links between fishers and institutions or government	A stronger link indicate a better access to up to date information on fishing related matters	Likert scale	31.2
	Physical capital	Built house	Tenant or owner of house	Owning a house indicates higher physical capital and AC	Closed	48.1
			Number of rooms in house	More rooms indicate higher physical capital and AC	Open	48.3
			Need for maintenance or renovations	The need for maintenance lowers physical capital and AC	Closed	48.5
			Main construction material of house	Permanent and long-lasting construction materials indicate higher physical capital compared to temporary, low quality and short-lasting building materials	MCQ's	48.6
			Relative condition of roof	The better the condition of the roof the higher the physical capital and AC	Closed	77.1
			Relative condition of building	The better the condition of the building the higher the physical capital and AC	Closed	77.2
		Boat assets	Possession of a boat	Owning a boat indicates higher physical capital and AC	Closed	49.1

Category	Component	Sub-component	Indicator	Rationale	Question type	Question No.
			Type, number and size of boat owned	More and larger boat assets indicate higher physical capital and AC. Boat type influences the physical capital of these assets and hence AC. Some types increase AC to a greater or lesser extent (depending on construction material and price and longevity)	MCQ's, open, open	49.1 & 49.2 & 49.3
		Condition of assets	Amount of possessions/assets in good condition	The greater the number of possessions in good condition indicates higher physical capital and AC	Closed	61.2
		Material assets	Number of assets owned from list of 16 items	The higher total number of different assets owned in the list indicates higher physical capital and AC. Certain items provide greater levels of AC than others	MCQ's	74.1 – 74.16
		Water	Possession of fresh water tank	Possession of a freshwater tank(s) indicates a source of freshwater and increases physical capital and AC	closed	50.1
			Main source of drinking water	A more reliable (and sometimes technologically advanced) source of drinking water indicates a higher physical capital and AC	MCQ's	50.2
		Energy	Main source of energy	A more reliable (and sometimes technologically advanced) source of energy indicates higher physical capital and AC	MCQ's	51.1
			Main source of water heating	A more reliable (and sometimes technologically advanced) source of water heating indicates higher physical capital and AC	MCQ's	51.2
			Main source of cooking fuel	A more reliable (and sometimes technologically advanced) fuel for cooking indicates higher physical capital and AC	MCQ's	52.1
		Waste	Route of waste water	The more reliable (and sometimes technologically advanced) the route of waste water the higher physical capital and AC	MCQ's	53.3
			Disposal of rubbish	The more reliable and hygienic the form of rubbish disposal the higher the physical capital and AC	MCQ's	53.4
		Community infrastructure	Number of infrastructure items present in the community from set list of 28 items	The higher the number of infrastructure items present in a community indicates higher physical capital and AC	MCQ's	Infrastructure appendix
	Financial capital	Credit	Main source of credit	The main source of credit depended upon can increase financial capital and AC, while others decrease financial capital and AC	MCQ's	46.1
		Insurance	Types of insurance policies held	Existence of insurance policies indicate ability to withstand potential losses = higher AC. Further, larger insurance policies indicate higher financial capital	MCQ's	47.1
		Savings	Presence of savings for emergencies	Presence of savings allows fallback money in times of emergencies and so increases financial capital and AC	Closed	44.1
		Household income	Monthly income	Higher amounts of income to a household indicates higher financial capital and potential for AC	Open	2.1
		Socioeconomic Index	Socioeconomic Index	FEA index	Mix open & close	2.2
		Household sharing income	Contribution of each household members income to household expenses	More household members contributing to expenses may indicate multiple income generators for the household and higher financial capital and AC	Closed	43.1

Category	Component	Sub-component	Indicator	Rationale	Question type	Question No.
		Income shocks	Ability to endure some income shocks (4 point scale)	Ability to endure income shocks indicates higher financial capital and AC	Likert scale	60.1
		Livelihood & income diversity, occupational multiplicity	Number of different livelihood activities per household	More livelihood activities may indicate higher livelihood diversity and so higher financial capital and AC	Open	Livelihoods appendix
	Personal flexibility	Perception of risk in approaching change	Level of habituation to changes in everyday life (4 point scale)	Those habituated to every-day changes are more likely to be adaptable in the future	Likert scale	21.1
		Ability to plan, learn and reorganise	Level of financial planning (4 point scale)	High levels of financial planning indicate good ability to plan and organise for the future	Likert scale	22.1
			Level of interest to learn new skills outside of fishing (4 point scale)	Interest in learning new skills indicates potential to develop alternative skills for future livelihoods	Likert scale	22.2
		Level of interest in adapting to change	Level of interest in changing employment	High interest in changing employment indicates dissatisfaction in current employment and/or interest in alternative livelihoods if marine based occupation becomes untenable in the future	Closed	10.1
		Employability	Perception of finding work in alternative sector	Higher perception in ability to find work in other sector indicates higher adaptability if fishing becomes untenable and greater options available for work	Closed	10.2
			Number of options for alternative work	Greater the number of options for alternative work indicate a higher adaptability to future changes	Closed	10.3
			Number of courses taken to improve employability	Greater the number of courses taken to improve employability indicates a higher chance of finding alternative livelihoods in the face of future change = greater adaptability	Closed	10.4
			Level of interest in working for someone else	Higher the level of interest in working for someone else indicates a greater adaptability in finding alternative work where it is not possible to work for oneself.	Closed	10.6
			Perception of utility of own skills to set up a business outside of fishing (4 point scale)	Higher perception indicates positive mindset in setting up a business outside of fishing and hence a greater adaptability if fishing becomes untenable	Likert scale	26.1
	Attitude and perception	Attitude and perception to Climate change	Hear about climate change	Heard about climate change will increase the possibility to adaptation	Closed	72.1
			Think that the climate has changed	Think that the climate is changing will help them to accept the adaptation process	Closed	72.2
		Interest in the environment	Number of ideas held to ensure sustainability of the target fish species locally	High the number of ideas greater the possibility to keep the activity for long time	Likert scale	34.3
		Perception of the ability to cope with change	Level of confidence that events will work out well regardless of everything else (4 point scale)	High confidence indicates a positive-minded, optimistic mindset about the future even if things change	Likert scale	23.1
	Occupational flexibility	Occupational mobility	Relative importance of fishing as economic activity locally (4 point scale)	High relative importance of fishing indicates the importance to safeguard the fishing industry in the face of future change and/or find alternative livelihoods for large section of the population	Likert scale	27.3
			Level of interest in working in non-fishing sector	High level of interest indicates greater interest in alternative livelihoods and greater potential adaptability	Closed	11.4

Category	Component	Sub-component	Indicator	Rationale	Question type	Question No.
			Types of livelihoods found by fishers leaving the fishery	Indication of the options available locally to those who have exited the fishery recently	Open-ended	11.8
			Level of occupational diversity throughout the year	Higher the level of occupational diversity indicates the greater adaptability of the individual as find work in multiple sectors each year	Closed	28.1
			Willingness to relocate for livelihood purposes (4 point scale)	High willingness to relocate indicates higher adaptability to make large changes in order to find income/livelihood if current work becomes untenable	Likert scale	28.2
		Business approach	Possibility to predict money made each month by your business (4 point scale)	High predictability indicates the business is centred around predictable flows of money and product or of a sound long-term business plan within a healthy system	Likert scale	29.4
			Level of detail of business plan for following year (4 point scale)	High levels of detail indicates a careful, thorough planner for the future with their business, which indicates potential greater adaptability in the future	Likert scale	29.5
	Institutional support	Resource management institutions	Presence of natural resource management institutions in community	The presence of natural resource management improves the possibilities to long term keep the ocean related livelihoods	Closed	13.1
			Type of management system	As much the community is part of the management process better the capacity to the local issue be attended by the marine resource management	Closed	13.2
			Level to which rules have changed due to environmental changes	The changes in the rules/practices due to climate change shows the institution work to keep the livelihoods and protect the natural resources	Closed & Open ended	13.3
			Degree of recording/reporting of catches required	High degree of recording/reporting means a better data to the institutions manage natural resources	Closed & Open ended	13.5
	Institutional flexibility	Fishing compliance and conflict	Relative occurrence of illegal fishing locally (4 point scale)	High levels of illegal fishing indicates a lack of compliance with official regulations and an individualistic, profit making mindset of local fishers	Likert scale	30.1
			Number of people who know those who break the rules (4 point scale)	High numbers of people who know who break the rules indicates how overt or covert illegal behaviour is and perhaps an indication of stigma attached to it and how good enforcement of rules is	Likert scale	30.4
			Level of enforcement of fishing rules (4 point scale)	Indication of the level of enforcement of fishing rules locally	Likert scale	30.5
		Markets	Number of markets to buy fish in the community	High number of markets indicates the degree of choice fishers have to sell their catch and therefore more markets often provides better prices and options when both large and small catches are landed	Closed	12.1
			Number and type of avenue to sell fish	Higher the number of avenues to sell fish provides greater adaptability to fishers as depending on catch, price and conditions they can still obtain fair prices for their fish	Closed	12.2
			Nature of relations between members of the market chain	Good relations between members of the market chain indicate a healthy chain and hence better prices, trust between actors and therefore potential to adapt well together in the future to changes	Closed	12.3 & 12.4

Category	Component	Sub-component	Indicator	Rationale	Question type	Question No.
			Number of markets to sell fish in the community	Higher the number of markets to sell fish provides more options to fishers and may contribute to better price competition	Closed	12.5
			Possibility of selling fish outside the community	High possibility to sell fish outside the community provides greater adaptability to fishers when local markets are not available or are oversupplied with fish	Closed	12.6
			Distance to markets outside the community	Short distances to markets provide fishers with more options and higher prices for their catch, which reduces their vulnerability to changes in their community	Closed	12.7
			Stability and factors controlling the local fish price	High stability of the local fish price can be good and bad – difficult to say if a stable price is always a positive factor	Closed	12.9
			Stability and factors controlling the local fish price	High stability of the local fish price can be good and bad – difficult to say if a stable price is always a positive factor	Closed	12.10
			Number of markets to sell meat and vegetables	Higher number of markets to sell meat and vegetables reduces vulnerability of those households who also grow vegetables or farm animals to provide cash income when fishing is not possible	Open	12.11
	Social dependence on fishing	Attachment to fishing (occupation)	Response to hypothetical change in primary livelihood (fishing) - what will you do if it becomes too difficult to find fish?	Those who answer they would continue to fish demonstrate high levels of attachment to the profession	Open-ended	70.2/70.3
			Response to hypothetical dropping in market price - what will you do in the event of market prices dropping by 50% and remaining there?	Those who have option to keep the earnings has better adaptive capacity	Open-ended	70.4

Appendix 3.1

Table 1. Comparison of vulnerability scores and their components between South Brazil Bight and Southern Cape fishing communities.

Component	Distribution	Statistical test	Difference	Higher
Sensitivity	**Not normal**	**Wilcoxon**	**NO**	**-**
Social dependence on fishing	Not normal	Wilcoxon	NO	-
Fishing frequency	Not normal	Wilcoxon	YES	BR
Attachment to place	Not normal	Wilcoxon	YES	BR
Attachment to fishing	Not normal	Wilcoxon	NO	-
Recreational dependence	Not normal	Wilcoxon	NO	-
Social dependence	Not normal	Wilcoxon	YES	SA
Historical & cultural dependence on fishing	Normal	t-test	YES	SA
Cultural importance of fishing	Not normal	Wilcoxon	YES	BR
Local ecological knowledge	Not normal	Wilcoxon	NO	-
Social mobility	Not normal	Wilcoxon	YES	SA
Economic dependence on fishing	Not normal	Wilcoxon	NO	-
Economic dependence	Not normal	Wilcoxon	NO	-
Competition for fish	Not normal	Wilcoxon	YES	BR
Economic dependence on other resources	Not normal	Wilcoxon	NO	-
Food source	Not normal	Wilcoxon	YES	SA
Subsistence agriculture	Not normal	Wilcoxon	NO	-
Adaptive capacity	**Normal**	**t-test**	**YES**	**BR**
Natural capital	Not normal	Wilcoxon	YES	BR
Changing resource base	Not normal	Wilcoxon	YES	BR
Human capital	Not normal	Wilcoxon	YES	BR
Knowledge	Not normal	Wilcoxon	YES	BR
Education	Not normal	Wilcoxon	YES	SA
Labor	Not normal	Wilcoxon	YES	BR
Skills	Not normal	Wilcoxon	NO	-
Health	Not normal	Wilcoxon	NO	-
Age	Not normal	Wilcoxon	NO	-
Social capital	Not normal	Wilcoxon	YES	BR
Decision making	Not normal	Wilcoxon	YES	BR
Gender equity	Not normal	Wilcoxon	NO	-
Leadership	Not normal	Wilcoxon	YES	BR
Community cohesion	Not normal	Wilcoxon	YES	BR
Bridging social capital	Not normal	Wilcoxon	NO	-
Access to institutional safety nets and information	Not normal	Wilcoxon	NO	-
Physical capital	Normal	t-test	YES	BR
Built house	Not normal	Wilcoxon	NO	-
Boat assets	Not normal	Wilcoxon	YES	BR
Condition of assets	Not normal	Wilcoxon	NO	-

Component	Distribution	Statistical test	Difference	Higher
Water	Not normal	Wilcoxon	NO	-
Energy	Not normal	Wilcoxon	YES	BR
Waste	Not normal	Wilcoxon	YES	SA
Material assets	Not normal	Wilcoxon	YES	BR
Infrastructure index	Not normal	Wilcoxon	YES	BR
Financial capital	Not normal	Wilcoxon	NO	-
Insurance	Not normal	Wilcoxon	NO	-
Savings	Not normal	Wilcoxon	NO	-
Household income	Not normal	Wilcoxon	NO	-
Socioeconomic Index	Not normal	Wilcoxon	NO	-
Household sharing income	Not normal	Wilcoxon	NO	-
Income shocks	Not normal	Wilcoxon	NO	-
Personal flexibility	Not normal	Wilcoxon	NO	-
Perception of risk	Not normal	Wilcoxon	NO	-
Ability to plan, learn and reorganize	Not normal	Wilcoxon	NO	-
Employability	Not normal	Wilcoxon	NO	-
Attitude and perception	Not normal	Wilcoxon	YES	BR
Attitude and perception to climate change	Not normal	Wilcoxon	NO	-
Interest in the environment	Not normal	Wilcoxon	YES	BR
Perception of the ability to cope with change	Not normal	Wilcoxon	NO	-
Occupational flexibility	Not normal	Wilcoxon	YES	SA
Occupationall mobility	Not normal	Wilcoxon	YES	SA
Institutional support	Not normal	Wilcoxon	YES	SA
Resource management institutions	Not normal	Wilcoxon	YES	SA
Institutional flexibility	Not normal	Wilcoxon	YES	SA
Fishing compliance and conflict	Not normal	Wilcoxon	YES	SA
Exposure	**Normal**	**t-test**	**YES**	**SA**
Environmental change	Not normal	Wilcoxon	YES	SA
Environmental change	Not normal	Wilcoxon	YES	SA
Institutional support	Not normal	Wilcoxon	NO	equal
Climate change focused institutions	Not normal	Wilcoxon	NO	equal
Personal exposure	Not normal	Wilcoxon	NO	equal
Safety at sea	Not normal	Wilcoxon	YES	SA
Storms	Not normal	Wilcoxon	YES	equal
Floods	Not normal	Wilcoxon	YES	SA
Drought	Not normal	Wilcoxon	NO	equal
Shoreline changes	Not normal	Wilcoxon	NO	equal
Attitude and perception	Not normal	Wilcoxon	NO	equal
Attitude to change	Not normal	Wilcoxon	NO	equal
Perceptions of change	Not normal	Wilcoxon	YES	SA
Vulnerability	**Normal**	**t-test**	**YES**	**SA**