Climate change and small-scale fishing in South Africa: A community scale social vulnerability assessment for the southern Cape handline fishery

Dissertation submitted in partial fulfilment for the degree of

Master of Science in Applied Ocean Sciences

in the Department of Biological Sciences & Marine and Antarctic Centre for Innovation & Sustainability (MARIS)

University of Cape Town (UCT)

2022

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This work was supported by the South African Department of Science and Innovation and the National Research Foundation through the South African Research Chair in Marine Ecology and Fisheries [Grant number 65238].

Acknowledgements

It is with my greatest thanks to my supervisors. Many thanks to Natasha Karenyi, for her support and knowledge regarding the multivariate statistics of this project. I could not have undertaken this journey without Astrid Jarre and Louise Gammage. Thanks to Astrid for welcoming me into her lab, providing me with a cosy space, supplying me with resources for this project, and for her invaluable time and expertise. A special thanks to Louise for her extensive time, availability, patience, and her encouragement and for teaching me about the writing process. I am extremely grateful to both Louise and Astrid for their constant understanding and care for my well-being throughout this project. I would not have been able to complete this project without this trio!

I would like to express my deepest appreciation to my large and loving family. I thank each of my six siblings (as well as their spouses and all my nieces and nephews). I especially thank Paige for her sisterly love and support and Cash for his sweet notes. I thank my Dad for instilling my passion for the ocean and for always making me smile. I am also grateful to (my) Alan for his support and encouragement, and for stepping in as a parental figure when it certainly was needed. Lastly, my mom, words cannot express my gratitude for her unconditional love, advice, and inspiration. I admire her for pursuing her Master's, especially while raising such a wild bunch. She is my hero. With my whole heart, I also thank Andre Roux. He has been by my side through this degree (from programme application to dissertation submission). He has supplied me with bottomless coffee and inexhaustible patience. Thank you for driving me to the university, keeping me company through the online courses, and supporting my decisions and passions every step of the way. Also, thank you for keeping me sane, motivating me to work when I did not 'feel like it', and making me take breaks and have fun when it was absolutely needed. You are one of a kind!

Most important of all, this endeavour would not have been possible without the fishers who were interviewed for this study. I thank them for changing my perspective. I have come to believe that we cannot protect or preserve many species without first protecting and taking care of our own. It is with my greatest hopes that this project will contribute to the betterment of those who were interviewed for this study and all those like them.

Abstract

Climate change is majorly affecting the quality and quantity of marine organisms, as well as people's livelihoods. Coastal communities, small-scale fishers, and fishing-reliant individuals are especially vulnerable to climate change impacts (and other stressors) that alter the state and availability of ocean resources. Therefore, implementing integrated management approaches (such as the Ecosystem Approach to Fisheries (EAF)) is crucial to address these vulnerabilities.

This study concerns the vulnerability to the impacts of climate change of fishers who act as crew members in the southern Cape commercial handline fishery. The southern Cape is a rural, peri-urban, and urban region characterised by agriculture, fishing, tourism, and retirement services as major economic activities. Aside from their documented social, governance, and economic stressors, small-scale fishers in the southern Cape also face biophysical stress (i.e., changes in wind, rainfall, and sea state).

The Global learning for understanding local solutions (GULLS) survey instrument and a social vulnerability framework were created to assess vulnerability and its comprising concepts (sensitivity, exposure, and adaptive capacity) for coastal communities experiencing notable climate change. This study presents the first quantitative analysis of the data collected in the southern Cape in 2014-15. Univariate and multivariate analyses were performed to answer four key questions to investigate whether social vulnerability (as well as sensitivity, exposure, and adaptive capacity) differed among the communities, how variable vulnerability is within the communities, what drives the differences among the communities and to gain insight on the implications for issues of scales.

The fishing communities differed significantly in their overall social vulnerability scores. Sensitivity and exposure were similar between the fishing communities. Sensitivity was the main driver of vulnerability for all fishers due to their attachment to fishing as an occupation, low self-sufficiency, and attachment to their communities. There was no significant difference in the dispersion (homogeneity) of the fishers' responses within the communities. The results also corroborate previous qualitative research, showing that

variations between the communities are driven by adaptive capacity. The “component” scale (the second scale of the four-scale GULLS framework) yielded the most beneficial results and is recommended for future analyses.

In addition, recommendations are made for future surveys to address uneven weighting, fundamental system changes (such as COVID-19), and questions irrelevant to the southern Cape small-scale fishers. Overall, with these recommendations, an improved survey offers a quicker methodology that can easily be communicated with various decision-makers and paves the way for consistent temporal comparisons that stimulate a long-term understanding of vulnerability. Most importantly, these recommendations and methods can contribute to the Ecosystem Approach to Fisheries (EAF) implementation in the southern Cape and the sustainability of this marine social-ecological system.

Keywords: Social Vulnerability, Climate Change, Small-Scale Fishery, Coastal Communities, Social-ecological system, Ecosystem Approach to Fisheries (EAF) Management

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Glossary of Terms and Acronyms

Terms

Adaptation: The process of proactive and anticipatory adjustments to either actual or expected impacts of climate change. In human systems, adaptation seeks to mitigate or avoid harm and to take advantage of opportunities. In natural systems, adaptation may take place by human interference to facilitate adjustment to the expected impacts of climate change {WGII, III} (IPCC, 2014).

Adaptive Capacity: In the context of climate change, adaptive capacity is the ability of systems, institutions, humans, and other organisms to adjust to potential damage, exploit beneficial opportunities, or modify behaviours to better anticipate and respond to changes in external conditions (such as climate variability, climate extremes, or social changes). {WGII, III} (IPCC, 2014).

Climate Change: Climate change refers to any change in the state of climate over time that can be identified by changes in mean and or variability of its properties and that persists for an extended period (typically decades or longer). Climate change can be due to either internal or external forces. The *United Framework Convention on Climate Change* (UNFCCC) distinguishes that climate change is attributed to anthropogenic activities that alter the atmospheric composition. In contrast, climate variability is attributed to natural causes (IPCC, 2014).

Communities: For this study, the communities represent the fishers within each area. As the SCIFR project refers to communities of practice that are neither homogenous nor geographically bound, this study refers to communities of fishers at the town level.

Ecosystem Approach to Management / Fisheries (EAM/EAF): "An ecosystem approach to fisheries strives to balance diverse societal objectives by taking into account the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries." (FAO, 2003).

Exposure: In the context of climate change, “the presence of people, livelihoods, species, or ecosystems; environmental functions, services, resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected” {WGII}

(IPCC, 2014) or the nature and degree to which a system is significantly exposed to climate change (Adger, 2006).

Full spectrum sustainability: is a transdisciplinary challenge that requires management to encompass a multiplicity of comprehensive methods and capacities to consider the multiple diverse objectives within marine SES (Foley et al., 2020; Stephenson et al., 2021).

Indicators: "Indicators constitute one approach to making theoretical concepts operational. An indicator is a function from observable variables (called indicating variables) to theoretical variables" (Hinkel, 2011).

Risk: "is the potential for adverse consequences for Social-ecological systems. In the context of climate change, risk can arise from climate change impacts and human responses to climate change" (IPCC, 2021).

Reaction: "signifies an unplanned response to an event or change" (Bennett et al., 2014).

Resilience: Resilience is often seen as the opposite of Vulnerability. It is a system's capacity to persist in the face of change and to continue to develop in ever-changing and dynamic environments. Resilience thinking is about how periods of gradual changes interact with abrupt changes and the capacity of social, economic, and environmental systems to learn, adapt or even transform into new development pathways {WGII, III} (IPCC, 2014).

Sensitivity: In the context of climate change and this study, Sensitivity is the extent to which a system is directly or indirectly affected by climate-related stimuli. Additionally, sensitivity is how a system will be affected, whether it be adversely or beneficially (IPCC fourth assessment report).

Small-scale Fisher: "persons that fish to meet food and basic livelihood needs or are directly involved in harvesting/processing or marketing of fish, traditionally operate on or near-shore fishing grounds, predominately employ traditional low technology or passive fishing gear, usually undertake single fishing trips; are engaged in sale or barter or are involved in commercial activity" (DAFF, 2012).

Social-Ecological Systems (SES): Integrated and complex systems that constitute social (human) and ecological (biophysical) subsystems, with dynamic components that interact in a two-way feedback relationship" (Berkes, 2011).

Sustainability: In the context of climate change, sustainability is a dynamic process that guarantees the persistence of linked natural and human systems in an equitable manner {WGII, III} (IPCC, 2014).

Vulnerability: Vulnerability is the degree to which a system, subsystem, or system component is susceptible to and unable to cope with harm or adverse effects of climate change (including climate variability and extremes). Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (Turner et al., 2003; IPCC, 2014).
Since the creation of the framework used in this study, the IPCC has updated their definition of Vulnerability, which now includes various concepts such as Risk.
Social Vulnerability: "The exposure of individuals or groups of individuals to stress (resulting from unexpected changes and disruption to livelihoods) as a result of environmental or social changes" (Adger, 1999).

Acronyms

ANOSIM: Analysis of Similarity

BCLME: Benguela Current Large Marine Ecosystem

CAP: Canonical Analysis of Principal Coordinates

DFFE: Department of Forestry, Fisheries, and the Environment

EAF: Ecosystem Approach to Fisheries Management

FAO: Food and Agricultural Organisation of the United Nations

FRAP: Fishing Rights Allocation Process

GULLS: Global learning and understanding for local solutions: Reducing vulnerability of marine-dependent coastal communities

IUCN: International Union for Conservation of Nature

MLRA: Marine Living Resources Act (No 18 of 1998)

PCA: Principal Component Analysis

PERMANOVA: Permutational multivariate analysis of variance

PERMDISP: Permutational multivariate analysis of dispersions

SARChI ME&F: South African Research Chair in Marine Ecology and Fisheries

SCIFR: Southern Cape Interdisciplinary Fisheries Research

SSFP: Small Scale Fishing Policy (No 274 of 2012)

SST: Sea surface temperature

TAB: Total Allowable Bycatch

TAC: Total Allowable Catch

TAE Total Applied Effort

UCT: University of Cape Town

UNFCCC: United Nations Framework Convention on Climate Change

CHAPTER 1: Introduction

1.1 Background

One cannot overestimate the importance of the ocean and its resources to humanity (Costanza, 1999; Martínez et al., 2007; Costanza et al., 2017). Human well-being is interconnected with the sea and jeopardised by unfavourable changes in marine resources and services (Kasperson and Kasperson, 2001; Perry et al., 2005; Brander, 2007; Doney et al., 2012; Cheung et al., 2013; Hollowed et al., 2013; Manes et al., 2021). Due to this interconnectedness between humans and the environment (here, in ocean contexts), we can no longer view these systems as mutually exclusive (Ommer et al., 2011). Instead, it then becomes helpful to view systems as complex adaptive social-ecological systems (SES) (Folke, 2006), which interact at global and local scales alike (Perry & Ommer, 2003; Ostrom, 2009; Ommer et al., 2012; Bennett et al., 2016; Link et al., 2017). Due to their complexity, fisheries and their associated coastal communities must be managed as part of integrated SES to achieve full-spectrum sustainability[1] amid global change (Ostrom, 2009; Pollnac et al., 2010; Berkes, 2011; Jarre et al., 2018; Leach et al., 2018; Foley et al., 2020; Stephenson et al., 2021).

Worldwide, marine SES face a suite of natural and anthropogenic stressors, including overexploitation, habitat degradation, and pollution, to mention but a few (Jackson et al., 2001; Halpern et al., 2007; Allison & Bassett, 2015; Jarre et al., 2018). The impacts of climate change and variability exert additional pressure and intensify uncertainty, further rendering marine SES some of the most vulnerable[2] systems (Harley et al., 2006; Badjeck et al., 2010), to the degree that no one can escape its effects (Solomon et al., 2009; Hoegh-Guldberg & Bruno, 2010; Gissi et al., 2021). However, humanity (at individual, communal, institutional, and global scales) will be unevenly affected by climate change (O'Brien et al., 2007; Thomas

[1] **Sustainability** is 'a dynamic process that guarantees the persistence of natural and human systems in an equitable manner' (IPCC, 2021). **Full-spectrum sustainability** is receiving increasing international attention and it is becoming apparent that sustainability is a transdisciplinary challenge that requires management to encompass a multiplicity of comprehensive methods and capacities to consider multiple diverse objectives in marine SES (Foley et al., 2020; Stephenson et al., 2021)

[2] **Vulnerability** is 'the degree to which a system, subsystem, or system component is susceptible to and unable to cope with, harm or adverse effects of climate change (including climate variability and extremes) (IPCC, 2014). Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

et al., 2019). Owing to both geographic and social inequalities, some will endure a more significant loss of the quality and quantity of their target resources and, thus, will take more significant impacts on livelihood activities than others (Allison et al., 2009; Badjeck et al., 2010; Yanda et al., 2019).

For instance, developing countries, coastal communities, and small-scale fishers (SSFs) rely heavily on the sea and are most at risk[3] of changing marine environments and natural resources. This is partly because of their proximity to the ocean and heavy dependence on fisheries for food security, financial collateral, cultural practices, and livelihoods (Bennett et al., 2014; Béné et al., 2016; Yanda et al., 2019). Moreover, SSFs are often further disadvantaged by geographic and political marginalisation, competition between each other and larger sectors, and poor management regimes (Jackson et al., 2001; Béné, 2009; Mendenhall et al., 2020). Fisheries historically have been managed from the 'top-down' where large-scale operators were favoured, SSFs were not accounted for, and resources became depleted due to, amongst others, permit overcapacity, single-stock management, and inadequate regulation (Berkes, 2001; Jentoft, 2014; Nayak et al., 2014; Jentoft et al., 2017; FAO, 2020).

In the last two decades, there has been international recognition of climate change uncertainty, disenfranchised SSFs, and the demand to change fisheries management practices (UNCED, 1992; FAO, 1995; Reykjavik declaration, 2001; UNCED WSSD, 2002). Hence the emergence of integrated ocean management concepts such as the Ecosystem Approach to Fisheries (EAF) management which strives to achieve sustainable development and to 'balance diverse societal objectives by considering the knowledge and uncertainties about biotic, abiotic, and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries' (Garcia et al., 2003) (**Figure 1.1**).

[3] **Risk** is the potential for adverse consequences for Social-ecological systems. In the context of climate change, risk can arise from climate change impacts and from human responses to climate change (IPCC, 2021).

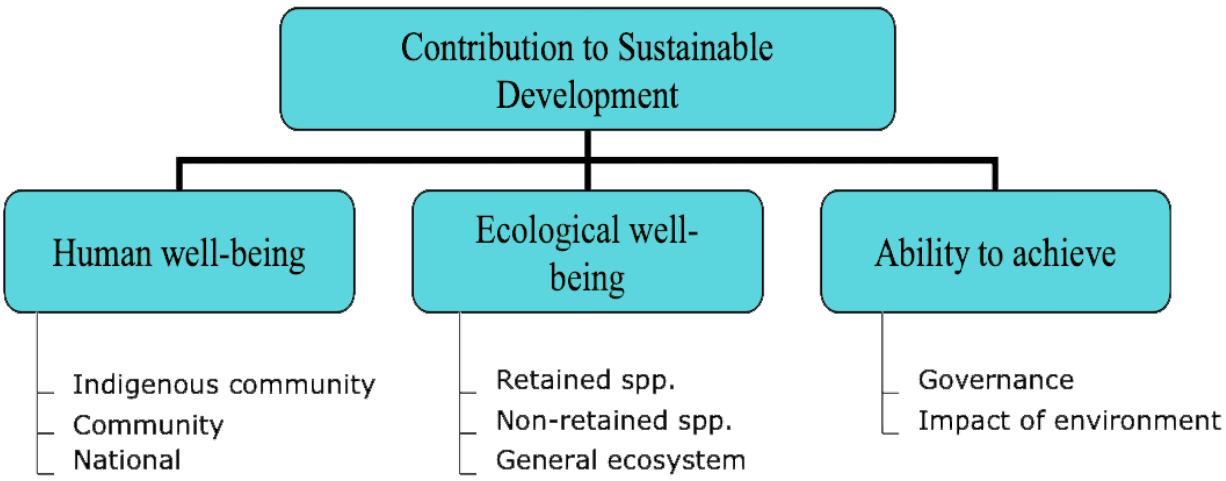

Figure 1.1 Hierarchal tree of the approach to implementing an EAF, where the three dimensions of sustainable development are listed along with important components and considerations to make each pillar operational (FAO, 2003).

One of the keys to making EAF operational is research into the human-social system, seeking to understand how ecosystems function, assess the effectiveness of management processes and uncover the interdependencies and interactions between the biophysical and human components of the ecosystem. Some methods for this type of research include ecological risk assessments (ERA), scenario planning, structured decision-making tools, ethnography, stakeholder identification and surveys, vulnerability assessments, and indicator and reference point development (Garcia et al., 2003; Reed, 2008; Peterson et al., 2010; Lee, 2014; Gammage & Jarre, 2021). These EAF-related tools are advantageous because they can point out the drivers of vulnerability, identify those who suffer greater consequences of change, facilitate better communication between academia and policymakers, and precipitate adaptation strategies that reduce vulnerability (Berkes, 2007; Bennett et al., 2016). For this reason, the successful implementation of an EAF, SES thinking, and social vulnerability research are critical contributors to the sustainability of marine SES. Furthermore, EAF is especially critical for regions that are anticipated to undergo impacts of climate change on larger scales and for resource users who are less equipped to respond to such disturbances (Adger, 1999; Hobday et al., 2016; Johnson et al., 2016).

The South African Context

The Benguela Current Large Marine Ecosystem (BCLME) is an eastern boundary current system characterised by inherent natural variability, upwelling properties, and productivity

that sustain numerous fisheries and livelihoods (Shillington et al., 2006; Blamey et al., 2015; Jarre et al., 2015; Raemaekers et al., 2016). The southern Cape handline fishery is situated on the south coast of South Africa, where the BCLME overlaps with the warming Agulhas Current and is adjacent to one of the southern hemisphere 'hot spot' regions that are undergoing climate change quicker than the average global rate (Hobday and Pecl, 2014). This means that the southern Cape SES is particularly exposed to climate change.

Both SSFs and scientists have reported environmental (biophysical) changes in the coastal regions of the southern Cape, including changes in fishing seasons, wind direction, current strength, sea state, and target species (Cockcroft et al., 2008, Winker et al., 2014; du Plessis, 2017; Ward et al., 2018; Currie et al., 2020; Lyttle et al., 2021). The SSFs also struggle with socio-economic and policy-related stressors that negatively impact their livelihoods (Sowman et al., 2014; Raemaekers et al., 2016; Gammage et al., 2017a, 2017b, 2019; Martins et al., 2019). In addition, SSFs, globally and in South Africa, are disadvantaged by the influx of and rivalry with outside large-scale fishers, control over market prices, costs to fish, and access to capital (Béné, 2009; Berkes, 2011; Nayak et al., 2014; Visser, 2015).

Despite the advent of democracy in South Africa, many communities, including coastal communities, continue to grapple with the legacy of Apartheid and are struggling with a slow transition to equality that is exacerbated by the ineffective or slow implementation of government policies (Paterson & Petersen, 2010; Cochrane et al., 2015). Although not successfully or fully implemented yet, South Africa has policies explicitly for small-scale sectors based on good practice EAF principles (DAFF, 2012; Sowman et al., 2014; Augustyn et al., 2014; Sowman & Sunde, 2021). Alongside the slow policy implementation, a holistic understanding of the southern Cape SES is still incomplete (Jarre et al., 2018).

The 'Global Understanding for Learning Local Solutions: reducing vulnerability for marine-dependent coastal communities' (GULLS) project (funded by the Belmont Forum) comprised interdisciplinary working groups that collaborated and aimed to improve the responses of marine SES, specifically to impacts of climate change (Hobday et al., 2016). GULLS focused on the southern hemisphere hotspot regions identified by Hobday and Pecl (2014) in Australia, Brazil, India, South Africa, and the Mozambique Channel.

South Africa, in addition to applying the survey, also participated (and led most of the process) in the development of a social vulnerability survey instrument and framework that can be applied and compared on local to global scales (Aswani et al., 2019). The Southern Cape Interdisciplinary Fisheries Research (SCIFR) project uses SES thinking, and EAF management approaches to communicate with various decision-makers and ultimately contribute to managing human interactions in a way that improves the sustainability of this SES (Jarre et al., 2018). The SCIFR project provided the GULLS survey a convenient entry into the local communities and facilitated the South African GULLS survey undertaken in 2014-2015. The survey has in turn, contributed to inter- and transdisciplinary research carried out by SCIFR.

1.2 Aim and Research Questions

This research investigates the concepts of social vulnerability in the context of climate change for the following communities: Mossel Bay, Bitouville, Melkhoutfontein, Vermaaklikheid, and Slangrivier. A better understanding of social vulnerability for these communities is essential for both decision-makers and community members to work towards reducing vulnerability to negative impacts (such as those of climate change). In this study, social vulnerability is based on sensitivity, exposure, and adaptive capacity. I have used the GULLS survey data (collected through completing a survey instrument with fishers from the southern Cape who were crew members in the line fishery in 2014-15) and applied a robust, quantitative vulnerability indicator framework (Aswani et al., 2019) that reduces these complex vulnerability concepts to representative scores. Finally, univariate and multivariate statistics were performed on the vulnerability scores to attempt to answer the following questions:

1. Do social vulnerability, sensitivity, exposure, and adaptive capacity scores for 2014-2015 differ between the southern Cape fishing communities?

2. How homogenous or heterogeneous are the fishers' responses within each community? What insight is gained about the dispersion or cohesiveness of fishers in the communities?

3. What drives the differences in social vulnerability between the communities for this period?

4. What insight is gained about scale when analysing the southern Cape survey data at various scales of the multiscale framework?

On a local scale, my results add to this dynamic social-ecological system's knowledge base and contribute to a long-term understanding of vulnerability and adaptation to climate change. From a broader perspective, this research contributes to both the SCIFR and GULLS project's long-term objectives of continuing and improving the understanding of the southern Cape commercial handline fishery towards improved full-spectrum sustainability.

1.3 Dissertation Outline

This dissertation proceeds with a literature review, covering the research's main topics, namely, climate change, small-scale fishers, and social vulnerability, in Chapter Two. The second chapter also provides an overview of the southern Cape handline fishery's major components (biological, physical, political, and social). The third chapter handles the methods of this study, where I delve into the conceptual framework, the GULLS social vulnerability framework, details of the study sites, and the statistical methods. In Chapter Four, the results of the analyses are divided into the following subsections: social vulnerability, sensitivity, exposure, adaptive capacity, and social vulnerability amidst scales. The fifth chapter contains the discussion, where the social vulnerability components, the framework scales, and the recommendations for future research using the GULLS surveys and methodology are discussed. Lastly, Chapter Six presents the conclusion of this study.

CHAPTER 2: Literature Review

This literature review introduces the three main topics of this research (Climate change, social vulnerability, and small-scale fishers) and also comprises a section discussing essential components of the southern Cape handline fishery.

2.1 Climate Change

The GULLS survey (the research tool applied in this vulnerability study) (Aswani et al., 2019) was created to better understand fishers' vulnerability to climate change. Thus, it is essential first to discuss climate change, its complexities and challenges, and its implications for the ocean and its dependents.

2.1.1 Definition, Uncertainty, and Complexity

Climate change amounts to any shift in climate across extended periods caused by internal forces like natural variability or external forces such as human activity (IPCC, 2014). Part of climate change is modern-day global warming, which is the steady rise of the temperature of the earth's surfaces (Houghton, 2009). Climate change and global warming are part of the earth's natural history. However, these phenomena' exacerbated scale and accelerating rate (post industrialisation) are what alarm most (Adger et al., 2003; Halpern et al., 2007; McCauley et al., 2015; Swain et al., 2020; Arias et al., 2021; Andrello et al., 2022). As reported by the Intergovernmental Panel on Climate Change (IPCC)[4], anthropogenic pressures are liable for 1.1°C of warming between 1850 and 1900, with a projected global increase in temperature of at least 1.5°C over the next two decades (IPCC, 2021). However, the consistent increase in global temperatures does not yield consistent impacts. Therefore, anticipating and responding to the effects of climate change is extremely difficult due to multiple complexities (Hoegh-Guldberg & Bruno, 2010; Hall, 2011; Allison & Bassett, 2015). Below, I will discuss just three complexities of climate change that contribute to this difficulty.

[4] The Intergovernmental Panel on Climate Change (IPCC) is responsible for providing current scientific climate change reports to the public and policymakers. They seek to advance the body of knowledge on global anthropogenic climate change and facilitate potential mitigation and adaptation options (IPCC, 2021).

First, the effects of climate change are not linear or easily disentangled (Harley et al., 2006; Doney et al., 2012; Potts et al., 2015; Mendenhall et al., 2020). Instead, they interact with other exogenous and endogenous factors on a multi-scalar level, producing 'wicked'[5] problems for ecosystems and their dependents (Perry & Ommer, 2003; O'Brien et al., 2004; Akamani et al., 2016; Yanda et al., 2019). For instance, in the context of ocean systems, impacts of climate change simultaneously interact with anthropogenic impacts like overfishing, pollution, and habitat degradation (Harley et al., 2006; Hoegh-Guldberg & Bruno, 2010; Doney et al., 2012; Hollowed et al., 2013; Arias et al., 2021). These interactions make it difficult to tease out how and to what degree these individual pressures impact environmental resources and services (Bennett et al., 2016).

A second complexity arises due to the obstacle of discerning which climate change impacts are due to human-induced climate change and which are a result of natural variability (Hoegh-Guldberg & Bruno, 2010; McCauley et al., 2015; Gissi et al., 2021). As before, this uncertainty makes it difficult to discern the extent to which certain human activities contribute to climate change and what this holds for future effects.

Thirdly, scale mismatches and various climate model shortcomings kindle further uncertainty and inability to predict future projections (O'Brien et al., 2004; Vincent, 2007; Swain et al., 2020). For instance, results from a model projecting climate change impacts at a global scale might not be relevant at regional or local scales and vice versa (Gibson et al., 2000; Perry & Ommer, 2003), and appropriate downscaled models may not be available. However, these uncertainties do not deprecate the significance of climate change (Solomon et al., 2009; Doney et al., 2012; Allison & Bassett, 2015). The limited capacity to predict the future of climate change (Berkes, 2007; Blamey et al., 2015) instead sparks an urgency to identify those most affected and prioritise those generally most in need of intervention (Hobday & Pecl, 2014; Raemaekers et al., 2016; Sowman & Raemaekers, 2018; Thomas et al., 2019).

[5] Obstacles in managing SES are often conceptualized as "Wicked" problems. Wicked problems consist of complexity and an absence of consensus in clear definitions or solutions (Akamani et al., 2016).

2.1.2 Climate Change and ocean systems

Ocean systems, fisheries, and their associated coastal communities, which are best described as integrated marine social-ecological systems (SES) (Ommer et al., 2012; Link et al., 2017), are among the most threatened by environmental change (Harley et al., 2006; Pollnac et al., 2010; Cinner et al., 2012; Yanda et al., 2019). In terms of how climate change directly affects marine SES, impacts often involve changes in shorelines, sea oxygen content and salinity, storm frequencies, ocean currents, and ocean acidification (Hoegh-Guldberg & Bruno, 2010; Cheung et al., 2013; Ortega-Cisneros et al., 2021; Salvadeo et al., 2021). Even further, each of these climate change-induced consequences trigger an expansive range of their own direct and indirect impacts.

Delving into the effects of sea temperature changes alone emerges consequences such as significant shifts in marine fauna (i.e., in behaviour, size, distribution, and composition) (Perry et al., 2005; Hollowed et al., 2013; Jarre et al., 2015; Poloczanska et al., 2016; Manes et al., 2021). The direct effect of ocean acidification is coupled with indirect effects such as thwarted olfactory abilities and hindered skeletal development in many fish species (Munday et al., 2009). Changes in rainfall and ocean salinity can invoke stress on estuarine-dependent species due to disruptions in nutrient content (James et al., 2013). Sea-level rise transforms coastal species' delicate habitats and nursery grounds and, as a result, influences ecosystem dynamics (Nicholls & Cazenave, 2010).

Observations already coincide with the above impacts and their cascade of effects, which are only the ‘tip of the iceberg’ concerning how climate change can influence marine ecosystems and threaten those who rely on ocean resources (Doney et al., 2012). Furthermore, these changes will positively and negatively impact marine ecosystems and resource users (Harley et al., 2006; Badjeck et al., 2010; Hollowed et al., 2013; Thomas et al., 2019). Therefore, to secure the sustainability of marine SES, resource users must become aware of the current state of their resources and how they may be influenced by climate change, as well as by the way they are currently impacting the system and how these dynamics might change. It is also fundamental to identify those with a greater dependence

on marine resources and prioritise those who will be most at risk of the adverse effects of climate change, such as the handline fishers in the southern Cape of South Africa.

2.1.3 Climate Change and the Benguela

The Benguela Current Large Marine Ecosystem (BCLME) sustains a multitude of marine SES in South Africa, Namibia, and Angola (Augustyn et al., 2014; van der Lingen & Hampton, 2018). Climate change effects in the Benguela are difficult to discern because the system has undergone a considerable amount of environmental change because of its inherent natural variability (Hutchings et al., 2009; Hampton & Willemse, 2012; Jarre et al., 2015). Moreover, overfishing has driven substantial environmental disruptions (i.e., distributional shifts in important species: the west coast rock lobster, sardine, anchovy, etc.) that have wreaked havoc on the livelihoods of fishers and coastal communities (Cockcroft et al., 2008; Coetzee et al., 2008; Jarre et al., 2013; Sowman & Raemaekers, 2018). As in other marine systems, the variability, climate change, overfishing, and other anthropogenic impacts interact in complex ways, leaving a comprehensive understanding of climate change in the BCLME challenging to achieve (Hampton & Willemse, 2012; van der Lingen & Hampton, 2018; Ortega-Cisneros et al., 2021).

Nevertheless, in the last 30 years, sea surface temperature (SST) warming trends have been noted, and an additional 3°C increase is anticipated before the turn of the century (Popova et al., 2016). In addition, an increase in upwelling wind patterns and seasonality have also been observed, especially toward the southern Benguela (Blamey et al., 2012, 2015) and on the Agulhas Bank (Ward et al., 2018), where the southern Cape handline fishery resides (also see section 2.4.1 for an overview of the smaller-scale physical components and climate change impacts on southern Cape). These climate change effects are linked to and shape the fisher's vulnerability, particularly those that depend most on marine resources for food security and income, in different ways. However, before delving into climate change-induced vulnerabilities, it is first important to understand what social vulnerability entails.

2.2 Social Vulnerability

First, the definition, importance, and history of social vulnerability research are discussed. Following is a discussion of fisher vulnerability research, where the definitions used for this study are provided.

2.2.1 Definition and Importance of Social Vulnerability

Vulnerability studies have an extensive history with various interdisciplinary definitions, frameworks, and applications (Füssel, 2007; O'Brien et al., 2007). Over the past few decades, vulnerability research has transitioned from solely measuring physical features of vulnerability to holistically including more social elements of vulnerability: physical vulnerability assessments are associated with natural disasters, geographic hazards, and biophysical conditions (Cutter, 1996; Berkes, 2007), while social vulnerability acknowledges social and ecological conditions alike, recognising ecosystems as integrated SES (Cutter et al., 2003; Bennett et al., 2016).

A definition proposed by Alger, 1999 declares that social vulnerability arises upon the exposure of individuals or groups to stress stemming from environmental and social changes (Adger, 1999). Cutter et al. (2003) further suggest that social vulnerability is shaped by inequalities of social conditions and disparities amongst localities. Social inequality often involves aspects of governance, resource access, infrastructure, and individual characteristics such as age, education, poverty, culture, and living standards (Thomas et al., 2019). Location disparities often include economic vitality, urbanization, and the built environment (Cutter et al., 2003). The social and economic factors tend to have a stronger influence on vulnerability than the exposure to or the nature of the environmental changes (Thomas et al., 2019). Therefore, focusing on the social components of vulnerability is perhaps most important for enhancing or mitigating the effects of natural disasters and climate-related events (Adger, 1999; Bennett et al., 2016; Martins & Gasalla, 2020).

Social vulnerability research has become critical to investigating and increasing the knowledge bases of marine SES in response to climate change (Adger, 1999; Kelly & Adger, 2000; Lee, 2014; Bennett et al., 2016; Thomas et al., 2019). Through understanding the

conditions of SES and their susceptibility to negative consequences of change, decision-makers can adopt transformative actions that maximise resilience and minimise harmful impacts (Folke, 2006; Lee, 2014). However, social vulnerability is not a straightforward subject. It is tricky to quantify because it is a theoretical and directly unmeasurable concept (Hinkel, 2011). As introduced above, vulnerability is shaped by multiple dimensions (i.e., economic, social, governmental, and biophysical) that interact and make it difficult to pinpoint underlying drivers (Adger, 1999; Adger, 2006; Satapath et al., 2014; Bennett et al., 2016).

Vulnerability also fluctuates across regions (global to national), economic sectors (fisheries, manufacturers, shipping), social groups (coastal communities, urban or developing populations), and depends on which sub-systems are emphasised (natural, social, and economic) (Cutter et al., 2003; Satapath et al., 2014; Thomas et al., 2019; Gammage & Jarre, 2021), hence its 'place-based' or 'context-dependent' nature (O'Brien et al., 2007). The dynamic nature of the concept has resulted in a diverse set of definitions, aims, and approaches applied across multiple disciplines (Watts & Bohle, 1993; Cutter, 1996; O'Brien et al., 2007; Lee, 2014; Satapath et al., 2014). Each approach is unique in that each asks different questions, is concerned with different scales, and has different methods, interpretations, and outcomes (Füssel, 2007; O'Brien et al., 2007) (see section 3.1 for an overview of vulnerability methods, tools, and frameworks considered for this study).

The International Panel on Climate Change (IPCC) definitions are used for this study. The IPCC reports have been updated six times since their original output. Here, the definitions in the fifth IPCC assessment are used because the GULLS framework is based on these concepts (Aswani et al., 2019). Therefore, for this study, social vulnerability encompasses the interaction of three primary concepts: sensitivity, exposure, and adaptive capacity (IPCC, 2014) (**Figure 2.1**).

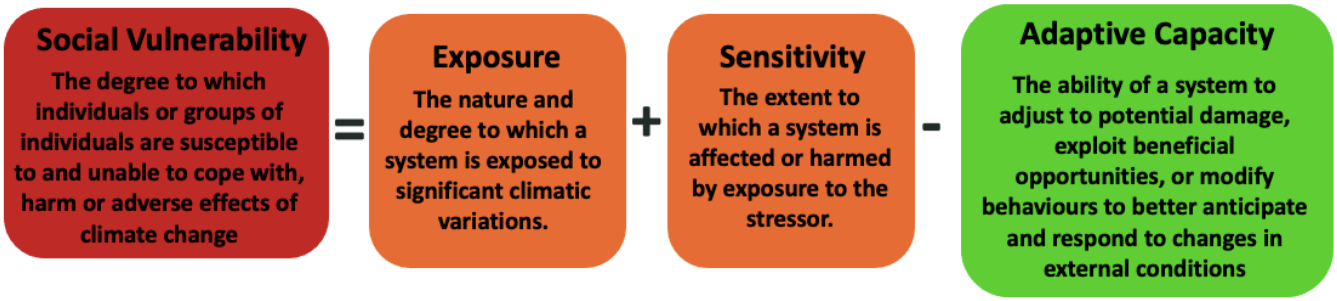

Figure 2.1 Social vulnerability framework defined by the IPCC; Where social vulnerability arises due to exposure to changes like climate change is compounded by the sensitivity of the social-ecological system, and is potentially compensated by its adaptive capacity (IPCC, 2014).

2.2.2 Fisher Social Vulnerability and Adaptive Capacity

In the context of this study, I am measuring the impact of climate change on SSFs from their perspectives. One benefit of measuring SSF social vulnerability is that it sheds light on aspects of the social drivers that influence fishing activity (Reed, 2008; Umamaheswari et al., 2021). One can also unravel how fishing activities contribute to poverty relief and how they have changed over time (Allison et al., 2009; Béné, 2009). However, compared to other sectors (e.g., energy, transport, and agriculture), fisher vulnerability has not acquired the same degree of attention in climate change adaptation research (Allison et al., 2009). Fisher vulnerability research is crucial mainly because climate change mitigation and adaptation are argued to predominately take place through individual action (Adger et al., 2005) and awareness of vulnerability (and adaptive capacity) at the scale of the relevant SES can help capacitate fishers to improve their adaptive capacities.

Thus, because exposure encapsulates environmental and climate disturbances, and sensitivity often accounts for economic, cultural, and political characteristics, adaptive capacity is arguably where fishers, individuals, and collective communities can take the most action and have most influence to mitigate the impacts of climate change and reduce their vulnerability (Smit & Wandel, 2006; Vincent, 2007 Engle, 2011; Hinkel, 2011; Martins & Gasalla, 2020). Therefore, fisher vulnerability research and adaptive capacity analyses performed at a community level are vital for implementing EAF approaches and for marine SES to respond favourably to the future impacts of climate change.

2.3 Small-Scale Fisheries

Small-scale fishers are some of the more vulnerable marine resource users and will likely be most at risk of environmental and social changes, such as climate change. To give an overview of SSFs, this section examines what constitutes small-scale fishing, their characteristic vulnerabilities, and the global management of small-scale sectors.

2.3.1 Definition and Importance of Small-Scale Fishers

The small-scale fishing sector is not distinct or simply defined (Garcia et al., 2003; Jentoft, 2014). It is a complex sector where SSFs are often described with interchangeable terms such as artisanal, traditional, and subsistence (Garcia et al., 2003; Berkes, 2007; Sowman, 2011). Furthermore, small-scale fishing activities are context-dependent, and they vary across countries and between individual fishers (Berkes, 2001; McGoodwin, 2001). Nevertheless, the Food and Agriculture Organization of the United Nations (UN FAO) has compiled discerning generalities and typical features to define the sector. By their definition, small-scale fishing refers to artisanal fishers who operate at household scales and require relatively small amounts of capital and time at sea (FAO, 2020). Small-scale fishing is by and large more labour-intensive than large-scale fishing, and it employs a diverse range of strategies, including line, pole and line, longline, trawling, gill nets, beach seine, and manual collection (FAO, 2020). The sector targets a broad spectrum of species (i.e., cephalopods, shellfish, reef fish, pelagic species, and demersal species) which can be caught at subsistence and commercial extents. When the opportunity arises, most SSFs operate commercially and supply local markets or sell surplus catch for additional income (Berkes et al., 2001). Therefore, when referring to 'commercial' fisheries, one must heed the existence of both large and small-scale operators.

Although historically overlooked, today, the value of small-scale fishing to global poverty relief, employment, and food security, is well known (Béné, 2009; Jentoft, 2014; Béné et al., 2016). The sector constitutes most of the world's catch (Pauly & Zeller, 2016), of which approximately 95% is consumed locally and contributes to food security in the developing world (FAO, 2020). On top of this, out of 51 million fishers worldwide, an estimated 50 million operate in small-scale sectors, comprising over 90% of the world's fishers (Berkes et

al., 2001; FAO, 2015). Together with direct employment, the sector supports an additional 40 million people through indirectly associated enterprises such as those concerned with catch production, processing, marketing, and distribution (McGoodwin, 2001). In South Africa, small-scale fishing is crucial. Although SSFs only constitute less than one per cent of the country's Gross Domestic Product (GDP), it employs just under 30,000 people while indirectly supporting an additional 50,000 fishers through small-scale and artisanal operations (Sowman et al., 2014).

2.3.2 Marginalisation and Competition

Despite the SSF sector's vital contribution to maintaining culture, alleviating poverty, and supplying essential nutrients and sources of protein (both around the world and in South Africa), there is a persistent past of marginalisation and disenfranchisement of SSFs across the globe (Isaacs, 2006; Béné, 2009; Nayak et al., 2014). Their coastal locality is an important contributing factor to their history of marginalisation and disadvantaged conditions. This holds to an environmental extent, for example, owing to rising sea levels, increasing coastal flooding, and erosion disasters (Harley et al., 2006; Nicholls & Cazenave, 2010; Yanda et al., 2019). This also holds to a social extent, as SSFs are often remotely settled and consequently alienated from decision-making processes (Nayak et al., 2014). The alienation and lack of accommodation for SSFs are especially persistent because many management approaches focus on fisheries in more developed countries. These approaches are less applicable for management in developing regions (Berkes, 2001; Jentoft, 2014; Ratner et al., 2014; Jentoft et al., 2017; Umamaheswari et al., 2021).

Additionally, some posit that SSFs have little to no influence on the governance systems on which they depend (Béné, 2009; Raemaekers et al., 2016; Martins et al., 2019), mainly because older policies do not consider SSFs (Berkes, 2001; Allison & Horemans, 2006; Béné, 2009; Béné & Friend, 2011; Jentoft, 2014; Nayak et al., 2014) and partly because collaboration amongst small-scale operators is often hampered by strife over authority and conflict among the many individuals and small enterprises (Mendenhall et al., 2020). The clashing voices of the SSFs are pale compared to those of large-scale operators, who benefit from more structured representation and unified decision-making. Consequently, fisheries management approaches favour larger-scale over small-scale operators (Allison &

Horemans, 2006; Visser, 2015; Raemaekers et al., 2016). Internationally, SSFs grapple with these management biases that entail undue rights allocation and inequitable access to stocks shared among small and large-scale fishers (Kleinschmidt et al., 2003). The SFFs of South Africa are no exception (see section 2.4.3 for an extensive overview of the policy and regulations of the handline sector in the southern Cape).

2.3.3 Small Scale Fisheries and Ecosystem-Based Management Approaches

To address these critical issues and improve the international management of SSF sectors, the UN FAO created global, voluntary Small Scale Fishery guidelines (SSFG) (FAO, 2015). These guidelines recognise the contribution of SSFs to sustainable fishing, poverty eradication, and society's overall well-being and oblige governments responsible for providing SSFs fair access to marine resources and markets. Furthermore, the FAO guidelines touch on human rights and emphasise the vital role of SSFs in decision-making procedures (Ratner et al., 2014; FAO, 2015), which backs the FAO recommendation to governments, fishing communities, and stakeholders to work together through holistic and integrated approaches (Garcia et al., 2003; Jentoft, 2014; Jentoft et al., 2017).

More generally and including both large and small-scale fisheries, there has been a surge in ecosystem-based management approaches, like the Ecosystem Approach to Fisheries (EAF) management (see the introduction and **Figure 1.1**), emphasising the social and economic features of vulnerable systems as a priority in ocean governance (integrated management (IM), marine spatial planning (MSP), precautionary approach (PA), and participatory co-management (PCM), to name a few others) (Stephenson et al., 2021). These approaches have somewhat different emphases, but all explicitly acknowledge the human dimensions of the ecosystems and recognise the value of integrating SSF, indigenous knowledge, and coastal communities into management procedures (Bennett et al., 2016; Johnson et al., 2016; Raemaekers et al., 2016; Ford et al., 2018; Sowman & Raemaekers, 2018; Martins et al., 2019; Martins & Gasalla, 2020; Salvadeo et al., 2021; Umamaheswari et al., 2021). Notably, many of these approaches have called for collaborative research (such as social vulnerability research) as a first step toward developing the adaptive capacity, resilience, and sustainability of SSFs and their coupled SES, at multiple scales.

Despite the progress in global SSF management and research, many fishery management systems are still far behind in their practice and implementation of these principles (Ommer et al., 2012; Link et al., 2017). Regarding SSF management in South Africa, in 2003, the country committed to EAF management that has yet to be fully practised and applied (Shannon et al., 2010; Paterson & Petersen, 2010; Augustyn et al., 2014). Furthermore, there is a dire need for a more comprehensive understanding of the social components of the southern Cape marine SES (Jarre et al., 2018), the focus of this research.

2.4 Southern Cape Commercial Handline Fishery

This study concerns the southern Cape handline fishery. Five small-scale fishing communities were chosen to represent the southern Cape handline fishers: Mossel Bay, Bitouville, Melkhoutfontein, Vermaaklikheid, and Slangrivier (**Figure 2.2**). These communities range from rural to peri-urban, with Mossel Bay as the most urban and developed site (Gammage et al., 2017b, 2017a; Jarre et al., 2018). According to prior research, fishers in these communities face similar challenges but manage the impacts to a greater or lesser extent (Gammage et al., 2019). For instance, communities such as Melkhoutfontein and Vermaaklikheid are among the most underprivileged by their geographic isolation, indirect access to the ocean and post-Apartheid inequalities (Gammage et al., 2019). Nevertheless, at somewhat larger scales, these communities are exposed to comparable biophysical, social, and political drivers of vulnerability (Sowman, 2006; Blamey et al., 2015; Potts et al., 2015; Martins et al., 2019; Sunde & Erwin, 2020; Currie et al., 2020; Ortega-Cisneros et al., 2021; Lyttle et al., 2021).

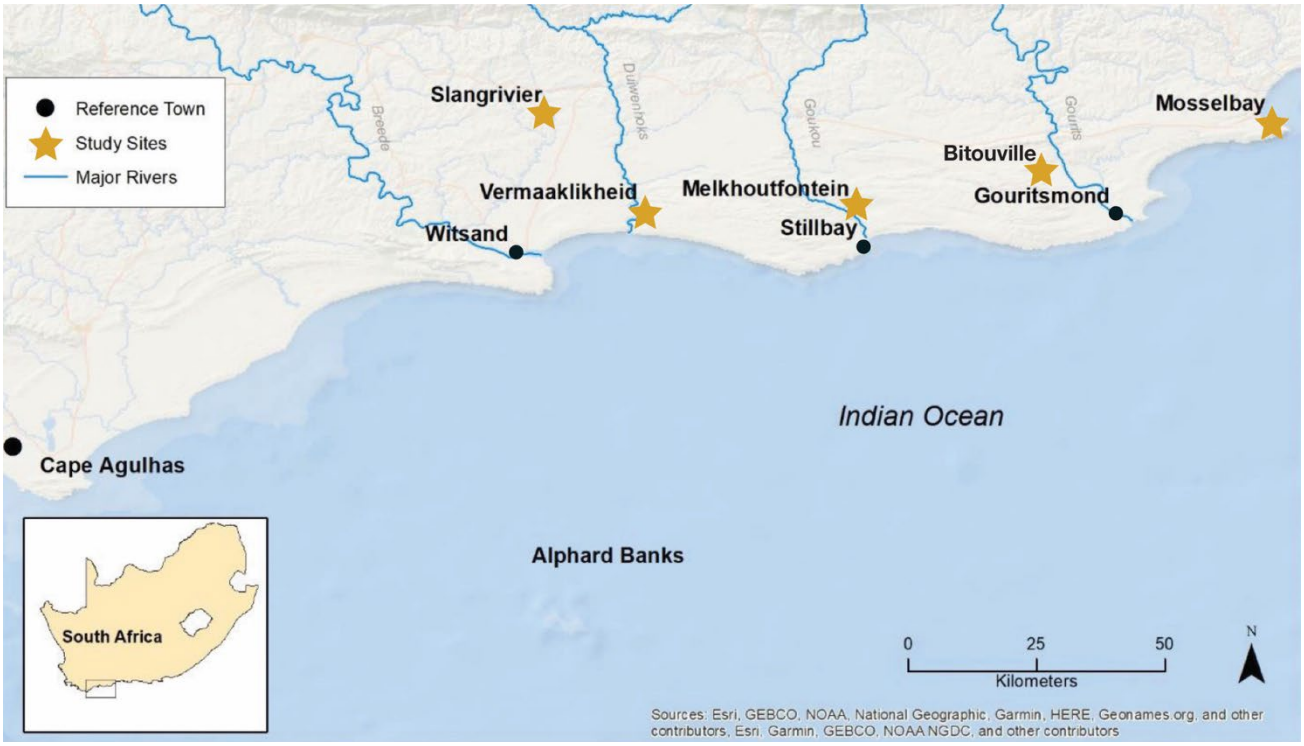

Figure 2.2 Map of the study area, adapted from Gammage et al., 2019. The golden stars represent the study sites: Mossel Bay, Bitouville, Melkhoutfontein, Vermaaklikheid, and Slangrivier, whilst the black dots represent important reference towns.

2.4.1 Physical Components

In the southern Cape, the southern component of the BCLME dominates the western coastline. On the other hand, the Agulhas western boundary current system dominates the eastern coast, creating a unique and dynamic ecosystem where both overlay (Hutchings et al., 2002, 2009). The Benguela current is driven by south-easterly trade winds that drive a productive upwelling system (Ryther, 1969; Shillington et al., 2006). The upwelling process enriches the coastal waters with nutrients, making ideal spawning grounds that provide a lucrative resource base for a diverse group of subsistence, small- and large-scale commercial fishers (Blamey et al., 2015; Jarre et al., 2015; Raemaekers et al., 2016). In terms of how climate change has manifested in the BCLME, long-term changes include lower oxygen levels, fluctuations in the speed and direction of favourable winds, offshore warming, and inshore cooling of sea surface temperatures (Hampton & Willemse, 2012; Jarre et al., 2015; van der Lingen & Hampton, 2018). There is also evidence of changes in ocean acidification, rainfall, sea-level rise, and primary production (Blamey et al., 2015; Jarre et al., 2015; Ward et al., 2018).

The Agulhas current imparts its own qualities to the Agulhas Bank and southern Cape SES. While the BCLME is dominated by high variability and cold Atlantic waters, the Agulhas current is dominated by warm subtropical waters. Consequently, it has increased in strength and temperature notably since the 1980s (Rouault et al., 2009). Although scale mismatches and lack of long-term climatic data bear uncertainty (Blamey et al., 2015; Ward et al., 2021), the eastern Agulhas bank is recognised as one of the world's 'Hot Spot' regions identified by Hobday & Pecl (2014). This means that this region is undergoing the effects of climate change at quicker rates than the global average, exposing its resources and resource users to more severe climate change consequences (Hobday & Pecl, 2014). Attesting to this, fishers in the southern Cape have reported increased difficulty when heading to sea owing to higher waves, stronger winds, and less viable sea days (Gammage et al., 2017a, 2017b, 2019). Furthermore, their observations have been supported by scientific datasets (Ward et al., 2021; Lyttle et al., 2021).

2.4.2 Biological Components

The southern Cape handline fishery is a multispecies fishery involving recreational, small-scale commercial, and community rights-based line fishing (DFFE, 2020). The fishery is boat-based and targets the Silver Kob (*Argyrosomus inodorus*) as the most sustainable and commercially viable catch (Griffiths, 2000). However, *A. inodorus* is deemed a severely depleted species that has continuously been overfished (Winker et al., 2017; Currie et al., 2020). Additionally, behavioural changes such as biting have been observed (Duggan, 2018). A large contributing factor to the Kob depletion is the strain of overfishing from multiple sectors, including the inshore trawl fishery (Greenston, 2014). The trawl fishery overlaps with and is tough competition for the small-scale handline fishery owing to their TAB[6], which contains no restrictions on the size limits of their bycatch (Attwood et al., 2011; Visser, 2015) in contrast to the minimum size limit, which is in place for the handline fishery. Thus, the trawl fishery can extract juvenile fish below the size limit set for the line fishers (Attwood et al., 2011). Interviews with the handline fishers shed light on the history of

[6] South African fisheries are generally managed through Operational Management Procedures (OMP) that put forward recommendations for Total Allowable Effort (TAE), Total Allowable Catches (TACs) limits and Total Allowable Bycatches (TABs) limits. The handline fishery is managed through TAEs with restrictions placed on the number of boats allowed at sea (DFFE, 2020).

conflict and strong opinions on the trawl fisheries' impacts on shared resources (Gammage et al., 2017a, 2017b). Although there is uncertainty about the trawlers' impacts from their bycatch, and although the SSFs' opinions could be fraught with bias, the implications of trawling for marine environments are well documented and contribute to the changing demersal and reef habitats of the Agulhas Bank (Atkinson et al., 2011; Currie et al., 2020).

As a result of Kob depletion, the handline fishers target alternative species such as Silvers (carpenters) (*Argyrozona argyrozona*), temperature reef fish like the Red Roman (*Chrysoblephus laticeps*) and the Hottentot Seabream (*Pachymetopon blochii*), and various shark species (*Chondrichthyes sp*) (Griffiths, 2000; Gammage et al., 2017a; DFFE, 2020). Snoek (*Thyrsites atun*) and Yellowtail (*Seriola lalandi*) are also caught when available in their area. However, many of these alternatives cannot assure fruitful catch in the long term (for instance, the Red Roman is a slow-growing species). On top of this, the distributional shifts and change in species composition propel the fishers to venture further distances and face more dangerous conditions (Duggan et al., 2018), only to secure comparably smaller and lower value catch.

The fishers leave from small harbours or river mouths and primarily use ski boats (DFFE; 2020). Ski-boats are limited in their capacity to withstand harsh weather and conditions further out at sea. In response to more challenging conditions and decreasing catch, few handline fishers in Mossel Bay have had the required capital and upgraded to deck boats (Gammage et al., 2017a, 2017b). However, access to this type of capital is not common, and the increased fishing pressure from this upgrade could be maladaptive due to the additional strain placed on the biological components of the system (Gammage et al., 2017b). It is also worth noting that many of the coping and adaptation strategies adopted by the southern Cape handline fishers have been discouraging in terms of profitable alternatives that are sustainable in the long term (Gammage et al., 2017b).

2.4.3 Policy and Regulation

Linefishing in South Africa is thought to have begun with the Khoi people[7] in the 1500s (DFFE, 2020). With origins tracing back to the 1800s, the southern Cape handline fishery is one of the oldest commercial fisheries in South Africa (Griffiths, 2000). The first concerns around overexploitation in this sector arose in 1940 and led to regulatory measures of minimum size limits for various species (DFFE, 2020). In 1985, the fishery was formally registered, and management implemented mixed regulatory measures, including a cap on the commercial sector catch, minimum catch size constraints, season closures, bans for various species, and daily bag limits (DFFE, 2020). Today, South Africa's fisheries are managed by the Department of Forestry, Fisheries, and the Environment (DFFE) (formerly called the Department of Agriculture, Forestry, and Fisheries (DAFF), and before that; the Department of Environmental Affairs and Tourism (DEAT).

The commercial sector in the southern Cape handline fishery is managed through an individual-based fishing rights allocation process (FRAP). The fishery is controlled by restrictions on the number of fishing boats allowed at sea, otherwise known as a total applied effort (TAE). In addition, the Small Scale Fisheries Policy (Act 474 of 2012) (DAFF, 2012) is under implementation. However, policy formulation and implementation for the SSFs in South Africa and this sector have been plagued with several so-called 'sticky issues' (Sowman et al., 2014) linked to South Africa's transition to democracy.

Following the democratic elections of 1994, the 1998 Marine Living Resources Act (MLRA) was gazetted (Act No. 18 of 1998) to, amongst others, resolve the unequal access to marine resources. However, this aim has yet to be fully achieved due to the inherent challenges of re-allocating resources and striving for social equity amidst resource scarcity (Kleinschmidt et al., 2003). Importantly for SSFs, the MLRA (Act No. 18 of 1998) did not formally recognise small-scale fishing as a sector (Sowman & Sunde, 2021), leaving many fishers (especially those operating part-time or on a small-scale) unacknowledged and without access to the coastal resources they have historically depended on (Witbooi, 2002; Sunde & Erwin, 2020).

[7] The indigenous Khoi (also known as 'Khoisan' or 'Khoikhoi') natives were the first to encounter European seafarers. They were thought of as foragers and created coastal traps to hunt for fish in the intertidal zones. Although they did not have boats or means for offshore fishing, line fishing activities have been traced back to their time (Parker et al., 2018).

To illustrate, in the beginning stages of the Fishing Rights Allocation Process (FRAP), only 50% of applicants received fishing rights and at least 20,000 fishers were not included in the FRAP application phase (DAFF, 2014; Sunde & Erwin, 2020).

Meanwhile, fishing pressure in this sector had expanded exponentially (Parker et al., 2018). As a result, most line fish stocks were depleted by the end of the century, leading to the infamous 'Line fish Emergency' of 2000 (Griffiths, 2000). This compelled management to drastically reduce effort and available individual rights, which further prevented the chance of equal rights and recognition for SSFs (Sowman, 2006). By 2005, researchers, NGOs, and civil society groups took legal action and brought attention to the lack of accommodation for SSFs (Isaacs, 2006; Sowman et al., 2014). In 2007, the Equality Court favoured the SSFs and mandated that government amend the MLRA and create the Small-Scale Fishery Policy (SSFP) (Act 474 of 2012) (DAFF, 2012). The Court Ruling also called for an immediate 'Interim Relief' programme to grant temporary access to marine resources until the requested policies were rolled out (Sowman et al., 2014). While Interim permits were only created as a temporary solution to support fishers through this transition, interim relief is still in place today.

The resulting SSFP was gazetted in 2012, and the amended MLRA (No 5 of 2014), which was gazetted in 2016, made provisions for a SSF sector and epitomizes a paradigm shift from a resource-centred to a people-centred approach (DAFF, 2012; DAFF, 2013; Jentoft, 2014; Jentoft et al., 2017; Sowman & Sunde, 2021). This policy framework aligns with EAF principles, which South Africa officially committed to in 2002 at the World Summit of Sustainable Development (WSSD). The SSFP strives to balance resource management and human rights to natural resources without compromising long-term sustainability (Paterson & Petersen, 2010). However, while the SSFP encapsulates better-day practices and holistic fishery management, implementation has been infested with delays and challenged by the complicated nature of managing marine SES (Sowman & Sunde, 2021).

Some other social and political drivers of vulnerability in this fishery include low levels of formal education, insufficient access to resources, and an absence of stakeholders in decision-making processes (Isaacs, 2006; Gammage et al., 2017a, 2017b; Jarre et al., 2018;

Sowman & Raemaekers, 2018; Sowman et al., 2021). Nevertheless, regardless of the struggle to fully implement policy objectives and grant fair rights, Gammage (2015) found some fishers to be highly resilient[8]. Moreover, there are initiatives (such as the SCIFR project) in the southern Cape working towards ecosystem-based approaches, social-ecological thinking, and stakeholder involvement, which are steps in the right direction (Paterson & Petersen, 2010; Shannon et al., 2010; Augustyn et al., 2014; Jarre et al., 2018; Gammage & Jarre, 2021). Continuing this progress and improving the understanding of what drives the vulnerability of the southern Cape handline fishers is critical for the full implementation of the SSFP and EAF management and long-term sustainability.

It must be noted that there is previous vulnerability research for the southern Cape fishers. However, the assessments comprise a Rapid Vulnerability Assessment (RVA) in Struisbaai (Raemaekers et al., 2016), ethnographic and mixed-method research (Gammage et al., 2017a, 2017b; Duggan, 2018; Ward, 2018), and a cross-country comparison with Brazil (Martins et al., 2019). Yet, there is a deficit of appropriately scaled quantitative research. Thus, the results of a community-level, quantitative analysis of the GULLS survey are needed to provide context to better understand and contribute to managing the southern Cape handline fishery.

To conclude this chapter, there is considerably more that augments the complexity and vulnerability of the southern Cape SES and the small-scale commercial handline fishery. However, the crux of the matter is that the livelihoods and ways of life of the SSFs in this sector are vulnerable to change, whether the change is socially, politically, or biophysically linked. Unravelling these inequities, identifying uncertainties, and understanding better what drives and reduces vulnerability, are crucial preliminary steps to preparing for and alleviating adverse effects of climate change (Adger, 2006; Smit & Wandel, 2006; Berkes, 2007) to ultimately secure livelihoods and sustain fisheries.

[8] Note that there is controversy around the benefit of displaying Resilience, which could also have negative consequences and cause individuals, communities, and systems to expect and hope for the system to return to the previous state rather than making productive, long-term changes for current and future states (Folke, 2006).

CHAPTER 3: Approach and Methods

This section comprises four parts. The first is the conceptual framework, which provides an overview of some of the tools commonly used to measure social vulnerability, the early vulnerability frameworks, and the development of the social vulnerability framework that this study draws on. The second part concerns the survey instrument and each study site (fishing community) summary. The third part explains the rationale behind the scoring and quantification process, survey question inclusion or omission, and framework organisation. The fourth part provides the statistical analyses applied to the data to support this social vulnerability assessment.

3.1 Conceptual Framework

As mentioned in the literature review (section 2.2), social vulnerability is the predisposition of individuals or groups to be adversely affected by biophysical, economic, or political changes (IPCC, 2014). The social vulnerability of marine social-ecological systems (SES) is a complex concept influenced by multifaceted drivers that interact at multiple scales and include cascading effects (Cutter et al., 2003; Perry & Ommer, 2003). Therefore, characterising and understanding the concept is a vital first step for management actions that ultimately address and reduce vulnerability (Bohle et al., 1994; Bennett et al., 2016; Johnson et al., 2016; Thomas et al., 2019). However, it is not an easy concept to quantify, measure, or interpret because of its theoretical and complex nature.

3.1.1 Tools to measure Social Vulnerability

Defining the core concepts of social vulnerability (e.g. sensitivity, exposure, and adaptive capacity) is only part of the challenge in facilitating productive vulnerability research (Ford et al., 2018). Given the social factors that operate across scales, the uncertainty of climate change, the natural variability of the southern Benguela ecosystem, the compounding anthropogenic factors (such as overfishing), and the unique composition of its subsystems, the following question inevitably arises: How are sensitivity, exposure, and adaptive capacity appropriately represented, measured, and interpreted into a description of vulnerability?

Climate change-related social vulnerability assessments are often approached from two different angles and are distinguished as either ‘Top-down’ or ‘Bottom-up.’ The distinction is

similar to the concept of 'starting-points' and 'ending-points' commonly used in the scientific literature (Kelly & Adger, 2000). While using a top-down or starting-point approach, one would begin by analysing general climate-related changes and impacts (Lindegren & Brander, 2018). These impacts are typically biophysical, readily quantifiable, performed at large scales, and are future-focused (Hoegh-Guldberg & Bruno, 2010; Hollowed et al., 2013). Although useful for rapid analyses and global-scale comparisons, results derived from top-down approaches are flawed by over-generalisation and tend to impose theoretical and irrelevant strategies on smaller-scaled, vulnerable systems (Vincent, 2007; Aswani et al., 2019).

A bottom-up or end-point approach first considers more context-specific determinants such as the social components of a system. To successfully implement ecosystem-based management approaches such as an EAF (refer to **Figure 1.1** for a visual representation of EAF core principles), information and insight into the current state of the social components of the SES are required (Link et al., 2017). Thus, at the centre of bottom-up approaches is the notion of representative indices and participatory methods (e.g. community mapping, focal groups, and town meetings, to name a few) that require extensive stakeholder involvement and shed light on which individuals or groups are most vulnerable (Reed, 2008; Ommer et al., 2012). In the context of coastal community assessments, using a bottom-up approach and involving stakeholders is especially advantageous due to the deep connection with their ocean resources and the resultant rich knowledge that local fishers and stakeholders offer for realistic adaptation strategies (Beierle, 2002; Smit & Wandel 2006; Duggan, 2018; Salvadeo et al., 2021). Although identifying relevant stakeholders is fraught with complexity, the outcome is worthwhile because it ensures the advantageous opportunity to co-develop more practical adaptation strategies (Munaretto et al., 2014). Moreover, when stakeholders are included, there is high value in the subsequent learnings and community empowerment (Reed, 2008; Fazey et al., 2010; Gianelli et al., 2021).

Bottom-up approaches also comprise direct data collection and social vulnerability assessments, where the concepts of vulnerability (collected at a refined, local scale) can be quantified and represented by observable variables that are synthesised into indicators (Cinner et al., 2012; Lee, 2014). According to Hinkel (2011), indicators are valuable tools

because they cut through the complexity of multifaceted concepts such as vulnerability. This simplification contributes to bridging the gap between academia and policy. Policymakers can more easily understand the complex social-ecological phenomena when they are reduced, quantified, and binned into simple results (Lee, 2014) that are presented in a transparent and defendable way. Given the ability to unravel and analyse what drives vulnerability, it is apparent that bottom-up approaches, participatory research, and meaningful indices are critical tools for assessing community-scale social vulnerabilities.

However, producing meaningful indices is difficult because simplifying complex information comes with the cost of pertinent uncertainties, the dependency on scale, and the risk of neglecting important components (Adger et al., 2005; Vincent, 2007). Further, bottom-up results are not easily generalised for locations or scales that differ from those at hand (Hinkel, 2011). This is why vulnerability assessments and methodologies are often bound to specific locations and contexts (Cutter et al., 2003; O'Brien et al., 2004) and why vulnerability assessment results should be interpreted with an appreciation of the limitations and the incapacity to account for all intertwining complexities.

The indices used in this research (explained in section 3.1.3 below) were created with a multiscale design to address the difficulties mentioned above. The framework comprises indices where vulnerability can be calculated at different scales. This multiscale design better preserves important information that is often lost when concepts of vulnerability are reduced to the easiest understood format.

3.1.2 Developing the GULLS Social Vulnerability Framework

The global transition to ecosystem-based approaches for fisheries management has incited various vulnerability frameworks (Füssel, 2007). Some of the most popular frameworks include the evolving Intergovernmental Panel on Climate Change (IPCC) framework, the Food Security (FS) framework, the combined Sustainable Livelihoods Approach (SLA) and Livelihood Vulnerability Index (LVI), the joint IPCC and LVI approach, and the merged IPCC, LVI, and FS approach. The advantages and pitfalls of each framework are presented below (**Table 3.1**).

Table 3.1 Frameworks reviewed to create the social vulnerability framework for this study (adapted from Aswani et al., 2019).

Framework	Emphasis	Disadvantage	Reference
Intergovernmental Panel on Climate Change (IPCC)	Ecological and Social	Broad datasets not suitable for local scale assessments	Allison et al., 2009; IPCC, 2021
Food Security (FS) Approach	Food-based welfare derived from FAO data	Large scale not suitable for local scale assessments	Godfray et al., 2010
Sustainable Livelihoods Approach (SLA) and Livelihood Vulnerability Index (LVI)	Economics, Institutions, poverty, and policy	Little climate considerations	Allison & Horemans, 2006; Metcalf et al., 2015
IPCC and LVI	Social components derived from household data	Physical components largely ignored	Mohan and Sinha, 2016
IPCC and LVI and FS	Holistic considerations of both social and ecological components	Extensive time required due to long list of indicators	Aswani et al., 2019

The classic IPCC framework[9] has evolved numerous times since 2001. It is advantageous owing to its comprehensive approach that is relevant at each spatial scale of vulnerability (e.g. global, regional, and local) (Allison et al., 2009; Cinner et al., 2012). However, it has attracted scrutiny due to the oversimplification of adaptive capacity, solely represented by economic indicators (Aswani et al., 2019). A combined SLA and LVI approach is favourable for emphasising economics, institutions, poverty, and policy (Allison & Horemans, 2006). However, owing to the high priority of sensitivity and adaptive capacity, there is little consideration of climate exposures within this framework (Aswani et al., 2019). The FS approach is valuable for decision-making at larger scales and the use of general datasets like the FAO national-level datasets; yet, results from this method are often irrelevant at local levels (Aswani et al., 2019). The joint IPCC and LVI approach (Mohan & Sinha, 2016) integrally prioritises social features of vulnerability by incorporating household data. Although it is beneficial because of its ability to run without climatic risk models, physical components are largely ignored. Lastly, the IPCC, LVI, and FS approach offers a holistic, flexible, strong framework. This approach highlights social and ecological dimensions and enables relevant comparisons across varying communities. The primary criticism of this

[9] The most recent IPCC framework can be found here: https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_FinalDraft_Chapter01.pdf and now frames the concept of vulnerability within the context of "Risk".

approach is its lengthy list of indicators that hinder the possibility of rapid assessment (Aswani et al., 2019). Along with the shortcomings of each approach, there is a shared weakness among most vulnerability frameworks: their failure to provide subsequent adaptation guidance, which abandons vulnerable systems with trifling scores that are often meaningless to the decision-makers responsible for managing the adaptive capacities of the system (Vincent, 2007). Below I discuss how the framework applied in this study addresses many of the disadvantages mentioned above.

3.1.3 The GULLS Social Vulnerability framework

To meet the GULLS objectives (discussed in section 1.1), a multilateral scientific team came together and called for an integrated framework that could be used to assemble survey questionnaires for each 'hot spot' region of marine ecosystem change (Australia, Brazil, India, South Africa, and the Solomon Islands), as defined by Hobday & Pecl (2014).

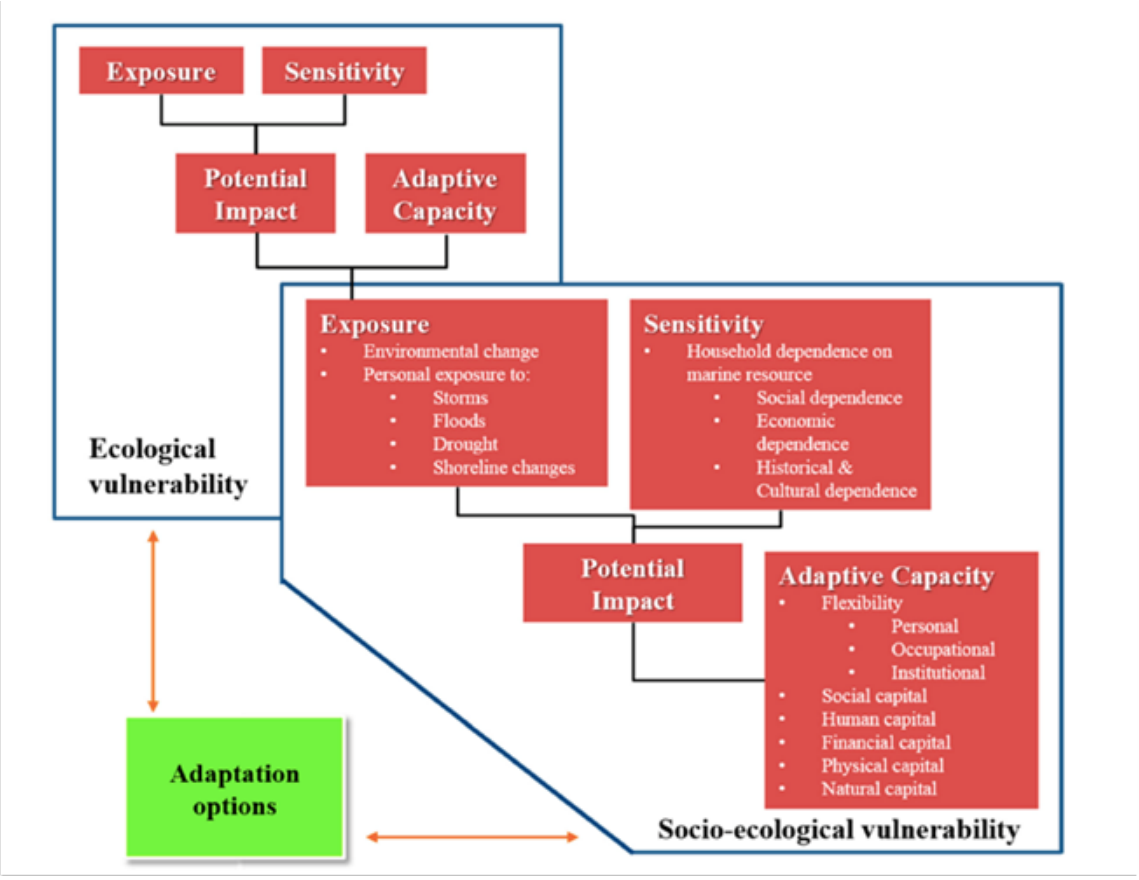

Figure 3.1 Figure representing the Aswani et al., 2019 social vulnerability framework, with integrating the approaches reviewed under section 3.1.2 of this dissertation.

The GULLS team created a universally comparable framework that is simultaneously valuable at local scales (Aswani et al., 2019). This framework was designed with the overarching aim to facilitate assessments that go beyond the vulnerability scores by offering deeper insight into the drivers of vulnerability, which is critical for formulating practical climate change adaptation strategies. To accomplish this, the team took account of both ecological (biological) and socio-ecological (human) dimensions to produce meaningful scores of sensitivity, exposure, and adaptive capacity. **Figure 3.1** represents the two dimensions' interdependencies, where the exposure of the human system relies on the biological system and its adaptive capacity to any potential impact[10]. Furthermore, the human dimension is based on the communities and individuals' dependency on marine resources, as seen in the descriptive components of the sensitivity category (**Figure 3.1**). Finally, adaptive capacity is defined by different components of flexibility and capital access, which contribute to the eventual development of potential adaptation options.

In this framework, there are four levels at which vulnerability can be calculated: Category (3 categories), Component (18 components), Subcomponent (71 subcomponents), and Indicator (192 indicators). Establishing different levels and scores of vulnerability (e.g. categories, components, subcomponents, and indicators) is key to enabling comparative research among the coastal communities at multiple scales (local, regional, national, and global). A complete list of the categories, components, and subcomponents used in the South African survey is shown in **Figure 3.2**.

[10] To give an example, this study is specifically concerned with the impacts of climate change on small-scale fishers. If the biological system (let's say, a certain fish stock) faces a climate change impact (such as ocean acidification), the fish stock and its adaptive capacity (ability to withstand a more acidic environment), will determine how exposed the people who depend on this fish stock are to climate change impacts. In other words, if the fish are not negatively impacted by the change, there is less exposure to the fishers. If the fish stock is negatively affected, the fishers are more exposed to climate change affects.

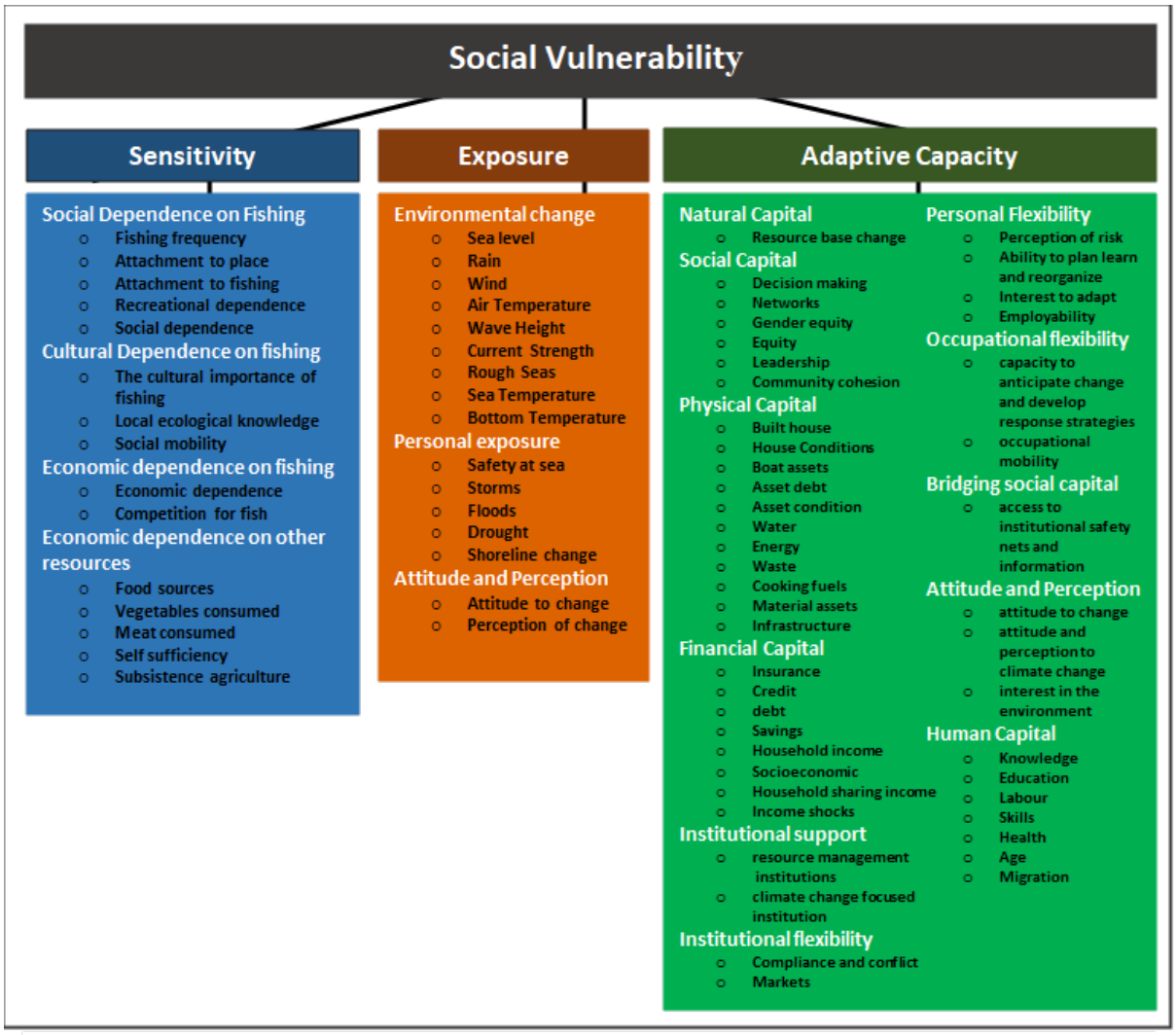

Figure 3.2. The GULLS social vulnerability framework adapted for the South African survey. The three categories are shown, along with their components (left-aligned in white), and subcomponents (bulleted in black under the components) (adapted from Martins et al., 2019).

Figure 3.3 exemplifies the different levels of complexity and reveals how a category (e.g. sensitivity, exposure, or adaptive capacity) is scaled down from the categorical level to the indicator level. To illustrate how the framework is organised and scaled, a scaling example is provided from **Figure 3.3**. Many components define sensitivity, one being the 'historical and cultural dependence on fishing' component. This component can be scaled down to multiple subcomponents, one being the 'cultural importance of fishing' subcomponent. To measure the cultural importance of fishing, representative indicators were created that disclose the age of the fishery, ancestral involvement, fishing family identity, and concern for future generations entering the fishery. In the opposite direction (from an indicator level up to a category level), an indicator, such as 'the degree of anxiety about observed environmental

change', influences the subcomponent 'attitude to change', which contributes to the component 'attitude and perception', and partly defines the adaptive capacity category (**Figure 3.3**).

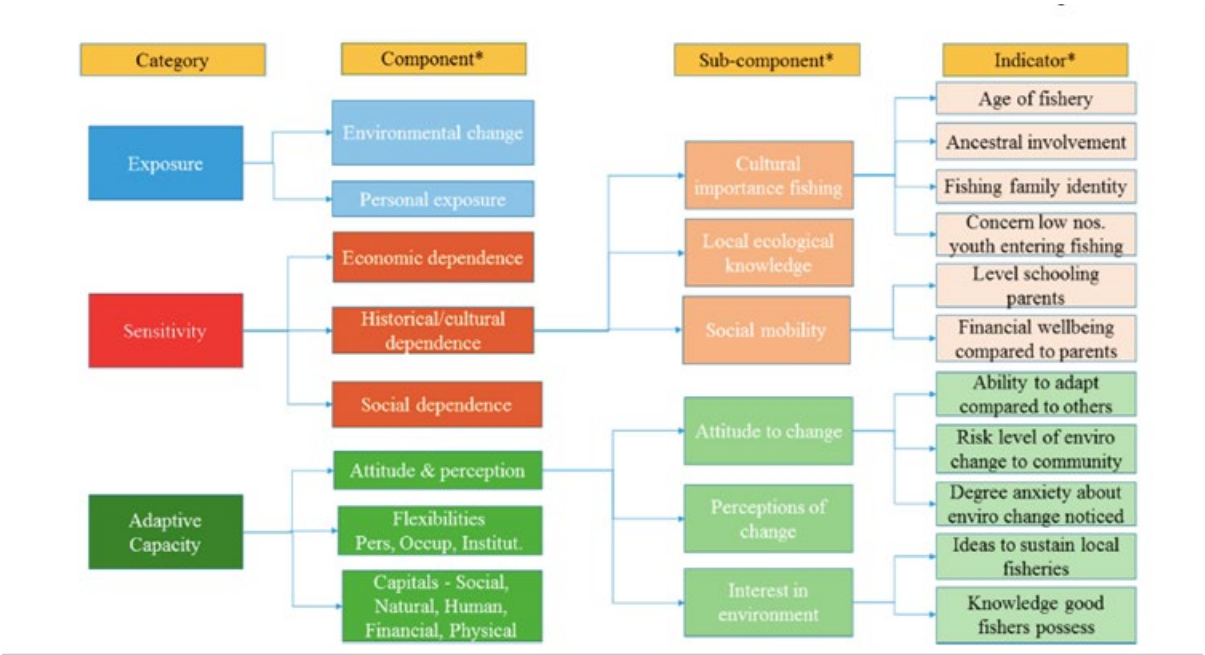

Figure 3.3. Representation of the integrated framework that shows a few examples of how the categories are scaled down to more local levels through components, subcomponents, and indicators, that ultimately were obtained through survey questions. Due to space limitations, exposure is only shown up to the component level, and only some of the subcomponents and indicators are shown for sensitivity and adaptive capacity (adopted from Aswani et al., 2019).

The GULLS team designed the survey instrument based on the framework represented in **Figures 3.1-3.3**. The surveys proved effective and transferrable, encapsulating important dimensions of vulnerability while catering to each community's context-specific features. In addition, field testing and comparison among the hotspot countries verified the capacity of this framework to gather rich, local-level data that can be compared at regional, national, and global scales (Hobday et al., 2016; Aswani et al., 2019).

3.2 The South African Survey and Study Sites

Regarding the South African GULLS survey, 253 questions were derived from the framework. To ensure cross-country comparability, questions were chosen so that there was at least one question (at most four) to represent each subcategory (see Aswani et al (2019) for more detail regarding survey design). The interviews were performed by a trained research

interviewer and a translator, as most of the stakeholders spoke Afrikaans, but the researcher did not. The survey underwent a pre-testing stage to ensure reliability. The questions that did not yield reliable results in the field testing stage were either improved or omitted. Members or stakeholders were chosen based on whether they self-identified as marine-dependent (Aswani et al., 2019). Overall, 65 self-identified fishing-dependent households were interviewed among five coastal communities in the southern Cape. However, only 59 surveys were retained for this study due to incomplete or insufficient observations for the remaining six. The five communities were Slangrivier, Vermaaklikheid, Melkhoutfontein, Bitouville, and Mossel Bay (see **Figure 2.2** in the literature review), briefly described below using STATS from the 2011 South Africa census data.

3.2.1 Slangrivier

Slangrivier is a town with a population size of 3002 (as of 2011) situated 35 km inland from the southern Cape coast. Basic infrastructure services are available; however, more sophisticated services such as education, municipal, and administrative services are located outside town (the closest town, Heidelberg, is 15 km away) (Ward et al., 2022). The fishers in this community operate as crew and work under skippers that are part of the commercial handline fishery located in Witsand (32 km away). Owing to the remoteness of their town, the lack of transportation, and the lack of physical capital, the crew members of Slangrivier have struggled to advance to skippers or become business owners (Gammage et al., 2017b). For the GULLS dataset, three fishers were interviewed and I used all three interviews to represent the Slangrivier fishing community.

3.2.2 Vermaaklikheid

Vermaaklikheid is a hamlet with a population size of 356 (as of 2011) remotely situated along the Duiwenhoks river. Although only 10 km inland from the coast, Vermaaklikheid is isolated. At the time of the interviews, there were only two gravel roads leading to the two nearest towns, both more than 34 km away. This marginalisation is especially concerning because there was only one vehicle owner in the resident fishing community, and at the time of the survey, there was no public transportation system (Gammage, 2015). Furthermore, according to the 2011 census data, more than half of the community members had no income just a few years before these interviews, making the community

heavily reliant on social grants. Their unfavourable circumstances are evident in their 'hopelessness' reported in Gammage et al. (2017b), where their most important coping strategy was identified (their "Ubuntu"[11] spirit and tendency to work together to cope by pooling resources) (Gammage, 2015). Historically, Vermaaklikheid had been a subsistence fishing community. However, the fishers have struggled due to gentrification (i.e. the influx of local tourism, holiday homes, and incoming landowners who have limited their access to important parts of the river, coasts, and agricultural land, withholding resident fishers from critical resources) (Ward et al., 2022). Aside from the resulting conflict with those restricting access to resources, most fishers operate as crew on handline commercial fishing vessels due to disadvantages similarly experienced by Slangrivier (i.e., remoteness, lack of capital, lack of transportation, etc.) (Gammage, 2015). For the GULLS survey, nine fishers were interviewed and I used all nine interviews for this study.

3.2.3 Melkhoutfontein

Melkhoutfontein is a town with a population size of 2533 (as of 2011) that is based up shore the Goukou river, 7 km inland from the southern Cape coast. Melkhoutfontein struggles with persistent post-apartheid consequences, such as unequal access to resources, limited economic opportunities, and heavy dependence on government grants, especially compared to their neighbouring coastal town, Stilbaai (Ward et al., 2022). Stilbaai is located at the mouth of the Goukou river, with a population of 3510 (as of 2011) that mainly comprises white landowners, retirees, and holiday homeowners. Stilbaai and Melkhoutfontein are characterised by a long fishing history and a strong connection to the small-scale line fishery (Ward et al., 2022). Fishers of Melkhoutfontein operate as crew members for predominately white boat owners, skippers, and right holders within the commercial line fishery of Stilbaai (Gammage, 2015). However, this fishery in Stilbaai faces a myriad of stressors (i.e., competition with inshore trawl fishers, decreasing lucrative catch, remote location, and unfavourable policies) that have motivated many fishers to exit the industry (Norton, 2014; Gammage, 2015). For the GULLS surveys, there had been 25 fishers

[11] "Ubuntu" is a phrase used in African cultures to describe a strong spirit and feeling of humanity or community. The phrase is often translated to "I am because we are". It is a cultural commitment to "become more human" and embraces an intimate relationship between and virtuous obligation of humans to their communities and native environments (Chibvongodze, 2016).

interviewed to represent the Melkhoutfontein fishing community, and I used all 25 interviews for this study.

3.2.4 Bitouville

Bitouville is a small town part of a larger community known as Gouritsmond. Owing to apartheid spatial planning, wealthier and predominately white residents are situated in developments near the coast, whilst people of colour generally reside in Bitouville (a few kilometres inland) in smaller RDP housing. Gouritsmond is primarily a holiday town cluttered with tourist accommodation, camping grounds, and holiday homes (Ward et al., 2022). Gouritsmond is well-known for recreational fishing, and Bitouville is well known for its strong community of small-scale fishers. The primary challenge for Bitouville fishers is the ongoing competition with the inshore trawl fishery, the stress posed by unevenly allocated fishing rights, and the slow implementation of the SSFP (Gammage, 2015). For the GULLS survey, ten fishers were interviewed to represent the fishers of Bitouville, and I used all ten interviews for this study.

3.2.5 Mossel Bay

Mossel Bay is a large town subjected to post-apartheid spatial planning and inequity. The Mossel Bay area has a strong historical dependence on farming, fishing, and its commercial harbour. Within the last century, Mossel Bay gained a major industrial component with high involvement in the oil and gas industry. It also has a strong tourism component comprising large holiday and retirement areas with multiple charters and tourist accommodation. In terms of fishery involvement, the Mossel Bay port and harbour are important assets to the industrial fisheries in South Africa. The inshore trawl fishery dominates the coast, co-existing and competing with the commercial line fishery. However, a history of monopolistic governing and bias toward the trawling industry has resulted in marginalisation and little independence and access to markets for the handline fishers (Duggan et al., 2020). Most small-scale fishers reside in poor communities of Mossel Bay. For the GULLS survey, two participants were from Kwanonqaba, one of two townships 5 km away from central Mossel Bay. The townships face extreme poverty and high unemployment, mainly housing black African residents. The remaining participants are from other parts of Mossel Bay, including some from the suburb D'Almeida. The Mossel Bay area's high fishing profile is threatened by

decreasing catch, increasing costs, slow policy implementation, and a shortage of crew members (Gammage, 2015). For the GULLS surveys, 18 participants represented the small-scale fishers of Mossel Bay, and I used 12 for this study (the other six were omitted due to incomplete or insufficient answers).

3.3 Quantification and Data Organisation

3.3.1 Scoring and quantifying Indicators

Each interview had been recorded, transcribed, and uploaded into a data spreadsheet (see **Figure 3.4a** on page 52 for a summary of the work done for and on the GULLS surveys before this study). When I received the data[12], the surveys were only partially scored. Therefore, I scored many of the answers provided by the participants. I also checked each survey question to ensure each indicator aligned with the original GULLS rationale table (regarding the scoring process and indicator organisation). If the scoring or organisation did not coincide with the GULLS framework, I re-scored or re-organised the answers (a rationale table for the re-scoring or data alterations I did can be found in **Appendix B**).

The survey comprised a blend of question formats, including multiple-choice lists, Likert scales, open-ended questions, numerical answers, and binary (yes or no) questions. Regardless of varying formats, all answers were reduced to a scale of 1-4 to achieve consistent ordinal values. This was achieved by normalising all survey answers, whether they had 2,4 or 5 categories, by dividing four by the number of categories (i.e., a question with six categories was scored in intervals of 0.67). For the sensitivity and exposure categories, a score of 1 represents the most favourable outcome (low sensitivity or low exposure), and a score of 4 represents the worst outcome (high sensitivity or high exposure). For adaptive capacity, the inverse is true (i.e., high adaptive capacity was represented by a 4 and low adaptive capacity by a 1). Therefore, if a community has high scores in sensitivity and exposure, its vulnerability score might be reduced by high scores in adaptive capacity.

[12] When I received the survey dataset, it was also anonymised to comply with the requirements of the ethics clearance (Appendix A).

In the forms of numbers, amounts, and percentages, numerical answers were scored using quantiles (e.g., 0-25% represented by a 1, 26-50% represented by a 2, and so forth). Open-ended questions were converted to a 1-4 scale or were left in their qualitative form to complement quantitative findings. As an example of the quantification process, question 14.1 of the survey is in multiple-choice form and asks the interviewee whether they feel like they belong to their community or town. A greater feeling of belonging indicated a stronger attachment to place, greater social dependence on fishing, and higher sensitivity. The quantification and scoring of the four possible answers are as follows: Strongly belong (score = 4); Belong (score = 3); Slightly belong (score = 2); Not at all belong (score = 1) (a full rationale table behind the framework organisation and scoring process of each question can be found in **Appendix C**).

3.3.2 Indicator selection, Framework Structure, and Calculation

Before analysing previous scores and scoring the remaining survey answers, a rigorous quality control process was carried out. This included checking unusual entries (such as unexpected answers or scores) against the original translated answers and re-organising the answers into the original GULLS grouping of the indicators, subcomponents, and components (when I received the dataset, it was not organised according to the GULLS categories). Additionally, each question and associated answers were analysed and omitted if they were a) not sufficiently answered by the participants, b) not applicable to most participants, and c) not easily quantified to represent the indicator at hand accurately. A full table of the rationale behind any omitted questions and behind any change in the organisation of the framework can also be viewed in **Appendix B**. After quantifying all the questions that were sufficiently answered, averages were calculated for each interviewee and community at the indicator, subcomponent, and component scale. Following this, averages for the sensitivity, exposure, and adaptive capacity categories were obtained and subjected to the following formula to calculate the overall social vulnerability scores: **Social Vulnerability = (Exposure + Sensitivity) – Adaptive Capacity** (Allison et al., 2009; Cinner et al., 2012). Owing to the limited scope of this dissertation and the complexity of the weighting process (Gelman, 2007), I used equal weighting for all components and survey questions. To see a summary of the GULLS data processing I did for this study, see **Figure 3.4b** on page 52.

3.4 Statistical Analyses

Basic descriptive statistics were initially performed to visualise the data. Next, all univariate analyses were undertaken using R-Studio (v4.1.2; R Core Team, 2021) and the following packages: *ggplot2* (Wickham, 2016), *Coin* (Hothorn et al., 2006), and *Dunn's test* (Dinno, 2015). Finally, all multivariate analyses were undertaken using the PRIMER v.6 software (Clarke & Gorley, 2006) with the PERMANOVA+ add-on (Anderson et al., 2008). A visual summary of the statistical analyses applied in this study can be viewed in **Figure 3.4c** on page 52.

3.4.1 Vulnerability differences among southern Cape communities

Determining whether exposure, sensitivity, adaptive capacity, and social vulnerability differ between communities (Question 1, see page 15) indicates whether communities are homogeneous. Whether the communities are homogeneous or not could have management implications. To test for differences in social vulnerability scores in the context of climate change, an Analysis of Similarity (ANOSIM) was performed (ANOSIM; 999 max permutations, correlation method = Speakman rank; model = one-way; type = unordered). Due to the mixed data format, the ANOSIM tests were run on untransformed data subjected to analysis between samples, GOWER[13] dissimilarity resemblance matrix. The ANOSIM test is a robust hypothesis testing framework that ranks the values in a dissimilarity resemblance matrix based on ranks rather than actual distances. The ANOSIM statistic (R-value) is based on permutation and offers a direct measure of the strength of the difference between groups by comparing the mean of ranked dissimilarities between groups to the mean of ranked dissimilarities within groups. A test statistic with an absolute value close to "0" suggests an even permutation distribution within groups. Therefore, it suggests that there is no difference among the groups. In contrast, a test statistic closer to the absolute value of "1.0" indicates dissimilarity between groups and suggests that the groups exist (Anderson & Walsh, 2013). For this study, I use ANOSIM to test against the null hypothesis that there is no difference between the community social vulnerability scores. The ANOSIM test was applied four times to test for community differences among the exposure, sensitivity,

[13] The Gower's distance (or Gower's coefficient) is a metric that is applied to compute pairwise dissimilarities and analyse how different two data sets are. It is appropriate for this study owing to the mixed data types.

adaptive capacity, and overall vulnerability categories. Pairwise comparisons were performed when significant differences were detected.

Alongside the ANOSIM tests, Kruskal-Wallis tests were applied four times to test for community differences among the exposure, sensitivity, adaptive capacity, and overall vulnerability categories. The null hypothesis for the Kruskal-Wallis test is that two populations are equal in terms of their vulnerability scores, which is interpreted as the two populations being equal regarding their central tendency. Non-parametric tests were chosen to accommodate the mixed data type, uneven sample sizes, and non-normal distribution amongst the communities (i.e., the sample size from Melkhoutfontein is much larger than that of other communities)[14]. Moreover, non-parametric tests were chosen because the data violated the criteria for the Shapiro-Wilk normality test, which was applied in the pre-testing phase. When appropriate, a DUNN's post hoc pairwise comparison analysis was applied to determine which communities differed from each other (Dunn, 1964). Both the ANOSIM and Kruskal Wallis tests were performed on the categorical (highest) scale of the framework because the Kruskal Wallis is a univariate statistic based on the actual vulnerability scores. The ANOSIM is a multivariate statistic based on multiple variables based on ranks of distances and dissimilarities. Including both in my analyses made it possible to determine if results are consistent regardless of whether univariate or multivariate methods are applied.

To test for community differences at a smaller scale (at the component level) of the framework, Kruskal-Wallis tests were applied 18 more times, once for each component of vulnerability (see **Figure 3.2** for the full list of components). ANOSIM tests were not applied alongside the Kruskal-Wallis for the component level analyses because both the univariate and multivariate tests run at the higher scale (at the categorical level) gave consistent results.

3.4.2 Potential Influencing Drivers and Community Dispersion

[14] Although sample sizes are uneven, they are representative of the fishers in each community and not a result of research flaws or insufficient sampling.

Determining how cohesive or homogeneous fishers are (in terms of their vulnerability) within and among the southern Cape fishing communities (Question 2, see page 15) and identifying the potential social vulnerability drivers (Question 3, see page 15) play an important role in increasing the knowledge base of the SES, which can contribute to successful adaptation plans that help reduce vulnerability. To characterise community vulnerability scores, visualise the difference among them, and assess how distinct the communities are from one another, a Principal Component Analysis (PCA) was generated for each category (sensitivity, exposure, and adaptive capacity). The PCA is a dimensionality reduction technique in which samples (in this study, interviewee social vulnerability scores) are projected onto a best-fitting plane along with Principal Components (PCs) (Clarke & Gorley, 2006). PCs are axes calculated from eigenvectors and eigenvalues[15] that depict the data's direction and explain the maximal amount of variance. The longer the eigenvector, the greater PC ‘s influence on the vulnerability score at hand.

In addition to the PCAs, Canonical analyses of principal components (CAP) were also performed. In cases where the Principal Components did not sufficiently explain or account for the variation in the data, the CAP was used to visualise better and represent the results. A CAP routine generates a constrained ordination based on distance/dissimilarity matrices (Anderson and Robinson, 2003; Anderson and Willis, 2003) to detect axes that best distinguish the community differences. This test differs from a PCA because a PCA is an unconstrained ordination that looks for the maximum variation in the data, while a CAP is a constrained ordination that detects the maximum separation. Therefore, the CAP can detect differences that are not often apparent in unconstrained ordinations. The CAP analysis generates canonical correlations where the size represents the strength of association between the multivariate data and the hypothesis of group differences (Anderson and Willis, 2003). In the context of this study, the CAP suggests which components best characterise community differences in terms of their adaptive capacity. I ran a CAP analysis on the analysis between samples, GOWER dissimilarity resemblance matrix. Vectors were layered on the CAP ordination using the Spearman rank correlations and the resulting CAP

[15] Eigenvectors represent the directions of the axes that capture the most information/variance of the data, while eigenvalues are coefficients that represent the amount of information/variance associated with each eigenvector.

axes to visualise the results. For a direct measure of relative distinctness between the communities (in terms of their adaptive capacity scores) cross-validation[16] was performed.

3.4.3 Vulnerability Amidst Scales

The scale at which a vulnerability assessment is performed plays an important role in either preserving or omitting information. Therefore, the scale might affect the variation detected among the communities (Question 4, see page 16). The four-scale social vulnerability framework designed by Aswani et al. (2019) was used to test the robustness of the findings at different scales of the GULLS survey data. Data averaged at the Category, Component, Subcomponent, and Indicator scales were tested for homogeneity of dispersion (PERMDISP) and differences in social vulnerability of communities (PERMANOVA). By performing these tests multiple times, one can determine whether and how information changes across scales (for instance, whether more variation is detected at smaller scales).

All survey scores were left untransformed and were subjected to analysis between samples using a GOWER dissimilarity resemblance matrix. To test for homogeneity of multivariate dispersions among the communities, the permutational tests of multivariate dispersion (PERMDISP) were applied (Anderson, 2006; Anderson & Walsh, 2013), with 9999 permutations and a 0.05 significance level. A one-way Permutational Manovas (PERMANOVAS), which detects differences in locations (centroids) of groups, was applied to the same resemblance matrices (PERMANOVA; 9999 permutations, Type III SS, p-values calculated from an unrestricted permutation of the raw data) on the fixed "community" factor. Post-hoc PERMANOVA pairwise comparisons were applied where relevant.

It is valuable to include both the non-parametric PERMDISP and PERMANOVA tests in conjunction because they are complementary procedures. The PERMDISP tests against the null hypothesis of no difference in dispersion among *a priori* groups (Anderson, 2006), while a PERMANOVA is designed to test the null hypothesis of no difference in location of centroids among groups (Anderson et al., 2008). By including both test results in this

[16] Cross-validation is a procedure within the CAP routine that takes each sample (survey score) and tests the models' ability to correctly classify the sample into it's *a priori*-defined groups (communities). The higher the allocation success rate, the more distinct the group (community) (Anderson and Willis, 2003).

analysis, one can tease out whether significant community differences result from centroid location effects (whether they differ according to their mean social vulnerability scores) or are a result of dispersion effects (whether they differ according to their range of social vulnerability scores). Furthermore, one can infer whether scaling up or down through the framework influences the centroid locations or the between and within-group dispersions of the social vulnerability scores. The PERMANOVA and PERMDISP tests unravel whether or not more variation is detected when using smaller scales of the framework and reveal the nature of any potential changes in variation. For example, a significant PERMANOVA and non-significant PERMDISP result show a significant difference in the location of centroids in the community vulnerability scores. However, there is no significant difference in the dispersion of the vulnerability scores within the communities.

To gain further insight regarding how the data may vary (or not) between scales (Question 4, see page 16), RELATE tests were performed to determine whether the changes between scales are significant and to examine the relationship between the datasets when the scores are calculated at different scales. The RELATE test was performed three times to compare Category and Component, Component and Subcomponent, and Subcomponent and Indicator scores. It must be borne in mind that these datasets are not independent of each other (because they are all based on the same interview answers), and the RELATE test usually runs on independent datasets. However, I am not using the test in its usual application (i.e. to test for the best model). Here, the RELATE test is used to explore the differences in the data structure when the data are aggregated at different scales.

A RELATE analysis measures how closely two datasets are related by using Spearman's Rho to test the strength of the relationship between two sets of multivariate data (Clarke and Gorley, 2006). The test runs under the null hypothesis that there is no relationship between two similarity matrices. The RELATE tests were based on the GOWER resemblance matrices using the fixed community factor, 999 permutations, and Spearman's rank correlation. Additionally, to visualise the social vulnerability scores when calculated at the different levels of the GULLS framework, non-metric MDS ordinations were generated for the scores at each scale. A visual summary of the evolution of the South Africa GULLS surveys from the

creation of the framework to the statistical analyses applied in this study is shown in **Figure 3.4** below.

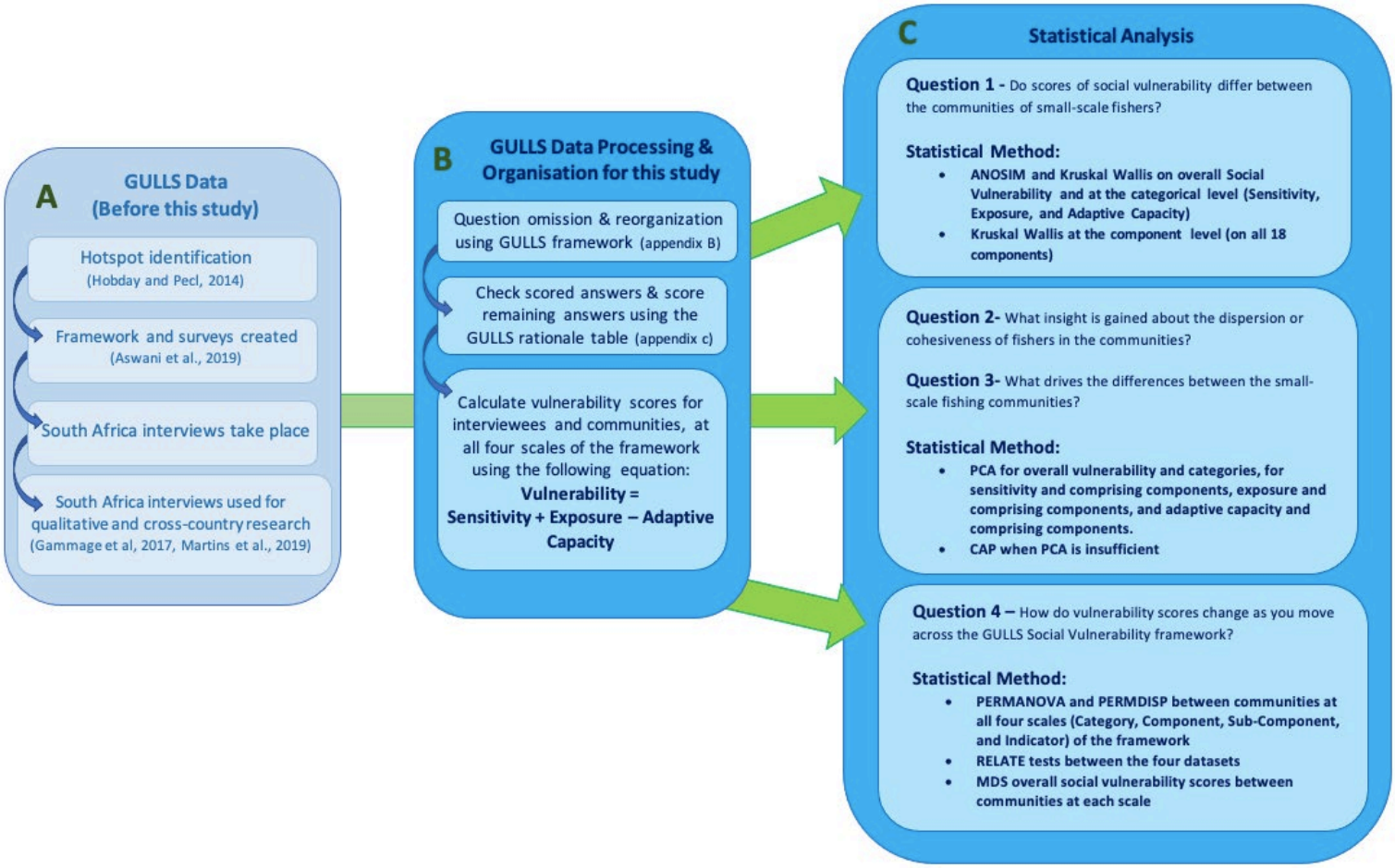

Figure 3.4 Flow chart showing A) the work done for and on the GULLS surveys before my study, B) the data organisation and quantification that I did with the GULLS surveys, and C) the statistical methods that I applied to answer the four research questions of this thesis.

CHAPTER 4: Results

Key demographic aspects of the communities are shown in **Table 4.1**. Overall, 59 surveys were used for the study. All participants were male, all but one participant spoke Afrikaans as their first language, all but three participants were coloured, both the average and the median age were 29 years (range 27-71), and 88% of the participants relied on fishing as their primary source of income.

Table 4.1 Key demographic features of the communities (adapted from Gammage, 2019 and based on STATS SA Census data).

	Bitouville	Melkhoutfontein	Mossel Bay (Kwanonqaba)	Mossel Bay (greater than Kwanonqaba)	Slangrivier	Vermaaklikheid
Estimated Population (Count)	515	2533	27561	29887	3011	356
Number of Households (Count)	206	614	8791	9033	688	99
Predominant Population Group (%)	Coloured (54%)	Coloured (99%)	Black African (67%)	Coloured (52%)	Coloured (96%)	Coloured (% Unknown)
Predominant First Language (%)	Afrikaans (93%)	Afrikaans (95%)	isiXhosa (54%)	Afrikaans (81%)	Afrikaans (96%)	Afrikaans (% Unknown)
Estimated Number of Fishing Households (n=111)	13	35	45	(included in KwaNonqaba estimate)	6	12
Number of Households Surveyed (n=59)	10 (77%)	25 (72%)	12 (27%)	(included in KwaNonqaba estimate)	3 (50%)	9 (75%)

The mean social vulnerability score for all fishers in this study was 2.75. The mean for each component, category, and the overall social vulnerability score for each community is shown in **Table 4.2**. Also shown is the number of indicators each component and category are based upon.

Table 4.2 Average social vulnerability index results by category and community (MK: Melkhoutfontein, V: Vermaaklikheid, B: Bitouville, S: Slangrivier, MB: Mossel Bay). The colour is according to value, binned into equal class size. For sensitivity, exposure, and overall social vulnerability indices: green 1.00-1.74; yellow 1.75-2.49; orange 2.50-3.24; red 3.25-4.00. The inverse is true for the adaptive capacity indices: green 3.25-4.00; yellow 2.50-3.24; orange 1.75-2.49; and red 1.00-1.74. Also shown is the number of indicators that are used to calculate each component and category.

Categories	Components	MK	V	B	S	MB	Average	Median
Sensitivity	Social dependence on fishing **(S.SDoF)**	2.88	3.08	2.83	2.71	2.84	2.87	2.84
	Historical and Cultural dependence on fishing **(S.HCDoF**	2.41	2.62	2.50	2.33	2.48	2.47	2.48
	Economic dependence on fishing **(S.EDoF)**	2.22	2.14	2.01	2.06	2.24	2.13	2.14
	Economic dependence on other resources **(S.ED)**	3.20	2.95	2.79	3.32	3.31	3.11	3.20
	Overall Sensitivity	**2.67**	**2.69**	**2.53**	**2.60**	**2.72**	**2.64**	**2.67**
Exposure	Environmental Change **(E.EC)**	2.81	3.11	2.63	3.17	3.28	3.00	3.11
	Personal Exposure **(E.PE)**	1.90	1.96	1.85	1.88	1.98	1.92	1.90
	Attitude and Perception **(E.AaP)**	2.88	2.96	2.48	2.50	3.05	2.77	2.88
	Overall Exposure	**2.53**	**2.68**	**2.32**	**2.39**	**2.77**	**2.54**	**2.53**
Adaptive Capacity	Natural Capital **(AC.NC)**	1.98	2.09	2.18	1.73	1.66	1.93	1.98
	Human Capital **(AC.HC)**	2.19	2.38	2.49	2.90	2.21	2.43	2.38
	Social Capital **(AC.SC)**	2.35	2.50	2.56	2.97	2.16	2.51	2.50
	Bridging Social Capital **(AC.BSC)**	2.10	1.72	2.35	1.00	1.29	1.69	1.72
	Physical Capital **(AC.PC)**	2.88	2.55	3.01	2.66	2.76	2.77	2.76
	Financial Capital **(AC.FC)**	2.56	2.91	2.86	2.82	2.54	2.74	2.82
	Personal Flexibility **(AC.PF)**	2.61	2.76	2.67	2.77	2.51	2.66	2.67
	Attitude and Perception **(AC.AaP)**	3.15	2.94	2.65	2.90	3.18	2.96	2.94
	Occupational flexibiltiy **(AC.OF)**	2.74	2.84	2.91	2.65	2.63	2.75	2.74
	Institutional Support **(AC.IS)**	2.72	2.42	2.52	2.30	2.24	2.44	2.42
	Institutional flexibility **(AC.IF)**	2.22	2.02	2.25	2.22	2.04	2.15	2.22
	Over all Adaptive Capacity	**2.50**	**2.47**	**2.59**	**2.45**	**2.29**	**2.46**	**2.47**
Vulnerability		**2.71**	**2.90**	**2.27**	**2.55**	**3.20**	**2.72**	**2.71**
Rank		3	2	5	4	1		

Figure 4.1 shows boxplots for the overall social vulnerability per community and each category (sensitivity, exposure, and adaptive capacity).

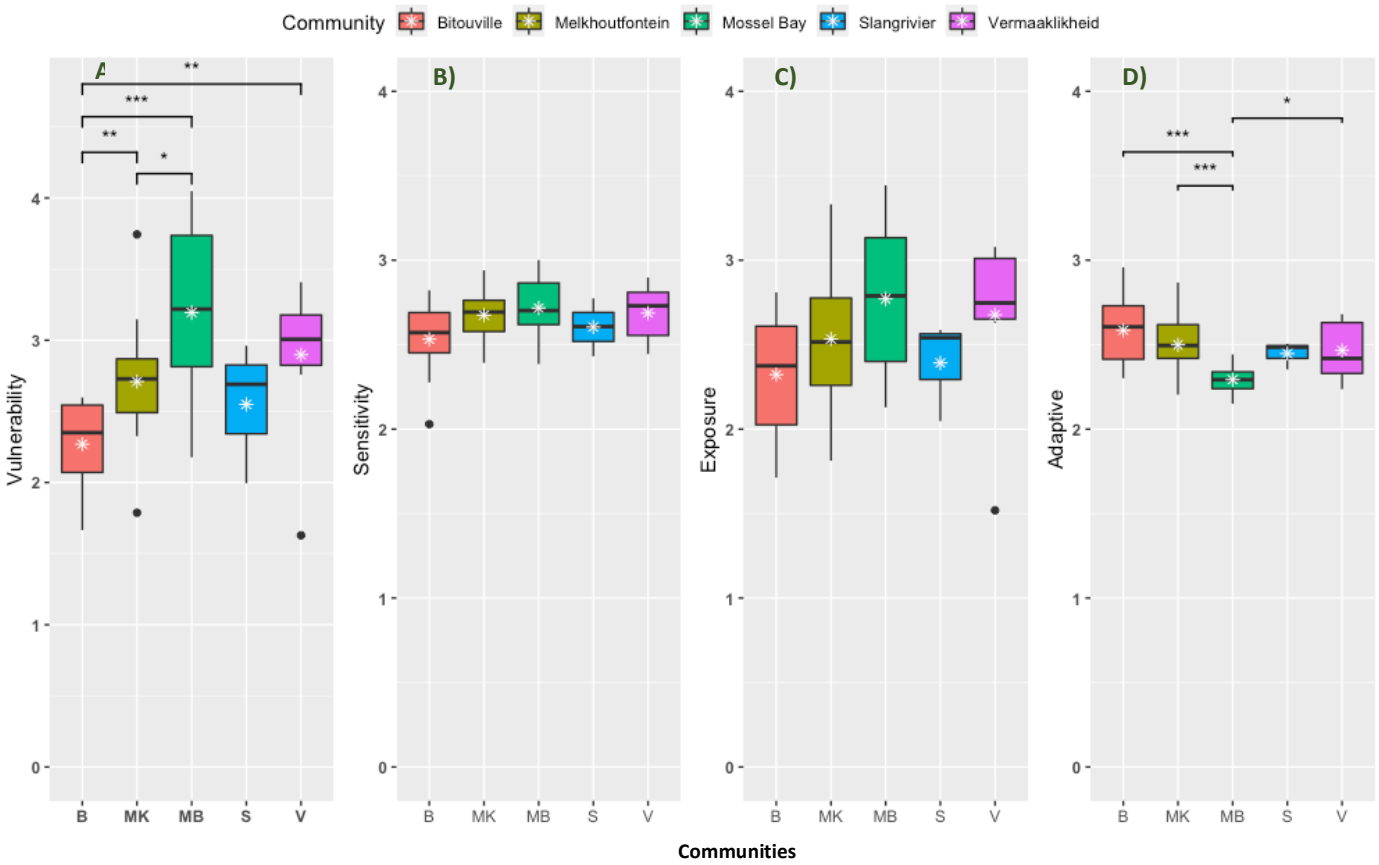

Figure 4.1 Boxplots showing A) social vulnerability, B) sensitivity, C) exposure, and D) adaptive capacity for all five small-scale fishing communities. The box itself represents the Interquartile range (IQR), so the box edges represent the 25th and 75th percentiles. The whiskers are the maximum and the minimum of 1.5 times the IQR. The line in the centre of each box is the median and the white stars in the middle of the boxes represent the mean. The brackets above the plots represent the pairwise comparisons that are significantly different. The asterisk above the brackets represent how significant the differences are (one asterisk indicates a p-value of 0.01-0.05, two asterisks indicate p<0.01 and three asterisks indicate p<0.001. The dots represent the outliers.

I will report my findings in sections for the remainder of this chapter. First, I will delve into the similarities and differences of the overall social vulnerability scores among the fishing communities. To unravel the differences detected among the communities, I will focus on each category individually, with sections for sensitivity, exposure, and adaptive capacity. Lastly, I will report the findings concerning the importance of scale within the GULLS social vulnerability framework.

4.1 Social Vulnerability

The social vulnerability scores were based on 189 indicators binned into 79 subcomponents, 18 components, and three categories (sensitivity, exposure, and adaptive capacity) (**Table 4.2**). The most vulnerable community was Mossel Bay, followed by Vermaaklikheid, Melkhoutfontein, Slangrivier, and Bitouville as the least vulnerable community (**Figure 4.1.A**). Mossel Bay was the most vulnerable (3.20) community because it had the highest exposure (2.77), highest sensitivity (3.28), and the lowest adaptive capacity scores (2.29). Contrarily, Bitouville was the least vulnerable (2.27) community because it scored the lowest in exposure (2.32) and sensitivity (2.53) while scoring the highest in adaptive capacity (2.59).

There is sufficient evidence that there is a significant difference in social vulnerability among the communities (ANOSIM, R=0.229, $p<0.05$) and that the communities are not equal in terms of their social vulnerability scores (Kruskal Wallis, X^2 =18.95, df=4, $p<0.05$) (**Figure 4.2**, also see **Appendix D** for ANOSIM results). Mossel Bay is significantly different from Melkhoutfontein ($p<0.05$) and Bitouville ($p<0.05$) and then Bitouville is significantly different from Vermaaklikheid ($p<0.05$) and Melkhoutfontein ($p<0.05$). Slangrivier is not significantly different from any other community. The Kruskal Wallis and ANOSIM tests detected significant differences for the same pairwise comparisons (**Appendix E.1.**). As an additional visual reference, see **Appendix I** for Radar plots for overall social vulnerability and each category.

To unravel which categories (and which of their components) contribute most to the differences between the community's social vulnerability, to test for differences at the component scale, and to better understand the different categories and components of social vulnerability, I analyse each category individually (sensitivity, exposure, and adaptive capacity).

4.2 Sensitivity

The sensitivity category comprises 42 indicators, 14 subcomponents, and 4 components (**Table 4.2**).

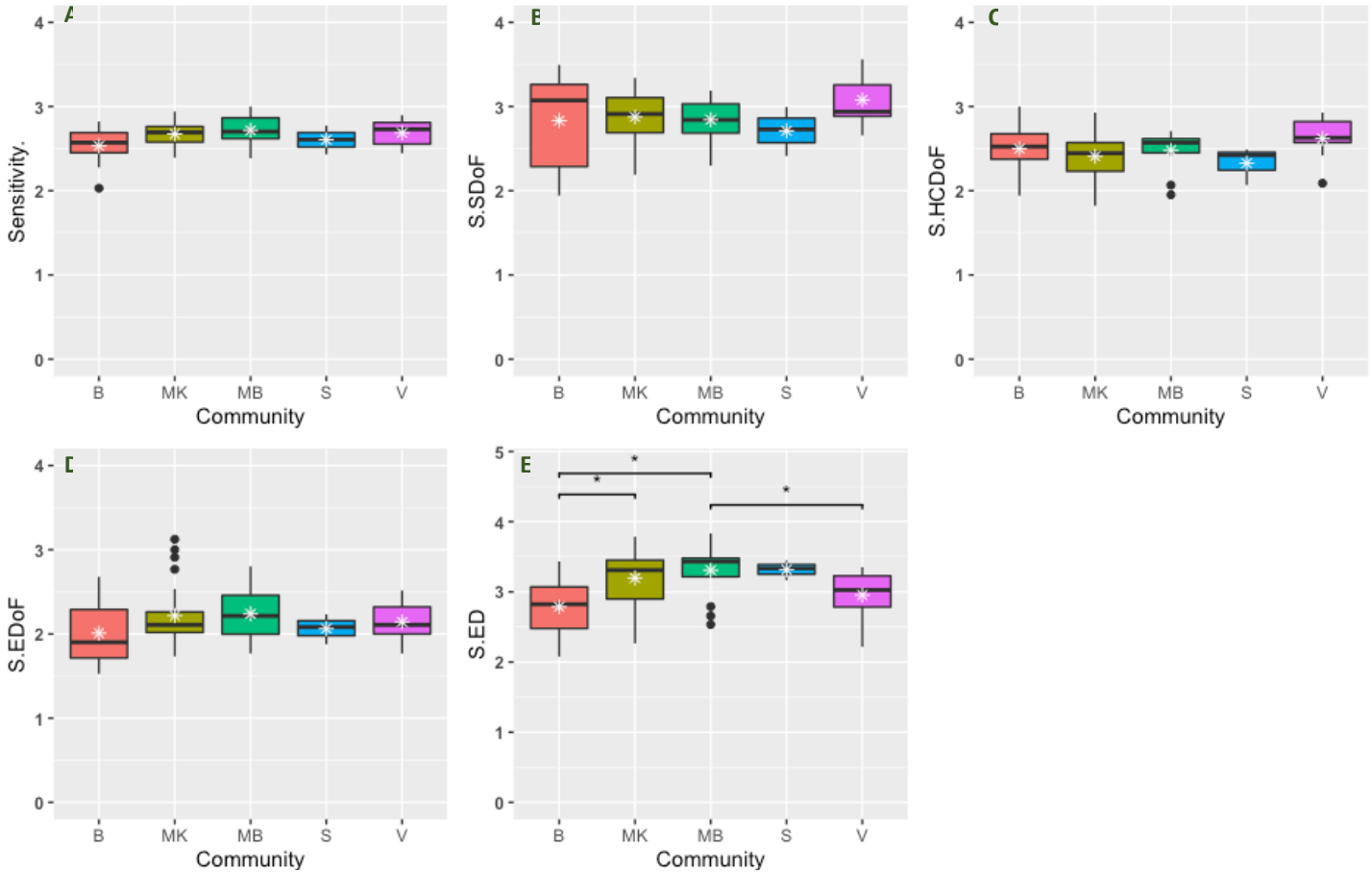

Figure 4.3 Boxplot showing A) sensitivity and the comprising components of sensitivity B) Social dependence on fishing, C) Historical and cultural dependence on fishing, D) Economic dependence on fishing, and E) Economic dependence on other resources, scores between the communities. The box itself represents the Interquartile range (IQR), so the box edges represent the 25th and 75th percentiles. The whiskers are the maximum and the minimum of 1.5 times the IQR. The line in the centre of each box is the median and the white stars in the middle of the boxes represent the mean. The brackets above the plots represent the pairwise comparisons that are significantly different. The asterisk above the brackets represent how significant the differences are (one asterisk indicates a p-value of 0.01-0.05, two asterisks indicate p<0.01 and three asterisks indicate p<0.001. The dots represent the outliers.

For the overall sensitivity scores, there is no significant difference between communities (ANOSIM, R=0.077, p>0.05), nor are they equal in terms of their sensitivity scores (Kruskal Wallis, X^2=4.12, df=4, p>0.05) (**Figure 4.3a**, see also **Appendix D** for ANOSIM results). Out of all the comprising sensitivity components, the Economic dependence on other resources (S.ED) component was the only component where communities were significantly different (Kruskal Wallis, X^2=11.25, df=4, p<0.05) (**Figure 4.3e**) (see **Appendix F** for a table of results

at the component level). This can be visualised in the Principal Component Analysis (PCA) ordination, where there is no clear community separation, and there is a high overlap in the data (**Figure 4.4**), but there is a strong influence by the S.ED (Economic dependence on other resources) component.

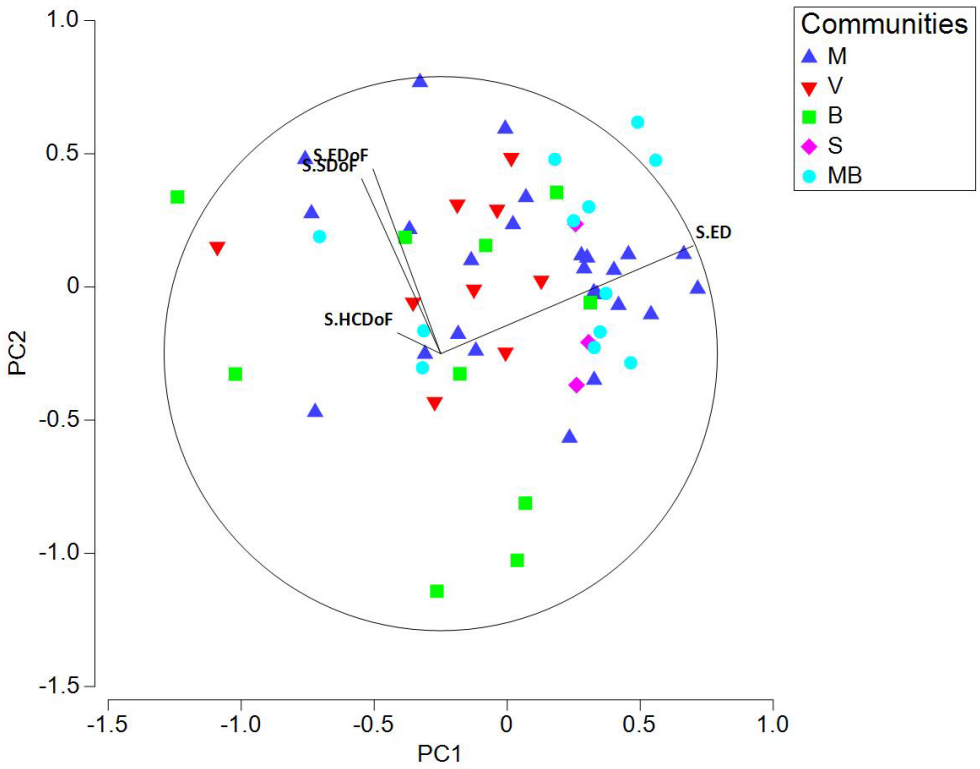

Figure 4.4. Principal component analysis (PCA) of the sensitivity category. S.SDoF (Social dependence on fishing); S.EDoF (Economic dependence on fishing); S.HCDoF (Historical and cultural dependence on fishing); and S.ED (Economic dependence on other resources).

The PCA is a good representation of the sensitivity data because the first three PCs account for a high amount of variation in the data (PC1=39.1 %, PC2=28.5%, PC3=18.5%). Based on a 0.913 correlation coefficient, PC1 is primarily a measure of the Economic dependence of other resources (S.ED) component. Therefore, communities with a higher PC1 score have a higher score for the S.ED component and a higher sensitivity score. PC2 increases with the S.EDoF and S.SDoF components and can therefore be viewed as a measure of how sensitive an interviewee is based on their Economic dependence on fishing (S.EDoF) and their Social dependence on fishing (S.SDoF) scores. The latter two components are still the most important in PC3. However, there is an increasing contribution of their Historical and cultural dependence on fishing (S.HCDoF) (**Appendix G**). It can be observed that Melkhoutfontein, Mossel Bay, and Slangrivier are most influenced by the Economic

dependence on other resources (S.ED) component (**Figure 4.4**). Otherwise, there is no clear pattern or contribution of any particular component toward Vermaaklikheid and Bitouville.

4.3 Exposure

The exposure category is split into 40 indicators, 17 subcomponents, and 3 components (**Table 4.2**).

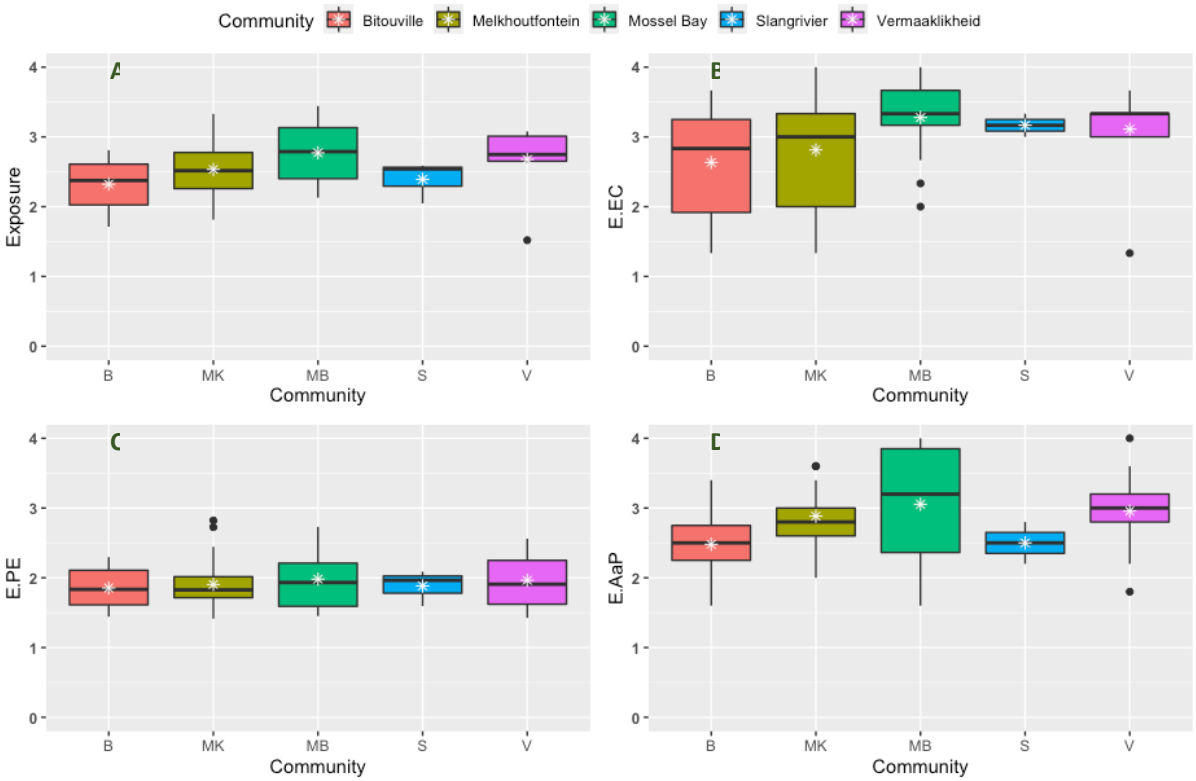

Figure 4.5 Boxplot showing A) exposure, and the comprising components of exposure B) Environmental Change, C) Personal Exposure, and D) Attitude and perception, scores between the communities. The box itself represents the Interquartile range (IQR), so the box edges represent the 25th and 75th percentiles. The whiskers are the maximum and the minimum of 1.5 times the IQR. The line in the centre of each box is the median and the white stars in the middle of the boxes represent the mean. The brackets above the plots represent the pairwise comparisons that are significantly different. The asterisk above the brackets represent how significant the differences are (one asterisk indicates a p-value of 0.01-0.05, two asterisks indicate p<0.01 and three asterisks indicate p<0.001. The dots represent the outliers.

There is no significant difference among the communities (ANOSIM, R=0.037, p>0.05) nor are they equal in terms of their exposure scores (Kruskal Wallis, X^2=8.00, df=4, p>0.05) (**Figure 4.5a**, see also **Appendix D** for ANOSIM results). Likewise, there is no significant difference among communities regarding the exposure components (see **Appendix F** for a table of results at the component level). This can be visualised in Principal Component Analysis (PCA) ordination, where there is little segregation among the communities (**Figure 4.6**).

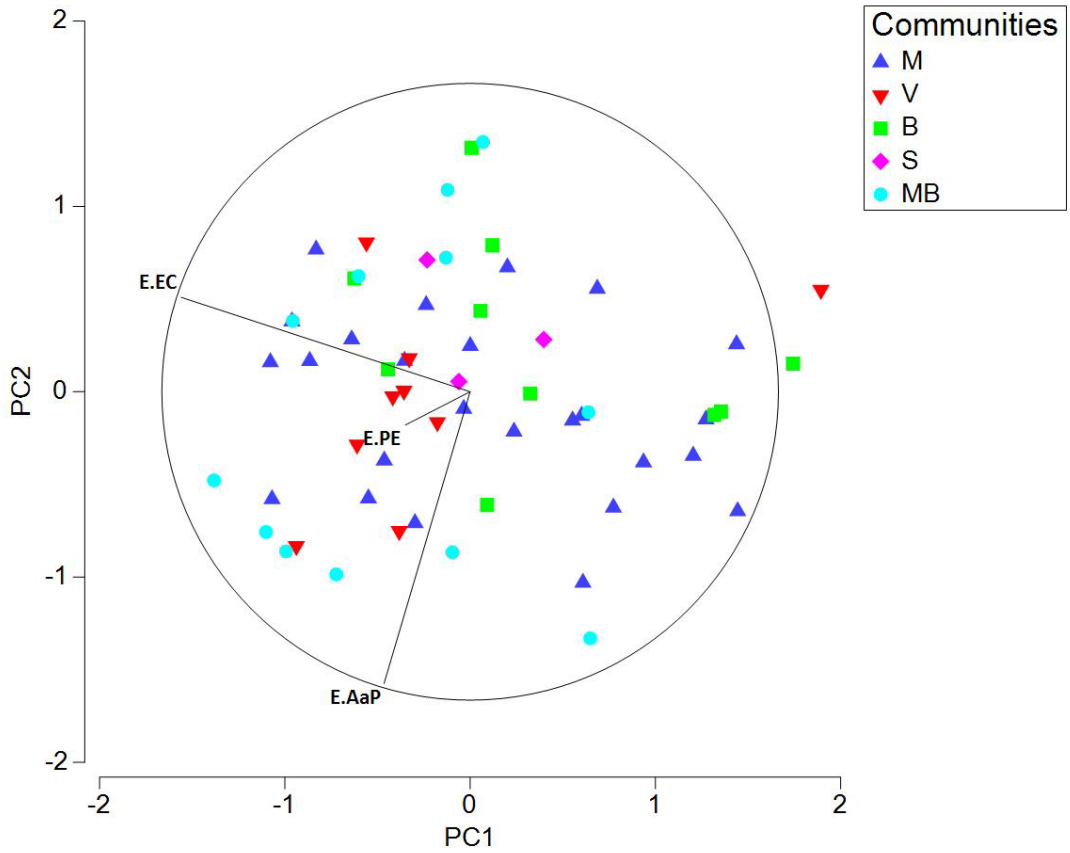

Figure 4.6 Principal component analyses (PCA) of the Exposure category. E.EC (Environmental change); E.PE (Personal exposure); E.AaP (Attitude and perception).

The PCA represents the exposure dataset well because most of the variation can be explained by the first two Principal Components (PC1=57.4%, PC2=33.2 %). Based on a correlation coefficient of 0.937, PC1 is primarily a measure of the Environmental change (E.EC) component. PC2 is mostly a measure of the Attitude and perception (E.AaP) component due to a correlation coefficient of 0.946. Therefore, participants with survey scores further along the x-axis are more influenced by Environmental change, while participants with scores further along the y-axis are more influenced by the Attitude and perception of their exposure and climate change. Otherwise, the Personal exposure (E.PE) component has a comparably small contribution to the exposure scores (**Appendix G**).

4.4 Adaptive Capacity

The adaptive capacity category is composed of 107 indicators which are split up into 48 subcomponents and 11 components (**Table 4.2**).

Figure 4.7 Boxplot showing A) Adaptive capacity, and the comprising components B) Natural capital, C) Human capital, D) Social capital, E) Bridging social capital, F) Physical capital, G) Financial capital, H) Personal flexibility, I) Attitude and perception, J) Occupational flexibility, K) Institutional support, and L) Institutional flexibility, scores between the communities. The box itself represents the Interquartile range (IQR), so the box edges represent the 25th and 75th percentiles. The whiskers are the maximum and the minimum of 1.5 times the IQR. The line in the centre of each box is the median and the white stars in the middle of the boxes represent the mean. The brackets above the plots represent the pairwise comparisons that are significantly different. The asterisk above the brackets represent how significant the differences are (one asterisk indicates a p-value of 0.01-0.05, two asterisks indicate p<0.01 and three asterisks indicate p<0.001. The dots represent the outliers.

There is sufficient evidence that there are significant differences among community adaptive capacity scores (ANOSIM, R=0.172, p<0.05) and that some communities are equal in their adaptive capacity scores (Kruskal Wallis, X^2=15.95, df=4, p<0.05) (**Figure 4.7a**, also see **Appendix D** for ANOSIM results). Mossel Bay's adaptive capacity is significantly different

from the adaptive capacity of Bitouville ($p<0.05$), Vermaaklikheid ($p<0.05$), and Melkhoutfontein ($p<0.05$). Up to this point, the ANOSIM and Kruskal Wallis gave similar results and were in agreement regarding pairwise comparisons and significant differences. However, for adaptive capacity pairwise comparisons, the ANOSIM identified two additional pairwise comparisons as significantly different (**Appendix E.2.**). According to the ANOSIM and not the Kruskal Wallis, Melkhoutfontein's adaptive capacity is significantly different from those of Bitouville ($p<0.05$) and Slangrivier ($p<0.05$).

Regarding the component level for adaptive capacity, there were four out of the 11 components that were significantly different between the communities: Human capital (AC.HC) (Kruskal Wallis, X^2=11.07, df=4, $p<0.05$) (**Figure 4.7c**), Bridging social capital (AC.BSC) (Kruskal Wallis, X^2=14.33, df=4, $p<0.05$) (**Figure 4.7e**), Physical capital (AC.PC) (Kruskal Wallis, X^2=16.86, df=4, $p<0.05$) (**Figure 4.7f**), and Institutional support (AC.IS) (Kruskal Wallis, X^2=12.37, df=4, $p<0.05$) (**Figure 4.7k**). See **Appendix F** for a table of results at the component level.

The data variability was not readily reduced using a PCA, as the first five PCs only explained a small fraction of the data (cumulative 75.3%) and did not represent the data well (see **Appendix G** for PCA results). Therefore, I generated a CAP analysis where only 4 axes are needed to distinguish the five communities (**Figure 4.8**). Bitouville is the most distinct with the highest allocation success rate (80%) under the cross-validation. Slangrivier, Melkhoutfontein, and Mossel Bay show smaller allocation success rates (66.7%, 60.0%, and 58.3%), while Vermaaklikheid has an allocation success rate of 0%. The first two axes in the CAP analysis have the highest canonical correlation (Δ_1=0.685, Δ_2=0.620) while the last two axes have relatively low canonical correlations (Δ_3=0.402, Δ_4=0.344), which indicates greater group differences that are mostly separated by the first and second canonical axes. It can be observed that the components with the longest axes best characterise the differences in adaptive capacity among the communities: Attitude and perception (AC.AaP), Human capital (AC.HC), Bridging social capital (AC.BSC), Institutional support (AC.IS), and Financial capital (AC.FC) (**Figure 4.8**).

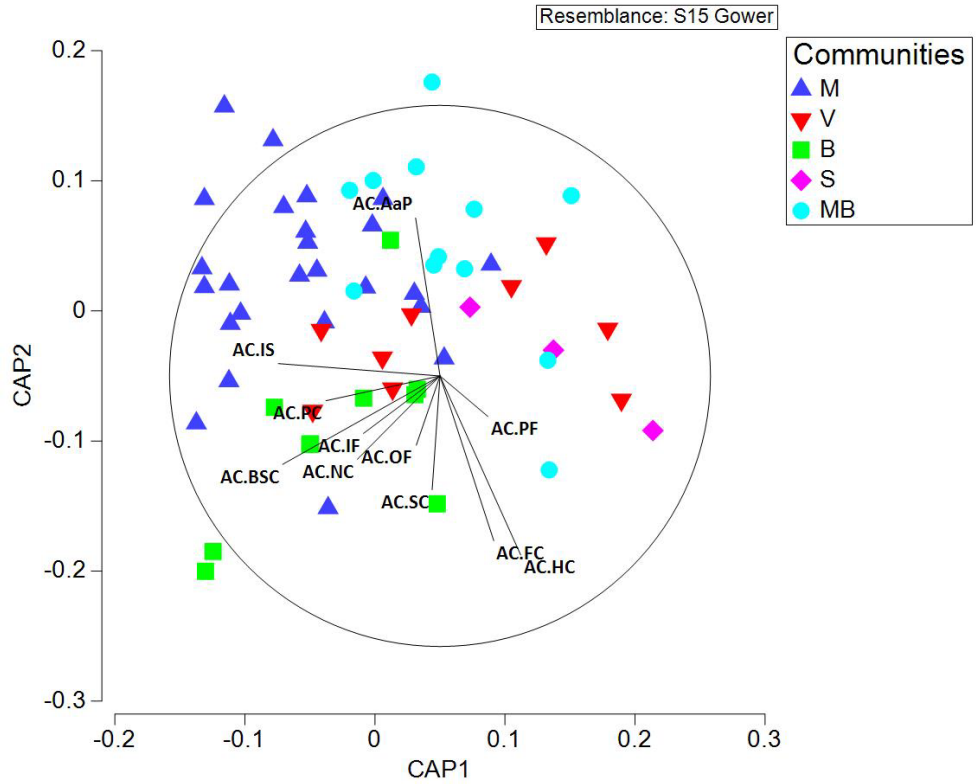

Figure 4.8 Canonical Analysis of Principal Coordinates (CAP) of the Adaptive capacity category. AC.AaP (Attitude and perception); AC.IS (Institutional support); AC.PC (Personal capital); AC.BSC (Bridging social capital); AC.IF (Institutional flexibility); AC.NC (Natural capital); AC.OF (Occupational flexibility); AC.SC (Social capital); AC.FC (Financial capital); AC.HC (Human capital); AC.PF (Personal flexibility).

4.5 GULLS Social Vulnerability across Scales

There is no significant difference in dispersion among the communities in terms of the overall community vulnerability scores at all levels of the four-scale framework (PERMDISP, F = 1.01-1.17, p>0.05). On the other hand, the PERMANOVA test indicated a significant difference in community vulnerability scores at all scales (**Table 4.3**).

Table 4.3 Results of the PERMANOVA and DERMDISP tests for each community comparison at all four scales (category, component, subcomponent, and indicator), showing whether the null hypotheses of no difference was accepted or rejected the based on a P-value less than 0.05 generated from each test.

	Category		Component		Subcomponent		Indicator	
	PERMANOVA	PERMDISP	PERMANOVA	PERMDISP	PERMANOVA	PERMDISP	PERMANOVA	PERMDISP
MK, V	Accept	Accept	REJECT	Accept	REJECT	Accept	REJECT	Accept
MK, B	Accept	Accept	REJECT	Accept	REJECT	Accept	REJECT	Accept
MK, S	Accept	Accept	REJECT	Accept	Accept	Accept	REJECT	Accept
MK, MB	REJECT	Accept	REJECT	Accept	REJECT	Accept	REJECT	Accept
V, B	Accept	Accept	REJECT	Accept	REJECT	Accept	REJECT	Accept
V, S	Accept	Accept	Accept	Accept	Accept	Accept	Accept	Accept
V, MB	Accept	Accept	Accept	Accept	REJECT	Accept	REJECT	Accept
B, S	Accept	Accept	Accept	Accept	Accept	Accept	Accept	Accept
B, MB	REJECT	Accept	REJECT	Accept	REJECT	Accept	REJECT	Accept
S, MB	Accept	Accept	Accept	Accept	Accept	Accept	REJECT	Accept

The PERMANOVA pairwise comparison tests for all four scales depict how variation generally increases as one scales down the framework (category to indicator) (**Table 4.4**). As one would expect, the smaller the scale of the framework, the more information will be preserved, and the more variation will be detected.

Table 4.4 PERMANOVA results of social vulnerability scores based on the A) categorical scale, B) component scale, C) sub-component scale, and D) indicator scale among the five southern cape SSF communities: Melkhoutfontein (MK), Vermaaklikheid (V), Bitouville (B), Slangrivier (S), and Mossel Bay (MB). Number of permutations ranged from 219 to 9929. The yellow highlights represent the significant pairwise comparisons.

A

PERMANOVA

Among Communities	df	Sum Sq	Pseudo-F	P(perm)
Community	*4*	*3180.3*	*2.70*	*0.0036*
Residual	*54*	*15887*		

Pairwise Test	t	P(perm)
MK, V	*0.76*	*0.62*
MK, B	*1.27*	*0.20*
MK, S	*0.57*	*0.77*
MK, MB	*2.43*	*0.00*
V, B	*1.42*	*0.14*
V, S	*0.93*	*0.49*
V, MB	*1.55*	*0.09*
B, S	*0.54*	*0.81*
B, MB	*2.88*	*0.00*
S, MB	*1.59*	*0.10*

B

PERMANOVA

Among Communities	df	Sum Sq	Pseudo-F	P(perm)
Community	*4*	*2601.2*	*2.42*	*0.0001*
Residual	*54*	*14531*		

Pairwise Test	t	P(perm)
MK, V	*1.62*	*0.001*
MK, B	*1.69*	*0.000*
MK, S	*1.62*	*0.005*
MK, MB	*1.53*	*0.007*
V, B	*1.37*	*0.034*
V, S	*1.34*	*0.055*
V, MB	*1.30*	*0.085*
B, S	*1.24*	*0.112*
B, MB	*1.93*	*0.000*
S, MB	*1.35*	*0.058*

C

PERMANOVA

Among Communities	df	Sum Sq	Pseudo-F	P(perm)
Community	*4*	*4173.2*	*2.80*	*0.0001*
Residual	*54*	*20098*		

Pairwise Test	t	P(perm)
MK, V	*1.57*	*0.000*
MK, B	*1.91*	*0.000*
MK, S	*1.17*	*0.104*
MK, MB	*1.88*	*0.000*
V, B	*1.39*	*0.004*
V, S	*1.03*	*0.378*
V, MB	*1.90*	*0.000*
B, S	*1.20*	*0.06*
B, MB	*2.27*	*0.000*
S, MB	*1.24*	*0.078*

D

PERMANOVA

Among Communities	df	Sum Sq	Pseudo-F	P(perm)
Community	*4*	*4641.3*	*2.56*	*0.0001*
Residual	*54*	*24447*		

Pairwise Test	t	P(perm)
MK, V	*1.57*	*0.000*
MK, B	*1.84*	*0.000*
MK, S	*1.21*	*0.044*
MK, MB	*1.71*	*0.000*
V, B	*1.36*	*0.005*
V, S	*1.19*	*0.081*
V, MB	*1.76*	*0.000*
B, S	*1.23*	*0.064*
B, MB	*2.05*	*0.000*
S, MB	*1.32*	*0.017*

This is visualised in **Figure 4.9**, where the communities are more distinctly grouped at smaller scales (indicator) compared to the framework's higher scales (category). The RELATE test coincided well with the findings of increased detected variation at smaller scales (confirmed by PERMANOVA results). However, owing to the limited space in this mini-dissertation and the complexity of the analogy of vulnerability scales in place of species

composition for the RELATE tests, I will not report the details of the test here (see **Appendix H** for RELATE results).

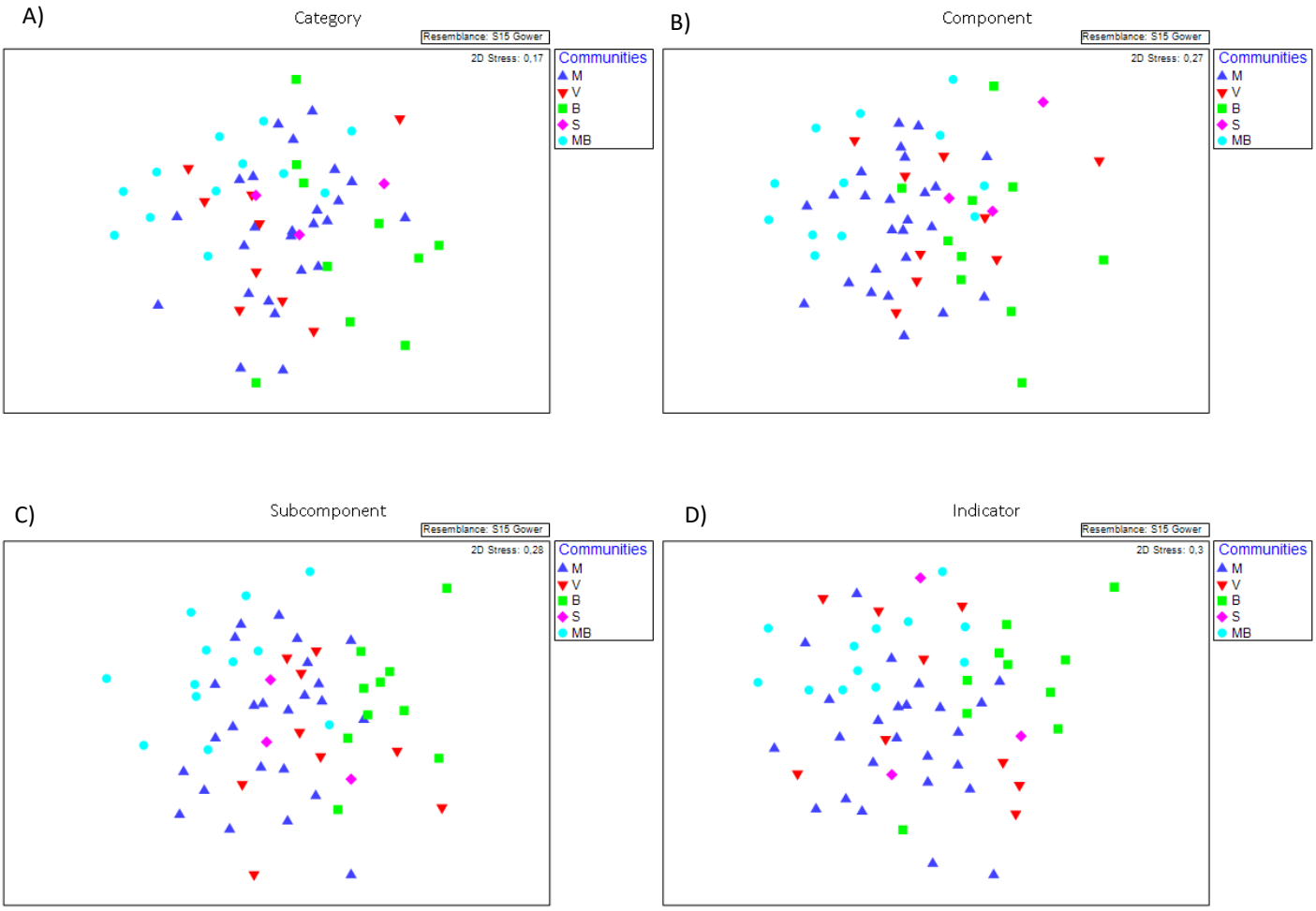

Figure 4.9 Non-metric MDS ordinations of the social vulnerability scores derived from different scales of the GULLS framework: A) category, B) component, C) subcomponent, D) indicator.

CHAPTER 5: Discussion

The analyses presented in this study provide a quantitative vulnerability assessment for the southern Cape handline fishers at a town/regional scale and in the context of fishers' perception of climate change in their immediate area. This assessment uses bottom-up methods to present a baseline for addressing the similarities and differences in SSF social vulnerability in the southern Cape handline fishery and to answer the four primary questions of this study. For this discussion, the overarching social vulnerability results are briefly discussed before discussing the categories (sensitivity, exposure, and adaptive capacity) in more detail. Whether the categories differ among the communities (Question 1) and how variable the scores are within the communities (Question 2) will be discussed for each category. The adaptive capacity category will be given the most attention because the results show it drives the differences among the communities (Question 3). This chapter concludes with a discussion on the implications for issues of scales (Question 4) before outlining some of the next steps for future work.

5.1 Social Vulnerability

The fishing communities differed significantly in their overall social vulnerability scores. The SSFs of Mossel Bay were the most vulnerable, while the SSFs of Bitouville were the least vulnerable. These differences were driven by their contrasting adaptive capacities (examined in section 5.1.3). These results are consistent with the qualitative results from Gammage (2015), who argued that these communities of fishers are non-homogenous, with the ability to respond to change responsible for the differentiation between the communities.

When looking into the categorical scales of the GULLS social vulnerability framework, sensitivity (discussed in section 5.1.1) was the main driver of social vulnerability for all the fishers in the study, and sensitivity scores did not differ significantly amongst them. The sensitivity category encapsulates economic, social, and historical components. Since the southern Cape fishers' livelihoods are affected most by social governance and economic stressors (see section 2.4), like many other SSFs around the globe, these results are consistent with what is known about these fishers (Sowman, 2006; Isaacs, 2006; Béné, 2009;

Gammage et al., 2017a, 2017b; Sowman & Raemaekers, 2018; Martins et al., 2019). Exposure scores were similar for all the fishers on both the categorical and component levels (section 5.1.2), which is expected owing to the large-scale impacts of climate change and the smaller (coastal) scale of this study. While sensitivity and exposure scores were similar amongst the fishing communities, adaptive capacity (section 5.1.3) was significantly different, driving and shaping the differences in vulnerability. The three categories are discussed below, and the most deliberation is given to the category where the most nuance resides: adaptive capacity.

5.1.1 Sensitivity

In earlier vulnerability frameworks, the concept of sensitivity is often solely represented by economic indicators (Allison & Horemans, 2006; Allison et al., 2009). The GULLS framework additionally considers historical, cultural, and social components to achieve a more comprehensive view of vulnerability through the lens of climate change (Aswani et al., 2019). At the framework's highest level (category), sensitivity was the strongest driver of vulnerability for all the fishers, and scores did not differ significantly. These results were expected as other analyses have also identified socio-economic pressures as the most urgent for coastal communities in the southern Benguela (Raemaekers et al., 2016; Gammage et al., 2017a, 2019; Sowman & Raemaekers, 2018; Kainge et al., 2020).

However, when scaling down and analysing at the component level, one of the four sensitivity components[17] differed between the fishing communities: The economic dependence on other resources (S.ED) component (refer to **Figure 4.3**). The S.ED indices take account of self-sufficiency (i.e., dependency on shops for food sources, distance to markets, ownership of gardens, consumption of one's catch, etc.). Bitouville fishers had the lowest S.ED score (were the least vulnerable) out of all the fishing communities due to their diverse ways of securing food sources, making them less dependent on shops and markets. To illustrate, at the time of the survey, all but one of the fishers in Bitouville had and ate from their gardens. On the other hand, Mossel Bay fishers had the highest scores for this

[17] The four sensitivity components include economic dependence on fishing, economic dependence on other resources, social dependence on fishing, and historical and cultural dependence on fishing.

component partly because none owned a garden or consumed their catch at the time. Therefore, based on the GULLS rationale (see **Appendix C**), the sensitivity of Mossel Bay fishers is mainly driven by their low self-sufficiency and high dependence on shops and markets for food security. These results are expected because they live in an urban setting, with limited space for gardens and proximity to shops and other infrastructure (Ward et al., 2022).

Two of the sensitivity components were primarily driving sensitivity and vulnerability for all the fishers in this study: Economic dependence on other resources (S.ED) (also driving the differences between fishing communities) and social dependence on fishing (S.SDoF). The S.SDoF indices consider the level of attachment to communities (i.e., feeling of belonging, the importance of friendships, etc.), attachment to fishing as an occupation (i.e., degree of pride as a fisher, occupational diversity, etc.), and amount of dependence on and interactions with others to fish. The fishers' strong attachment to their communities is apparent in other analyses from the southern Cape (for example, Gammage, 2015 observed a strong spirit of "Ubuntu", particularly in Vermaaklikheid) and may indicate that fishers are less likely to migrate to find alternative work if fishing fails them as a viable source of income (Gammage, 2015). An attachment to a community or place is not unique to the southern Cape and is characteristic of poor populations and coastal communities globally (Béné, 2009; Béné & Friend, 2011).

The high dependence on shops and low self-sufficiency displayed by the fishers in this study are atypical for SSFs around the globe. Many SSFs rely on their catch for personal consumption and as a viable protein source (Béné et al., 2016). However, in the southern Cape linefishery, fish are more often caught to be sold rather than consumed. These findings corroborate others that found that the vulnerability of the southern Cape fishers (compared to a group of SSFs in Brazil) was exacerbated by a lack of food security (Martins et al., 2019). This could have a wide range of implications. The most apparent implications arise because the fishers are not directly (nutritionally) benefiting from their catch (although they still do earn an income from it) and can be exploited by employers (or skippers).

5.1.2 Exposure

The exposure category considered the fishers' personal exposure to, personal experience with, and attitude and perception toward environmental changes. Exposure scores were similar for all communities on both the categorical and component levels. The similar climate exposure scores for all fishers are not surprising because of the study area size and the large-scale climate change impacts.

For all SSFs in the study, the Environmental change (E.EC) component[18] was the main driver of exposure (See **Figure 4.5** for results). The fishers' experiences of environmental change correspond with previous research in the southern Cape, which detected increased variability and shifts in climate drivers over the periods just before the GULLS survey (Blamey et al., 2015; Jarre et al., 2015). The SSFs interviewed for the GULLS survey reported rainfall, wind, wave height, and sea state changes. Of these components, fishers reported most concern with changes in wave height and sea state, which are both influenced by wind. These reports agree with previous studies that have identified lengthened summer conditions and heightened easterly winds in southern Benguela and the southern Cape's SES (Gammage, 2015; Blamey et al., 2015; Ward et al., 2018). The fishers' experiences of increasing wave height also coincide with results that suggest an overall deterioration in sea state and fewer 'sea days' from 1997 to 2014 (Lyttle et al., 2021).

Regarding rainfall, on a national scale, Southern Africa has exhibited more rainfall days and higher rainfall intensities (Lumsden, 2009). On a smaller scale, the south coast region of South Africa has displayed longer rainfall seasons attributed to climate change (du Plessis, 2017). At a coastal scale, research overlapping natural scientific and resource users' knowledge of climate change within the southern Cape SES has also indicated more variable rainfall (Ward et al., 2021). Changes in rainfall patterns have been identified as a pertinent stressor by fishers. They reported concern with the rainfall variability (Gammage et al., 2017a) and the possible effect of freshwater run-off on fish populations, distribution, and availability (especially in the towns near rivers and estuaries) (James et al., 2013; Ward et al., 2018). These environmental changes can impact the fishers' livelihoods by reducing their

[18] The other components include the Personal exposure and Attitude and Perception components.

available ‘sea days’, increasing the unpredictability and uncertainty of ocean resources, and curtailing sea safety, as also observed elsewhere (Berkes, 2007; Badjeck et al., 2010; Yanda et al., 2019). Nonetheless, the long-term effects of climate change in the southern Cape SES are not fully understood owing to the shortage of consistent long-term climatic data (Ward et al., 2021), the variability of the BCLME (Jarre et al., 2015) and the interactions of the warming Agulhas current with the southern Benguela (Rouault et al., 2009; Jackson et al., 2012).

Until now, the vulnerability categories that are similar across the fishing communities (sensitivity and exposure) have been discussed. Next, the adaptive capacity category (where most subtleties reside) will be examined with more extensive consideration.

5.1.3 Adaptive Capacity

Adaptive capacity is the category driving the social vulnerability differences between the SSFs of each community during 2014-15. Adaptive capacity can be conceptualised as the skill of resource users to transpose their available resources (natural, social, institutional, financial, or social) into productive strategies and responses that mitigate the impacts of negative change (such as diminishing resources). The GULLS adaptive capacity indices take account of the availability and use of different resource types. The survey also integrates elements of flexibility, which measures the fishers and institutions’ ability to respond and adapt to influence their current and future conditions (Aswani et al., 2019). Here, the adaptive capacity components that differed among the communities will be examined, followed by a discussion of the components that drove adaptive capacity (either positively or negatively) for all fishers in the study.

5.1.3.1 Adaptive Capacity Differences

Bitouville fishers stand out as the most distinct with the highest adaptive capacity scores, while the fishers of Mossel Bay had the lowest adaptive capacity scores. This parallels the vulnerability rankings and shows that adaptive capacity shapes vulnerability differences (see **Table 4.2**). When analysing the fishing communities at a component level, four of the 11

components[19] were significantly different between the fishing communities: Human capital (AC.HC), Bridging social capital (AC.BSC), Institutional support (AC.IS), and Physical capital (AC.PC) (See **Figure 4.7** and **Figure 4.8** in section 4.4 for results).

For the Human capital component, Slangrivier's fishers had the most favourable (highest) scores. The high scores resulted from having a higher number of family members who have moved elsewhere in the last five years to secure income, indicating more flexibility and less attachment to place (see **Appendix C** for Rationale Table). Slangrivier fishers also had higher levels of education, as all had at least a grade 12 level education and listed more alternative skills to fishing than other fishers. These results make sense because Slangrivier is more of an agricultural community than a fishing community (see section 3.2.1 for an overview of Slangrivier). Melkhoutfontein had the lowest Human capital scores driven by their low sets of alternative skills and their perceived difficulty finding work outside fishing. To illustrate, 65% of the Melkhoutfontein fishers reported having either none or only one alternative to fishing, and more than 80% reported difficulty finding work outside fishing.

These results are compatible with what is known about Melkhoutfontein, as they are characterised by a long history and involvement in the handline fishery and are particularly disadvantaged by the monopolistic impacts of fish buyers (Visser, 2015). This result also corroborates the negative outlooks of Melkhoutfontein fishers that were identified in Gammage (2015), where the linefishers showed pessimism and resistance to change (whether it be toward finding work, developing skills outside fishing, or dealing with unwelcomed changes posed to them by DAFF (now DFFE) in the MRLA and SSFP implementation) (Gammage et al., 2017a). Such pessimism may drive a fisher's vulnerability by preventing them from adapting to changes and result in merely coping or reacting to events[20] (Gammage et al., 2017a, 2017b).

[19] The other adaptive capacity components (of which were not significantly different between fishing communities) include natural capital, social capital, financial capital, personal flexibility, attitude and perception, occupational flexibility, and institutional flexibility.

[20] In Gammage, 2015, the fishers were evaluated based on whether they were reacting (reacting to an event signified an unplanned response to an event or change), coping (passively accepting events or changes and thus, not taking actions to alter the outcomes), or adapting (if a fisher was adapting, they were proactively planning, collectively or individually, for sustainable outcomes) to changes.

For the Bridging social capital component, Bitouville's fishers had the most favourable (highest) scores, and Slangrivier's fishers had the worst (lowest) scores. All the SSFs in Slangrivier reported they were unaware of any government safety nets or links to other institutions at the time. However, all three fishers received social grants. Thus, these claims were either backed by unawareness of the contribution of these institutions or by an unwillingness to recognise government and institutional presence. This also possibly denotes the negative associations SSFs of South Africa generally hold toward the government stemming from untransparent policy procedures and disappointment from the continuously delayed implementation of SSFP, which has fuelled a general mistrust that has only grown since the surveys (Sowman, 2011; Sowman & Sunde, 2021). On the other hand, Bitouville's fishers recognised the existence of institutions, and some reported that these institutions were 'well-linked' to their communities. The difference between the fishers' recognition of institutional presence in the area could indicate a difference in the presence of these institutions. However, this disparity most likely alludes to the difference in their perception of, communication between, and relationship with these institutions.

The Bridging social capital results are also influenced by the number of indicators selected to represent the component. Where the average number of indicators used to constitute a component in this framework is 11 (with a range of 2-26), only two indicators represent Bridging social capital (refer to **Table 4.2** for results and section 5.3 for recommendations to address the uneven weighting). The sample size (number of fishers) for each community might also play a role. For instance, there are only three fishers representing Slangrivier and all three crew on the same boat. Therefore, all three are more likely to give more homogenous answers than the other communities of fishers. Additionally, this has implications for the statistical tests used for this study (discussed further in section 5.3.2).

For the Institutional support component, the fishers of Melkhoutfontein had the most favourable (highest) scores, and Mossel Bay fishers had the worst (lowest) scores. Melkhoutfontein fishers had high scores driven by their higher awareness of reporting required for their fishing practices. All the fishers in Melkhoutfontein stated that their skippers had to report the number of catches at a landing site to authorities. In comparison, only nine other fishers in other communities declared such regulations. This disparity more

plausibly reveals a difference in the awareness of the skipper's reporting requirements rather than the actual reporting because the fishers in this study are crew members and are not responsible for recording catches. Additionally, although not many, more Melkhoutfontein fishers recognised institutions in the area addressing climate change or assisting adaptation to change in their community. Their acknowledgement of government institutions can perhaps be attributed to Melkhoutfontein's location (closer proximity to more efficient municipality offices in Stilbaai and Riversdale) and better coverage by DFFE (formerly DAFF) for roadshows, interventions, and co-ops (Gammage et al., 2019; Gammage & Jarre, 2021), as Melkhoutfontein is usually the venue for the DFFE roadshows.

In comparison, low scores for the fishers of Mossel Bay are also because no fishers reported awareness of any institutions working on climate change in the area at the time of the surveys. These results are surprising as DFFE meetings and road shows also occur in Mossel Bay. The results display a lack of awareness of these meetings and institutions rather than their absence, which could be because Mossel Bay is much more extensive, and the fishers reside in suburbs (D'Almeida and Kwanonqaba) of the town. On top of this, the cohesiveness of the line fishers has been restrained by the dominating and larger-scale inshore trawl industry (Visser, 2015) and by the industrial transition brought by the gas and oil industry (see section 3.2.5 for an overview of Mossel Bay). Thus, they are less unified, which could affect their participation in, awareness of, and communication with institutions.

The Physical capital component (AC.PC) includes indicators revolving around fishers' assets (i.e., home, water supply, energy, cooking fuels, waste, etc.) and the ownership of, conditions of, and debt on these assets[21]. Bitouville's fishers had the most favourable (highest) scores driven by the ownership, lack of debt, and conditions of their homes. All Bitouville fishers owned their homes, all made from sturdier materials (cement and bricks as opposed to wood), in which they did not foresee much need for near future maintenance.

[21] An important factor to weigh is that the economic results of this study could be skewed because people can feel particularly uncomfortable disclosing their financial information (Ross & Reynolds, 1996), which is essential to consider when analysing survey and census data that rely on self-reporting (Gammage et al., 2022).

Vermaaklikheid had the lowest scores for the Physical capital component. They had poorer infrastructure and less sophisticated technology concerning their physical capital (i.e., all had compost or long drop toilets, only three fishers used cooking fuels, three had no cooking methods, and one used wood to cook). These results parallel other studies that recognised Vermaaklikheid as an impoverished community that is heavily reliant on government grants and characterised by extremely poor housing characteristics (Gammage et al., 2015; Gammage et al., 2022). SSFs are internationally characterised by geographic isolation, which is affiliated with weak government provisioning aids, defective transportation systems, and limited infrastructure (Béné & Friend, 2011) and Vermaaklikheid fits this picture well.

It must be noted that the absence of debt and loans, shown in these results, is a positive indicator for the GULLS framework (see Rationale Table in **Appendix C**). However, it could also indicate the inability to access credit and financial services through formal institutions (Gammage et al., 2019). Instead, fishers may be accessing loans from family and friends (Issacs et al., 2013; Gammage, 2015). This highlights the value of the informal economy in the area and is congruent with what is found in the rest of South Africa (Davies & Thurlow, 2010). In this case, the lack of options to access loans possibly increases the vulnerability of the fishers and might raise the susceptibility to loan sharks and those who exploit the disadvantaged (Béné, 2009; Issacs et al., 2013).

This section comprised a detailed discussion of the adaptive capacity components that differed between the communities: Human capital (AC.HC), Bridging social capital (AC.BSC), Institutional support (AC.IS), and Physical capital (AC.PC) (See **Figure 4.7** and section 4.4 for results). Below, the adaptive capacity components that similarly drive all the fishers' vulnerability are considered.

5.1.3.2 Adaptive Capacity Similarities

This section refers to the adaptive capacity components that similarly shape vulnerability for all fishers in this study. First, the drivers that largely increase adaptive capacity (and reduce

vulnerability) for the fishers are explored, followed by a discussion of the drivers that predominately decrease fisher adaptive capacity (and increase vulnerability). Note that some of the components that similarly drive adaptive capacity for all communities are components that differ between the communities as well (namely, Physical capital, Human capital, and Bridging social capital).

Drivers increasing Adaptive Capacity

Three components were positively driving the adaptive capacities and reducing the vulnerability scores of all communities: Attitude and perception (AC.AaP), Occupational flexibility (AC.OF), and Physical capital (AC.PC) (refer to section 4.4 for results). The Attitude and perception component considers the fishers' knowledge of climate change and their belief in the importance of awareness and understanding of the biological system. Other studies have also found that southern Cape skippers found it important to know the biological system, as they ordinarily strive to balance profit and sustainability (Duggan, 2014). The fishers in this study are crew and are plausibly echoing the perspectives of their skippers. Additionally, more than 70% of the fishers reported an understanding of climate change, and 95% thought the climate had changed over time. The GULLS framework considers this to indicate awareness and, thus, identifies it as a positive indicator (since awareness might encourage the fishers to anticipate and address consequences). However, it may be that the reports of a changing climate could simultaneously indicate vulnerability. For instance, more than 90% of the handline fishers reported changes in weather and climate, and other studies have identified this as the stressor that negatively impacted daily fishing activities (Gammage, 2015; Gammage & Jarre, 2020). Thus, there is a slight contradiction in the interpretations and the strong awareness could also indicate increasing climate change impacts on the area. The second interpretation is more plausible because climate change projections indicate that substantial changes (such as changes in species abundance) in the southern Benguela are expected because of climate change (Ortega-Cisneros et al., 2018).

The Occupational flexibility component measures the capacity to anticipate and develop response strategies to change. Other studies found that these fishers wish to remain in the

fishery and will only branch out when necessary (Gammage et al., 2019). Many fishers in this study identified tourism activities as a lucrative alternative to fishing, and 70% of the fishers were interested in finding alternative work to fishing. However, the survey did not consider their actual engagement in tourism activities (see **Appendix C**). Gammage (2015) noted that where tourism is already prominent (i.e. in neighbouring Stilbaai), handline fishers were interested in tourism activities such as fishing charters. Other scenario-based techniques were applied in Melkhoutfontein, where fishers also explored tourism as a potential livelihood activity (Gammage & Jarre, 2021).

The Physical capital component (which was also driving differences between the communities) generally had a positive effect on adaptive capacity because almost all SSFs in this study owned their homes, most homes were in good condition, and there was not much debt reported on their homes. However, although the Physical capital component was a driver for adaptive capacity, the lack of debt may also be contradictory and indicate a lack of opportunity to take out loans. Additionally, many of the fishers in this study benefit from RDP[22] housing hence, the prominence of home ownership. Therefore, although home ownership is perceived as a positive indicator in the GULLS framework, the dependence on the government for housing and resources reflects poverty within these communities and which is indicative of vulnerability.

Drivers Reducing Adaptive Capacity

Five components were negatively influencing the fishers' adaptive capacities and driving their vulnerabilities: Natural capital (AC.NC), Human capital (AC.HC), Bridging social capital (AC.BSC), Institutional flexibility (AC.IF), and Institutional support (AC.IS) (refer to section 4.4). The Natural capital component was based on the stability of marine resources. However, due to the notable changes in the line fish resources leading up to the time of the study (i.e., less frequent biting behaviour, spatial shifts, and smaller size) (Winker et al., 2014; Duggan, 2018), Natural capital scores were foreseeably low for all fishers.

[22] The Reconstruction and Development Housing programme (RDP) was created to address inequities created by apartheid regimes, where those who qualify (cannot afford housing, are victims of apartheid segregation, and are married, living with a partner, or has dependents, etc.) are given government subsidy housing.

The low scores for the Human capital component were driven by an absence of skills beyond fishing and low levels of education. These results are characteristic of SSFs around the globe, who are often disadvantaged by geographic isolation and (compared to other urban areas) poor infrastructure, which also inhibits a higher level of education and human well-being (Béné, 2009; Nayak et al., 2014). In South Africa, the absence of skills outside of fishing is generally exacerbated by the legacy of apartheid and low levels of education (Isaacs, 2006; Sowman, 2006; Sowman & Raemaekers, 2018). Other studies have also noted the small alternative skillsets, where fishers asserted employers are less likely to employ fishers out of the expectation that fishers will leave those jobs once fishing is good and in season (Gammage et al., 2017a,b). This promotes involvement in the informal economy and prohibits many fishers from developing lucrative skills and income outside fishing (of which options are limited, and unemployment is high in South Africa and the southern Cape already) (Davies & Thurlow, 2010; Sowman et al., 2014).

The Bridging social capital, Institutional flexibility, and Institutional support components generally drove vulnerability. Bridging social capital differed between the communities (as discussed in section 5.1.3.1) but nonetheless drove vulnerability for all communities. This component took account of the government safety nets, links to governments and institutions, and the cohesiveness of the fishing communities. Institutional flexibility considered fishing regulation, enforcement, compliance, conflict, and markets. The primary driver in this component was the markets, mainly because the fishers in this study are crew members and have little control over the sale of their catches. Smaller volumes of catch and, thus, a smaller income for the crew members and remoteness from the markets and shops also influence the vulnerability of the fishing communities. As an example of what 'remoteness' resembles for these communities, Vermaaklikheid (the most remote community in the study) only had one small shop with inflated prices, no transportation system, and one community member with a vehicle that offered transportation at an expensive rate (per person), at the time of the surveys (Gammage, 2015).

The Institutional support component is based on the area's presence and type of institutions and whether these institutions address climate change. This component was influencing the vulnerability of the fishers because, at the time of the surveys, the fishers recognised no

institutions or co-ops that were community-run or directly addressed climate change issues. As mentioned, these indicators are most likely a reflection of awareness rather than the existence of these institutions and presumably depict the poor communication between institutions and SSFs. However, since the period of the surveys, there has been more involvement of researchers in the area (Gammage & Jarre, 2020, 2021), which may lead to a heightened awareness of institutions and result in better adaptive capacity scores in future surveys.

There is much more that can be derived from the results and said about the vulnerability of the southern Cape handline fishers. However, further detail is beyond the scope of this thesis. The core of the matter is that the methods used in this study allow for more detail and nuance to be examined when desired.

5.2 Scale

The issue of scale in marine SES management and implementation of ecosystem-based management approaches (such as EAF) is fundamental. For the global-scale application of EAF, dynamic interactions and diverse perspectives at all scales must be merged into decision-making processes (Paterson & Petersen, 2010; Ommer et al., 2012). Scale is crucial because the scale chosen for analysis can derail beneficial results by suppressing important drivers (if the scale is too large) or masking important results (if the scale is too fine) (Gibson et al., 2000; Perry & Ommer, 2003). Thus, the scale of analyses must be chosen carefully to avoid scale mismatches and ensure congruencies between assessments and management decisions (Gibson et al., 2000; Reed, 2008; Gammage & Jarre, 2020, 2021).

The GULLS social vulnerability framework is a four-scale framework that was created to facilitate cross-country vulnerability comparisons for SSF communities experiencing exacerbating rates of climate change (based on hotspots identified by Hobday and Pecl, 2014). These comparisons could uncover vital information about SSFs (an understudied and particularly vulnerable group) and future implications of climate change (Aswani et al., 2019). To avoid losing important detail when generalising community characteristics to compare fishers on a national scale, the GULLS team based these global comparisons on surveys that collect rich data, encapsulating vulnerabilities on a household level.

The analysis presented in this study measures vulnerability at smaller scales (between communities in a single biogeographical region rather than countries). This raises the question of what scale should be used to assess vulnerability while preventing scale mismatches and securing the most valuable results for decision-makers. Ideally, this would be the scale that simplifies the data as much as possible without losing important detail. Individual assessments preserve too much detail. In contrast, national indices often yield irrelevant management implications for SES, biogeographical, or community-scale management (Perry & Ommer, 2003).

I analysed the vulnerabilities of the SSFs at all four scales of the GULLS framework (category, component, subcomponent, and indicator) to compare and investigate how the different scales retained or altered the results and to uncover which scale would produce results that synchronised most with qualitative research. When testing for community differences at each scale of the framework, more differences were detected, and more variation was retained at small scales, as expected. Importantly, the results were also consistent regardless of scale (i.e., the vulnerability rankings were the same on all four scales) (see **Table 4.3** and **4.4**).

For the southern Cape handline fishers and the SCIFR research area, I propose that the component level is the ideal scale to assess vulnerability. The categorical scale generalised the vulnerabilities too much to derive management implications (i.e., it did not detect important community differences detected at smaller scales, such as the difference in vulnerability between Vermaaklikheid and Bitouville). In contrast, the indicator and subcomponent scales were cluttered with detail that obscured important information that managers need to address the vulnerability on either a national or biogeographical scale (see **Table 4.3** and **4.4**). The component scale results revealed important community similarities and differences that harmonised with previous research done in the SCIFR research area (qualitative, ethnographic, coastal wave output models) (Gammage et al., 2017a, 2017b, 2019; Ward et al., 2018; Lyttle et al., 2021; Ward, 2022). Furthermore, the component scale of the GULLS framework has also been chosen to assess the community-level vulnerability of SSFs in other “hot spot” areas (Martins & Gasalla, 2020).

Thus, the results suggest that the GULLS survey applied at the household level and analysed at a component scale offers a reliable tool to assess vulnerability for the SCIFR research area.

5.3 Future Surveys

The GULLS survey is a well-developed survey tool adapted from an intensive collaboration of an interdisciplinary team with the overarching aim to address vulnerability and facilitate adaptation strategies (Aswani et al., 2019). Before this study, the survey was backed by intensive reasoning and well-thought-out rationale (see **Appendix C**). The robustness of the survey is supported by the results of this study, especially because these findings are congruent with previous research (ethnographic, qualitative, and interdisciplinary) in this area. To enhance the already well-developed survey to be more relevant to the southern Cape and perhaps South African handline fishers, revisions and considerations are put forward for the future use and application of the GULLS survey below.

5.3.1 Modifications for the Southern Cape

Modifications are needed to improve the survey because the GULLS survey was created for large-scale comparisons and had to be appropriate for all GULLS partner countries. Hence, some questions were not meaningful to the fishers in the southern Cape and could be omitted. I also propose repositioning or regrouping some of the indicators and setting a minimum number of indicators for each component to achieve a more applicable and evenly weighted survey.

Concerning modifications for the sensitivity index, the components, subcomponents, and indicators reflect what is known about the economic and social features of the area. They correspond the best with previous research compared to the other categories. However, I suggest adding more indicators to the Economic dependence on other resources (S.ED) component to construct a more balanced framework. This component has the largest influence on the fishers' sensitivity scores but only features six indicators to represent the component (the average is 11 with a range of 2-23). Other economic indicators could be added to investigate the dependence of fishers on social assistance and government

programmes and discern the poverty level within households (similar to indicators used for a social vulnerability assessment for the southern Cape in Gammage et al., 2022).

Regarding the exposure indices, the GULLS survey was created with a strong climate change perspective to compare climate change impacts for all 'hotspot' countries. Thus, some exposure indices regarded climate change phenomena that were irrelevant to the southern Cape's biophysical conditions and did not contribute to this study (i.e., questions regarding floods, shoreline changes, etc.). For a future survey, such questions can be omitted and replaced by more detailed questions respecting the relevant and anticipated climate change phenomena experienced in the area (i.e., wind speed and direction, rainfall, and sea state) and for the characteristic natural variability (Lumsden, 2009; du Plessis, 2017; Ward et al., 2018; Kainge et al., 2020; Lyttle et al., 2021). The GULLS survey also asks whether the fishers have observed specific changes and whether they have affected their livelihoods (only allowing fishers to answer yes or no) (see **Appendix C**). A future survey could allow for open, Likert, or short answer questions that include more elaborate questions to examine the fishers' perceptions of the nature of these changes (i.e., seasons, patterns, etc.) and their impacts (days at sea, sea state, species distribution). The need to move beyond yes/no questions is because, in other research studies, fishers did not give detailed responses regarding climate variability (Ward et al., 2018; Gammage and Jarre, 2020).

There was a large range in the total indicators for the adaptive capacity indices and each component (2-23). Therefore, I recommend re-grouping some of the corresponding components that comprise a concerningly low number of indicators. For instance, Bridging social capital (2), Institutional support (5), and Institutional flexibility (8) either need more indicators in each component for even weighting or need to be reconstructed into new components. For instance, all three involve policy, government involvement, markets, regulation, and conflict with other sectors. As an example of how these components can be more efficiently structured, these components could be arranged into two components: a comprehensive policy and regulation component (concerning government and institution involvement, policy implementation, and regulation) and a general conflict component (concerning conflict with other sectors, fishers, and markets). In addition, detailed questions that are more appropriate to the southern Cape fishers should be added to each component

(i.e., questions regarding experiences with the trawl industry, the progress of SSFP implementation, and DFFE involvement and communication). These two comprehensive components would be more suitable than the three used in the original framework because policy and regulation and general conflict play fundamental roles in fishers' livelihoods and have been major stressors for South African fishers (see section 2.4.3). Concerning modifications for the other adaptive capacity components, questions could be added to the Occupational flexibility component to investigate further which tourism activities are of interest and available to the fishers.

5.3.2 Future Use and Application

Using this survey and quantitative methodology while applying these recommendations will contribute to improving the already well-developed GULLS survey, which can support a long-term understanding of the vulnerabilities of the SSFs in the area, and beyond. That being said, these suggested survey alterations aim explicitly at the southern Cape SCIFR research area. Therefore, applications of the survey and framework in different areas (particularly areas outside of South Africa or the southern Benguela) or other sectors might demand slightly different modifications[23].

Concerning suggestions for sample size, I put forward that more fishers must be considered for the interview process to meet the statistical requirements for the quantitative methods in this study. The sample sizes for the 2014-15 survey (namely the sample size for Slangrivier) are permissible for the purpose of this study because there were only six handline rights holders in Slangrivier and only three available at the time of the surveys. However, the statistical tests recommend five samples (fishers) from each site (community) as a minimum requirement to run the tests (Clarke, 1993).

[23] Although few modifications might be needed for survey application in other research areas, it is important that these improvements and modifications are made while aiming to keep results comparable across regions and scales. For instance, a survey that is generic enough to be applied across South Africa would be beneficial for EAF implementation. However, modifications for each survey are still useful to take account of the smaller nuances of different research areas (i.e., the impact of the trawling industry on SSFs in the southern Cape compared to the impact of diamond mining on SSFs on the west coasts of South Africa).

Another factor to be borne in mind with the extension of this survey is the fundamental changes that have impacted the system but were not thought of at the time of survey development. For instance, COVID-19 has notoriously impacted fishing supply chains worldwide and will hamper the temporal comparability of survey results without its consideration (FAO, 2020). Thus, questions regarding the impacts of COVID-19 should be added to the survey in future applications. This can simply be done by adding a 'pandemic' component to the Exposure category that contains indicators that represent the impacts of lockdowns and COVID-19. This way, the survey remains in the context of climate change while acknowledging fundamental changes that have certainly impacted the fishers' vulnerability (by potentially increasing their vulnerability to the impacts of climate change).

In terms of how future surveys should be analysed, I posit that the quantitative methods used in this study are crucial and worthwhile in addition to qualitative research for three primary reasons. First, the quantitative results offer a means to confidently identify and defend where true community differences reside, which are more easily communicated with, understood by and useful for various decision-making entities. Second, a consistently applied survey and an agreed quantitative method offer an element of practicality that is in line with and quicker than ethnographic methodologies. Likewise, numbers offer a reducible, transferable, and consistent way to analyse SES's complexity and nuanced characteristics. They are especially advantageous in a mixed methods format (such as the format of this study) where qualitative research helps give context to the quantitative results. Third, quantitative results make it possible to determine whether variability has changed over time. Owing to the subjectivity of interviews and the personal impact of likely different researchers, such temporal changes cannot be argued with qualitative results alone.

Most importantly, these robust quantitative methods are based on a bottom-up approach and coincide with the extensive qualitative research done in the area (Gammage et al., 2017a, 2017b). The consistent application of the survey and methods can help establish a reliable long-term data set and address the continued need to include human dimensions in research-related EAF implementation as part of DFFE.

CHAPTER 6: Conclusion

This study provides an extensive social vulnerability assessment of small-scale fishers in the southern Cape, who currently operate as crew in the commercial line fishery, in the context of climate change. Using a quantitative and robust statistical approach, I analysed the GULLS social vulnerability surveys conducted in 2014-15. This research aimed to answer four central questions and assess whether social vulnerability, as well as its comprising categories (sensitivity, exposure, and adaptive capacity), differed among the communities (Question 1), how variable the social vulnerability scores were within the communities (Question 2), what drove the differences among the communities (Question 3), and to shed light on the implications for issues of scales (Question 4). The objective of investigating these main questions was to gain insight about the social vulnerability of the communities at the time of the surveys, to better understand how they could be impacted by negative events, such as climate change.

The evidence from this study suggests that sensitivity and exposure were similar for all southern Cape fishing communities during 2014/15. The sensitivity indices largely increased all fishers' vulnerabilities, mainly driven by a strong attachment to their communities, an attachment to fishing as an occupation, and low self-sufficiency. For a future survey and vulnerability framework, few changes have been recommended for the sensitivity indices, as they coincided most with previous research. The exposure of all fishing communities in the study was driven by environmental change (i.e., change in rainfall, wind, wave height, and sea state). Recommendations have been made for future exposure questions (i.e., to omit irrelevant questions, allow for open questions, and include more detailed questions) to ensure they are appropriate for this research area. Adaptive capacity differed among the fishers in each community and drove the differences in vulnerability. The differences and similarities in adaptive capacity have extensively been discussed, as this is where most nuances reside. For future surveys, I recommend adding more questions investigating tourism activities as alternatives to fishing and reconstructing some of the adaptive capacity indicators and components to ensure equal weighting.

The results of my study have shown that asking the questions at the “household” scale, as designed by the GULLS team and done for this study, is advisable. Additionally, the “component” scale, as opposed to category, subcomponent, and indicator scales, is appropriate for analysis because this scale (the scale at which the survey is performed and analysed) produced results that gave an adequately nuanced picture without getting lost in detail. Moreover, the quantitative methods used for this study (based on bottom-up approaches and EAF principles) are effective and worthwhile owing to the categorised results that can be easily communicated to decision-makers, are quicker and produce more consistent results than qualitative methods, and therefore support long-term vulnerability research and temporal comparisons in the southern Cape.

In conclusion, the findings of this research can lead to an improved version of an already well-developed survey. Ultimately, such a survey and quantitative methodology can contribute to EAF implementation and aid the sustainability of the southern Cape handline fishery and its associated livelihoods.

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Appendices

A. Research Ethics Documentation

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19 August 2014

Dr James Howard
Department of Biological Sciences

Dear Dr Howard

GLOBAL LEARNING AND LOCAL SOLUTIONS: REDUCING THE VULNERABILITY OF MARINE-DEPENDENT COASTAL COMMUNITIES

I am pleased to inform you that the Faculty of Science Research Ethics Committee has approved the above-named application for research ethics clearance, subject to the conditions listed below. You are required to:

- implement the measures described in your application to ensure that the process of your research is ethically sound;
- uphold ethical principles throughout all stages of the research, responding appropriately to unanticipated issues: please contact me if you need advice on ethical issues that arise; and
- ensure that consent is recorded, either through a signature or mark if the participants cannot write, or alternatively since the interviews are to be recorded, through recording the participants giving verbal consent.

Your approval code is: FSREC 063– 2014

I wish you success in your research.

Yours sincerely

Dr Richard Hill
Chair: Faculty of Science Research Ethics Committee

Cc: Prof Astrid Jarre; Supervisor

A. Research Ethics Documentation continued

From: Shari Daya <shari.daya@uct.ac.za>
Sent: Monday, 30 August 2021 17:34
To: Louise Gammage <louise.gammage@uct.ac.za>
Subject: RE: Ethical clearance for study related to human subjects.

Dear Louise

If the student is actually working on the same project (i.e. same question/focus/aim) that Dr Howard collected the data for, no need to put in a new application. If the research project is different, but just using the same data, then she should put in an application as there are questions on the form about using third party data which would apply to her work.

Hope that makes sense.

Shari

Dr Shari Daya

Senior Lecturer, Environmental and Geographical Science

EGS Director of Graduate Studies

Chair, Faculty of Science Research Ethics Committee

Co-editor, Critical African Studies

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B. Rationale table for omission and re-organisation

GULLS Survey Q #	SA Survey Q #	Included in Assessment	Indicator	Rationale for Omission	Rationale for any other alternations
1.1	1.1	✓	Fishing main occupation		Fishing activity section (1.1-1.11) included as a subcomponent in the Personal Exposure component (under Exposure category). Nature of fishing activity influences overall exposure and vulnerability.
1.2	1.2	✓	Fishing frequency		
1.3	1.3	✓	Duration of trips		
1.4	1.4	X	Highest daily catch	Poorly answered and mostly crew.	
1.5	1.5	X	Best catch of the year	Poorly answered and mostly crew.	
1.6	1.6	X	Average distance from the coast where fishing takes place	Too difficult to define what is a 'vulnerable' average distance. Better represented by 1.7.	
1.7	1.7	✓	Directionality of change in the distance from the coast where fishing takes place		
1.8	1.8	X	Contribution of fisheries livelihoods to household income	Poorly answered.	
1.9	1.9	✓	Options available for work without fishing		
1.10	1.10	X	Most important commercial species	Scoring not appropriate or representative of vulnerability.	
1.11	1.11	✓	Observed change in main target species		
2.1	2.1	✓	Monthly income		
2.2	2.2	✓	Monthly income		
3.1	3.1	✓	Possession of own fishing business		
3.2	3.2	X	People provided work to in the last 12 months	Not applicable. Mostly crew.	
3.3	3.3	X	Business income over the year	Not applicable. Mostly crew.	
4.1	4.1	X	Location of store to purchase food/goods	Answers not clear. One shop does not clearly increase/decrease vulnerability over another	
4.2	4.2	✓	Relative contribution of different methods of obtaining food		

5.1	5.1	✓	Level of interaction and dependence on other people and institutions		
5.2	5.2	✓	Level of interaction and dependence on other people and institutions		
6.1	6.1	✓	Number of nights per week that household eats seafood		
6.2	6.2	✓	Source of seafood consumed		
6.3	6.3	X	Typical species eaten by household	Not an appropriate vulnerability indicator for the southern cape. Species consumed does not vary enough to impact vulnerability.	
7.1	7.1	✓	Number of nights per week that household consumes vegetables		
7.2	7.2	✓	Number of nights per week that household consumes meat		
7.3	7.3	✓	Relative importance of household's food source		
7.4	7.4	✓	How food is paid for (when not grown or caught themselves)		
7.5	7.5	✓	Level of farming/ subsistence activity		
7.6	7.6	X	Reason for growing food	Not applicable to most	
7.7	7.7	X	Crops grown for commercial purposes	Not applicable to most	
7.8	7.8	X	Where crops are planted	Not applicable to most	
7.9	7.9	X	Crops grown	Not applicable to most	
7.10	7.10	✓	Livestock (yes/no)		
7.11	7.11	X	Livestock activity	Not applicable to most	
7.12	7.12	X	Type of livestock and amount	Not applicable to most	
8.1	8.1	✓	Length of time as a fisher		
8.2	8.2	X	Age of fishery	Poorly answered. Most do not know or answer subjectively (i.e. 'very old', 'before I was born').	
8.3	8.3	✓	Extent of ancestral involvement in fishing		

8.4	8.4	X	The extent of ancestral involvement in fishing	Difficult to score the given answers. Scoring the amounts of family members listed would not be a good indicator of vulnerability.	
8.5	8.5	✓	Perception of a "fishing" family identity		
9.1	9.1	X	Difference in occupation from parents	Most answered fisher as father and domestic as mother. Scoring would not be appropriate.	
9.2 (a)	9.2 (a)	✓	Schooling of parents (father)		
9.2 (b)	9.2 (b)	✓	Schooling of parents (mother)		
9.3 (a)	9.3 (a)	✓	Level of schooling of parents (father)		
9.3 (b)	9.3 (b)	✓	Level of schooling of parents (mother)		
9.4	9.4	✓	House ownership of parents vs interviewee		
9.5	9.5	✓	Boat ownership of parents vs interviewee		
9.6	9.6	✓	Level of financial wellbeing compared to parents		
10.1	10.1	✓	Level of interest in changing employment		
10.2	10.2	✓	Perception of finding work in alternative sector		
10.3	10.3	✓	Number of options for alternative work		
10.4	10.4	✓	Number of courses taken to improve employability		
10.5	10.5	X	Courses completed	Not applicable to most and was poorly	
10.6	10.6	✓	Level of interest in working for someone else		
11.1	11.1	✓	Number of employment changes in past 5 years		
11.2	11.2	X	If yes, what work? (work available to fishers who are willing to engage)	Not applicable to most	
11.3	11.3	X	Preference of different livelihoods	Not applicable to most	

11.4	11.4	✓	Level of interest in working in non-fishing sector		
11.5	11.5	X	Criteria for job alternatives	More appropriate for qualitative analyses. Not easily quantified.	
11.6	11.6	✓	Factors and type of work sought in a different livelihood activity		
11.7	11.7	X	Factors affecting fishing livelihoods	Directionality of answers not obvious. Therefore quantifying answers would not be appropriate	
11.8	11.8	✓	Types of livelihoods found by fishers leaving the fishery		
12.1	12.1	X	Number of markets to buy fish in the community	Poorly answered and all had same answer (none).	
12.2	12.2	X	Number and type of avenue to sell fish	Poorly answered and all had same answer (middlemen/large companies).	
12.3	12.3	X	Nature of relations with middleman (if applicable)	Not applicable to most (crew).	
12.4	12.4	X	Nature of relations between other members of the market chain	Not applicable to most (crew).	
12.5	12.5	✓	Number of markets to sell fish in the community		
12.6	12.6	✓	Possibility of selling fish outside the community		
12.7	12.7	X	Distance to markets outside of community	Question was poorly answered	
12.8	12.8	X	Stability and factors controlling fish price	Question was poorly answered	
12.9	12.9	✓	Stability and factors controlling fish price		
12.10	12.10	X	Stability and factors controlling fish price	Question not answered well enough to score appropriately.	
12.11	12.11	✓	Number of markets to sell meat and vegetables		
13.1	13.1	✓	Presence of natural resource management institutions in community		
13.2	13.2	✓	Type of management system		

13.3	13.3	✓	Level to which rules have changed due to environmental changes		
13.4	13.4	X	Level to which rules have changed due to environmental changes	Not applicable to most interviewees.	
13.5	13.5	✓	Degree of recording/ reporting of catches required		
13.6	13.6	X	Degree of recording/ reporting of catches required	Not applicable to most interviewees.	
13.7	13.7	X	Active community organisations in the community.	Would not make sense to score. Better information for qualitative analyses.	
14.1	14.1	✓	Feeling of Belonging		
14.2	X	X	Length of time living in the area	Not in SA survey.	
14.3	X	X	Strength of friendships in the community	Not in SA survey.	
14.4	14.4	✓	Importance of friendships in the		
14.5	X	X	Possibility to seek advice from others in the community	Not in SA survey.	
14.6	X	X	Frequency of socialising with others in the community	Not in SA survey.	
15.1	X	X	Importance of recreational fishing in ones life	Not in SA survey.	
15.2	15.2	✓	Regularity of recreational fishing		
16.1	X	X	Opinion of whether fishing is a job or a lifestyle	Not in SA survey.	
16.2	X	X	Opinion of whether fishing is a job or a lifestyle	Not in SA survey.	
16.3	X	X	Appreciation of the independence of being a fisher	Not in SA survey.	
16.4	16.4	✓	Degree of pride in telling others one is a fisher		
16.5	X	X	Opinion of whether fishing is a job or a lifestyle	Not in SA survey.	

16.6	16.6	✓	Concern regarding the continuation of fishing as a livelihood among the next generation		Included twice in the Sensitivity category (under the Historical and cultural dependence and the Social dependence components).
17.1	X	**X**	Likelihood of need to sell house if fishing business fails	Not in SA survey.	
17.2	17.2	✓	Possibility to feed family without fishing		
18.1	18.1	✓	Perception of whether too many or too few fishers operate in the community		
18.2	18.2	✓	Perception of whether too many or too few fishers operate in the community		
18.3	18.3	✓	Degree of concern about illegal fishing levels locally		
18.4	X	**X**	Degree of concern about illegal fishing levels locally	Not in SA survey.	
18.5	X	**X**	Effect of industrial catches on small scale catches	Not in SA survey.	
19.1	19.1	✓	Inclusivity of local ecological knowledge within marine resource management planning		
19.2	19.2	✓	Concern regarding the continuation of fishing as a livelihood among the next generation		
20.1	20.1	✓	Level of knowledge about marine		
20.2	20.2	✓	Importance to ensure LEK is passed on to younger generations		
20.3	20.3	✓	Relative maintenance of LEK between		
21.1	21.1	✓	Level of habituation to changes in everyday life		
21.2	21.2	✓	Perception of which user groups are most at risk to future changes		
22.1	22.1	✓	Level of financial		
22.2	22.2	✓	Level of interest to learn new skills outside of fishing		

22.3	X	**X**	Frequency of thoughts about improving fishing business	Not in SA survey.	
22.4	22.4	✓	Perception of possibility to personally improve the marine environment		
23.1	23.1	✓	Level of confidence that events will work out well regardless of everything else		
23.2	X	**X**	Level of confidence that events will work out well regardless of everything else	Not in SA survey.	
24.1	24.1	✓	Perception of responsibility to protect the marine environment		
25.1	X	**X**	Frequency of time volunteered to help in community activities	Not in SA survey.	
25.2	25.2	✓	Perception of ability to adapt to change compared to others locally		
26.1	26.1	✓	Perception of utility of own skills to set up a business outside of fishing		
27.1	27.1	✓	Relative importance of tourism to community and natural resources to tourism		
27.2	27.2	✓	Health of the marine resources locally		
27.3	27.3	✓	Relative importance of fishing as economic activity locally		
28.1	28.1	✓	Level of occupational diversity throughout the year		Included twice. Once in Sensitivity (component: Attachment to fishing) and in Adaptive capacity (component: Occupational mobility)
28.2	28.2	✓	Willingness to relocate for livelihood purposes		
29.1	X	**X**	Comfort in making decisions about future change with limited information	Not in SA survey.	
29.2	X	**X**	Possibility to predict money made each month by your business	Not in SA survey.	

29.3	X	X	Frequency with which professional business advice is sought	Not in SA survey.	
29.4	29.4	X	Expected monthly revenue from business	Not applicable to most (crew).	
29.5	29.5	X	Detail of business plan for following year	Not applicable to most (crew).	
29.6	X	X	Level of interest in learning new business skills	Not in SA survey.	
30.1	30.1	✓	Relative occurrence of illegal fishing locally		
30.2	X	X	Observance of community set rules	Not in SA survey.	
30.3	X	X	Observance of official management rules	Not in SA survey.	
30.4	30.4	✓	Number of people who know those who break the rules		
30.5	30.5	✓	Level of enforcement of fishing rules		
30.6	30.6	✓	Relative occurrence of conflict among fishers		
31.1	31.1	✓	Number of governmental safety		
31.2	31.2	✓	Strength of links between fishers and institutions or		
31.3	X	X	Strength of links between fishers and institutions or	Not in SA survey.	
31.4	X	X	Level of government help to address marine related community	Not in SA survey.	
32.1	32.1	✓	Perceived level of risk to community from environmental change		Included twice, under both Exposure and Adaptive Capacity. (both under attitude and perception components).
32.2	X	X	Perceived level of risk to income and livelihood from environmental change	Not in SA survey.	
32.3	32.3	✓	Degree of anxiety felt about environmental changes observed locally		Included twice, under both Exposure and Adaptive Capacity. (both under attitude and perception components).
33.1	33.1	✓	Perceived level of danger to fishing from weather changes		

33.2	33.2	✓	Degree of difficulty in finding/catching fish compared to the past		
33.3	33.3	✓	Number of changes in marine species observed locally		
34.1	X	**X**	Perceived level of environmental	Not in SA survey.	
34.2	X	**X**	Interest in learning about the sustainability of the fisheries resource	Not in SA survey.	
34.3	34.3	✓	Number of ideas held to ensure sustainability of the target fish species locally		
34.4	34.4	✓	Amount of knowledge good fishers possess about target fish		
35.1	35.1	✓	Main source of assistance when have financial, food or basic		
36.1	36.1	✓	Number of women in leadership roles in the community and		
36.2	36.2	**X**	Number of women in leadership roles in the community and	Not applicable to most	
37.1	37.1	**X**	Sources of weather, sea, and fishing conditions information.	Question asks to name three sources. Scoring would not be a clear indicator of vulnerability.	
38.1	38.1	✓	Presence of infirm or unwell person in household in the last year		
38.2	38.2	✓	Presence of chronically ill person in the		
39.1	39.1	✓	Highest level of formal education attained		
40.1	40.1	✓	Possession of skill sets outside of fishing related activities		
41.1	41.1	✓	Possession of basic knowledge in environmental, marine, fishing, or business knowledge		
42.1	42.1	✓	Degree of difficulty in finding alternative work if known as a fisher		
42.2	42.2	✓	Types of community organisations actively participated in		

43.1	43.1	✓	Contribution of each household members income to household expenses		
43.2	43.2	✓	Possibility to obtain cash for an emergency today		
44.1	44.1	✓	Presence of savings for emergencies		
45.1	45.1	✓	Mortgage repayments		
45.2	45.2	X	If yes, how much?	Not applicable to enough interviewees.	
45.3	45.3	✓	Money owed excluding mortgage		
46.1	46.1	X	Who/where money is typically borrowed.	Not clear on which sources make a fisher more/less vulnerable (depends on relationship and dependability of the source).	
46.2	46.2	✓	Loan provision for others in past year		
47.1	47.1	✓	Types of insurance policies held		
48.1	48.1	✓	Tenant or owner of house		
48.2	48.2	✓	Age of building		
48.3	48.3	✓	Number of rooms		
48.4	48.4	✓	Estimated value of house		
48.5	48.5	✓	Need for maintenance or renovations		
48.6	48.6	✓	Main construction material of house		
49.1	49.1	✓	Possession of a boat		
49.2	49.2	X	Number of boats	Not applicable to most	
49.3	49.3	X	Size of boats	Not applicable to most	
50.1	50.1	✓	Possession of freshwater tank		
50.2	50.2	✓	Main source of drinking water		
51.1	51.1	✓	Main source of energy		
51.2	51.2	✓	Main source of water heating		
52.1	52.1	✓	Main source of cooking fuel		
53.1	53.1	✓	Possession of own toilet		
53.2	53.2	✓	Type of toilet		

53.3	53.3	✓	Route of wastewater		
53.4	53.4	✓	Disposal of rubbish		
54.1	54.1	✓	Observed changes in communities' marine resources during		
54.2	54.2	X	If yes, what do you believe is the main cause of changes?	Answers are too variable to quantify.	
54.3	54.3	✓	Perception of changes in the local sea habitat		
54.4	54.4	✓	Factors cause fish number declines locally		
54.5	54.5	X	What do you think would increase the number of fish in the sea in your area?	Not easily quantified. Does not clearly represent vulnerability.	
54.6	54.6	✓	Perception of overharvesting of marine resources locally		
54.7	54.7	✓	Observed changes to livelihood due to changes in marine environment locally		
55.1	55.1	✓	Relative confidence in calling on someone for help financially		
56.1	56.1	✓	Degree of involvement in community decision making		
56.2	X	X	Degree of involvement in regional decision	Not in SA survey.	
56.3	56.3	✓	Degree of involvement in MPA management/ decision making		
57.1	57.1	✓	Strength of community leadership		
57.2	X	X	Level of trust in management to help the community	Not in SA survey.	
57.3	X	X	Level of trust in management to help	Not in SA survey.	
57.4	57.4	✓	Accessibility of community leadership		
58.1	58.1	✓	Equality of access and control over livelihoods and resources between men and women		
58.2	58.2	✓	Degree of vulnerability to future harm among different community members		

58.3	X	X	Equality of access to resources	Not in SA survey.	
59.1	59.1	✓	Perception of relationship of role of technology and skill of		
59.2	59.2	✓	Confidence in own skills resulting in success in fishing industry		
60.1	60.1	✓	Ability to endure some income shocks		
60.2	60.2	✓	Possibility to access financial reserves during periods without work		
61.1	61.1	✓	Amount of money owed on main assets		
61.2	61.2	✓	Amount of possessions/ assets in good condition		
62.1	62.1	✓	Relative diversity of marine habitat locally		
62.2	62.2	✓	Perception of change in fish numbers in past 5 years		
62.3	62.3	✓	Perception of change in marine environment in past 5 years		
63.1	63.1	✓	Preference for presence of other boats at sea while fishing		
64.1	64.1	✓	Increase/ Decrease/ Same		
64.2	64.2	✓	Increase/ Decrease/ Same		
64.3	64.3	✓	Increase/ Decrease/ Same		
64.4	64.4	✓	Increase/ Decrease/ Same		
64.5	64.5	✓	Increase/ Decrease/ Same		
64.6	64.6	✓	Increase/ Decrease/ Same		
64.7	64.7	✓	Increase/ Decrease/ Same		
64.8	64.8	✓	Increase/ Decrease/ Same(depth of fishing/ area of fishing increase)		
64.9	64.9	✓	Increase/ Decrease/ Same		
65.2	65.2	✓	Perception of safety in current livelihood despite environmental/ climatic exposure		

66.1	66.1	✓	Occurrence of large storm in past 5 years		
66.2	66.2	✓	Personally, directly impacted by storm		
66.3	66.3	✓	Degree of damage to household		
66.4	66.4	✓	Action taken to prevent future large storm damage		
66.5	66.5	X	Action taken to prevent future large storm damage	Not applicable to most interviewees.	
66.6	66.6	✓	Number fishing days lost to large storms in past year		
67.1	67.1	✓	Freshwater source affected by heavy rains or flooding		Included twice under Exposure (Environmental change component) and Adaptive Capacity (Physical capital component).
67.2	67.2	✓	Occurrence of floods in past 5 years		
67.3	67.3	✓	Personally, directly impacted by flood		
67.4	67.4	✓	Degree of damage to household		
67.5	67.5	✓	Action taken to prevent future flood damage		
67.6	67.6	X	Action taken to prevent future flood damage	Not applicable to most interviewees.	
67.7	67.7	✓	Number fishing days lost to floods in past year		
68.1	68.1	✓	Occurrence of drought in past 5 years		
68.2	68.2	✓	Personally, directly impacted by drought		
68.3	68.3	✓	Degree of damage to household		
68.4	68.4	✓	Action taken to prevent future drought damage		
68.5	68.5	X	Action taken to prevent future drought damage	Not applicable to most interviewees.	
68.6	68.6	✓	Number fishing days lost to droughts in past year		
69.1	69.1	✓	Occurrence of shoreline changes in past 5 years		
69.2	69.2	✓	Observation of shoreline erosion by the sea		
69.3	69.3	✓	Degree of beach erosion over last 5 years		

69.4	69.4	✓	Impact of shoreline erosion on livelihood		
70.1	70.1	X	Plan if it becomes too difficult to find fish.	Answered well but too difficult to appropriately score.	
70.2	70.2	✓	Response to hypothetical change in primary livelihood (fishing) - what will you do if it becomes too		Included twice under Sensitivity (Attachment to fishing) and Adaptive capacity (Occupational mobility).
X	70.3	X	What will you do if catches decline by 50%?	Not in original GULLS survey	
X	70.4	X	What will you do if market prices drop by 50% and remain there?	Not in original GULLS survey	
70.5	70.5	X	If you were in charge of fishing activity in this area what would you do?	Not easily quantified. The changes they list do not clearly represent vulnerability.	
71.1	71.1	✓	Presence of climate change centred institutions or government departments in the		
71.2	71.2	X	Type of institution working with community on climate change	Not applicable to enough interviewees.	
71.3	X	X	Types of institutions working with community on climate change issues	Not in SA survey.	
72.1	72.1	✓	Awareness of Climate Change		Included in the Attitude and perc. Component under Adaptive Capacity (not included in original GULLS framework)
72.2	72.2	✓	Experience of Climate Change		
72.3	72.3	X	Top three changes noticed.	More of a qualitative answer. Not useful to quantify.	
72.4	72.4	X	Source of information about climate change.	More of a qualitative answer. Using one source over another does not increase/decrease vulnerability.	
73.1-74.7	73.1-74.7	X	Household expenses	Poorly answered.	
74.1-74.16	74.1-74.16	✓	Number of assets owned from 16 items		

76.1	76.1	✓	Household members who live/work elsewhere during past 5 years		Included Twice. Once in the Sensitivity Category (component: social dependence) and in Adaptive Capacity (component: human capital)
77.1	77.1	✓	Relative condition of roof		
77.2	77.2	✓	Relative condition of building		

C. Rationale table for scoring and quantification

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
S			Occupational dependence	1.1	Is fishing your main occupation?	yes= 4; no=1	Main occupation = greater attachment
S		**Recreational dependence**	Regularity of recreational fishing	15.2	How often do you fish recreationally?	Very often=4; Somewhat often=3; rarely=2; Never=1	More recreational fishing = greater dependence.
S		**Social dependence**	Level of interaction and dependence on other people and institutions	5.1	I depend on the following institutions and people for day to day resources to go fishing: Weather predictions and news, family, buyers of fish, fellow workers, none.	None= 0.8; one option named = 1.6; two options = 2.4; three options = 3.2; four options and above = 4	High levels of interaction show a greater social dependence of fishers on the community around them.
S			Level of interaction and dependence on other people and institutions	5.2	Who do you interact with when you go fishing? (other fishers, safety authorities, suppliers of fishing tackle/fuel, Marine Reserve Managers, & Company officials)	Nobody = 0.5; other fishers = 0.67 ; tourists, skippers, and fishers = 1.34; other fishers and another source (higher authority: i.e. gov or supplier) = 2.01; fishers and two sources = 2.68 ; fishers and three other sources = 3.35; four sources and above = 4	High levels of interaction show a greater social dependence of fishers on the community around them. (changed because could not figure out rationale in old scoring method).
S			Length of time as a fisher	8.1	How long have you been a fisher?	Less than 10 years = 0.50; 10-15 years = 1.00; 16-25 years = 1.5; 26-35 years = 2.00; 36-45 years = 2.50; 50-65 years = 3.00; more than 65 years = 4.00	Longer involvement means greater importance.
S			Perception of a "fishing" family identity	8.5	Would you describe your family as having a fishing identity/culture?	yes= 4; no=1	Closer identification with fishing means a change in the fishery could impact cultural identification.

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
S	Historical & cultural dependence on fishing	Cultural importance of fishing	Extent of ancestral involvement in fishing	8.3	Were previous generations of your family/ancestors fishers?	yes= 4; no=1	Family tradition of fishing= greater importance. Qualitative data to compliment = 8.4.
S			Concern regarding the continuation of fishing as a livelihood among the next generation	16.6	Would you like your children to continue in the fishing profession?	Like very much=4; Like=3; Not like=2; Not like it at all=1	Fishers who want their children to become fishers show high attachment to place.
S			Concern regarding the continuation of fishing as a livelihood among the next generation	19.2	How concerned are you by the lack of young people entering the fishing industry in your area?	Very concerned=1 ; Concerned=2 ; Slightly concerned=3 ; Not concerned at all= 4	Changed original scoring. if people are concerned, there might be a lack of focus on fishing as a lucrative future income. Therefore, decreased dependence for the future generations.
S		Local ecological knowledge	Inclusivity of local ecological knowledge within marine resource management planning	19.1	How much was your local knowledge about fishing included in local marine resource management plans?	Very=1; 'Minder'=2; Slightly=3; Not at all =4	More LEK indicates lower sensitivity because including LEK can improve management plans and their acceptance by the community.
S			Level of knowledge about marine environment	20.1	How much do you think you know about the environment in which you fish?	A lot=1; Quite a lot=2; A little=3; Nothing=4	If fishers have greater knowledge about the marine environment, they might notice change earlier and prepare in anticipation, thus reducing sensitivity.
S			Importance to ensure LEK is passed on to younger generations	20.2	How important do you think it is to pass on local knowledge about fishing to younger generations?	Very important=1; Important=2; Slightly important=3; Not at all important=4	Greater importance means the younger generation will be better informed and sensitivity would be reduced.

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
S			Relative maintenance of LEK between generations	20.3	Would you say local knowledge about fishing is being lost or maintained in this community?	Well maintained=1; Maintained=2; Partly lost=3; Almost all lost=4	As above, if information is passed to the younger generation, they will be better informed - reducing sensitivity.
S		**Social mobility**	Difference in occupation from parents	9.2 (a)	Did your father attend school?	No=4; Yes=1	The higher the education required for the main occupation, the greater likelihood for a higher income. Majority answered = Fisher
S			Difference in occupation from parents	9.2 (b)	Did your mother attend school?	No = 4; Yes = 1	The higher the education required for the main occupation, the greater likelihood for a higher income. Majority answered = House-wife
S			Difference in occupation from parents	9.3 (a)	To what level did your father attend school?	Above Matric= 1; Matric=1.71; Grade 8-11=2.28; Grade 5-7=2.85; Grade 1-4= 3.42; Below=4	Higher education are associated with greater opportunity and therefore, lower sensitivity.
S			Difference in occupation from parents	9.3 (b)	To what level did your mother attend school?	as above.	as above.
S			House ownership of parents' vs interviewee	9.4	Did your parents own their own house?	No=4; Yes=1	Greater house ownership of the interviewee reduces sensitivity.
S			Boat ownership of parents' vs interviewee	9.5	Did your parents own their own boat?	No=4; Yes=1	As above, increasing ownership of the younger generation reduces sensitivity.
S			Level of financial wellbeing compared to parents	9.6	Would you say you are financially better off than your parents?	No=4; Yes=1	Greater wellbeing compared to parents suggest upward mobility and reduced sensitivity.
S			Options available for work without fishing	1.9	Do you have alternative employment options if fishing fails to provide sufficient income?	No=4; Yes=1	If there are not many alternative employment opportunities available, this will mean a greater sensitivity should fishing resource availability diminish.

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
S	Economic dependence on fishing	Economic dependence	Number of nights per week that household consumes seafood	6.1	How many days a week do you and your household consume fresh marine food?	0 days = 0 ; 1 day = 0.57 ; 2 days = 1.14 ; 3 days = 1.71 ; 4 days =2.28 ; 5 days = 2.85 ; 6 days = 3.42 ; 7 days	More fish consumption shows greater impact if fishing resource availability is negatively impacted. Scored on own.
S			Source of seafood consumed	6.2	Is the fish you eat from your own catch or do you buy fish?	Own catch= 1 ; Bought/ Other = 4 (If answered both = 4)	Greater variety in the sources of seafood spreads the risk of food security being affected in the case of any adverse event.
S			Possession of own fishing business	3.1	Do you own your own fishing business? (License)	Yes = 4 ; No = 1	Owning a fishing business indicates stronger dependence on fishing and greater sensitivity to change in the fishing resource.
S			Possibility to feed family without fishing	17.2	How possible would it be to feed your family if you did not go fishing?	Not at all= 4; Slightly = 3; Possible=2; Very=1	If there are few feeding alternatives this means that families are more sensitivities.
S		Competition for fish	Perception of whether too many or too few fishers operate in the community	18.1	Would you say there are too many or too few fishers in the fishing industry or in this fishing community?	Too many = 4; Slightly too many= 3; Slightly too few=2 ; Too few =1; Enough = 1	Too many fishers = high pressure on fishing resources.
S			Perception of whether too many or too few fishers operate in the community	18.2	Would you say there are too many or too few fishers working in the areas that you fish?	Too many = 4; Slightly too many= 3; Slightly too few=2 ; Too few =1; Enough = 1	Too many fishers = high pressure on fishing resources.
S			Degree of concern about illegal fishing levels locally	18.3	How concerned are you about the level of illegal fishing that is occurring?	Very = 4; Concerned = 3; Slightly = 2; Not at all = 1	Little concern = adequate monitoring and surveillance.
S		Different food sources	Relative contribution of different methods obtaining food	4.2	What percentage of foods (by volume) are: Bought from the store, Exchanged, Grown by yourself?	100% shops = 4; 90% shops = 3.6; 80% shops = 3.2; 70% shops = 2.3; 50% shops = 2	Greater diversity in the method used to obtain food would suggest a greater number of options to fall back on in bad times. (most alternatives: grown. Little exchange seen).

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
S	Economic dependence on other resources	Vegetables consumed	Number of nights per week that household consumes vegetables	7.1	How many days a week do you and your household consume fresh vegetable product?	1 day = 0.57 ; 2 days = 1.14 ; 3 days = 1.71 ; 4=2.28 ; 5 days = 2.85 ; 6 days = 3.42 ; 7 days = 4	Although more veg would have a positive effect on nutrition, lower contribution of animal protein in diet might be an indicator of poverty. Here, high veg consumption is an indicator for sensitivity
S		Meat consumed	Number of nights per week that household consumes meat	7.2	How many days a week do you and your household consume fresh meat?	Never = 4.00 ; 1 day = 3.50 ; 2 days = 3.00 ; 3 days = 2.50 ; 4=2.00 ; 5 days = 1.50 ; 6 days = 1.00 ; 7 days = 0.5	Higher meat consumption might be an indicator of affluence. Higher number = lower sensitivity.
S		Self sufficiency	Relative importance of household's food source	7.3	What is the most important food source for your family's household?	Shops = 4; Own catch=3; Garden=2; Garden and sea=1	Better access to own home grown food sources = less exposed to changes in food market prices. Greater self-sufficiency = lower sensitivity.
S		Subsistence agriculture	Level of farming/ subsistence activity	7.5	Do you have a garden or plantation?	Yes = 1; No = 4	No garden = one less resource to draw on in hard times and therefore, greater sensitivity.
S			Level of farming/ subsistence activity	7.1	Do you have livestock?	Yes = 1; No = 4	as above.
AC			Observed changes in communities' marine resources during lifetime	54.1	Have you noticed changes in your communities' marine resources during your lifetime?	Yes = 1; No = 4	Changes observed in communities' marine resource base usually indicates a decrease in natural capital.
AC			Perception of changes in the local sea habitat	54.3	Do you think that the sea habitat in your area is:	Irreversibly damaged=1 ; Badly damaged = 1.6; Slightly damaged = 2.4; Remained the same = 3.2; Improved = 4	Higher levels of damage to the local sea habitat indicates larger decrease in natural capital and AC.

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
AC	Natural capital	Changing resource base	Factors cause fish number declines locally	54.4	What do you think are the factors that cause declines in fish numbers in your area?	Gave one factor = 3.2; two factors = 2.4; three factors = 1.6	higher number of factors of causes for fish declines indicate a decrease in natural capital decrease NC and AC to a greater extent than past, discrete causes of change.
AC			Perception of overharvesting of marine resources locally	54.6	Do you think your local marine resources are being over harvested at the moment?	Yes = 1; No = 4	Perceived overharvested marine resources indicates lower natural capital and AC
AC			Observed changes to livelihood due to changes in marine environment locally	54.7	Have you noticed any changes to the marine habitat?	Yes = 1; No = 4	Evidence of observed changes in livelihoods due to changes in the marine environment indicate higher natural capital and AC
AC			Relative diversity of marine habitat locally	62.1	How diverse is the marine habitat of your community?	Very high = 4; High = 3; Low = 2; Very low = 1	higher scores for the diversity of the marine habitat indicate higher natural capital and AC
AC			Perception of change in fish numbers in past 5 years	62.2	How has the number of fish in the area changed compared to 5 years ago?	Big decrease = 1; Decrease = 2; Increase = 3; Big increase= 4	Perception of increasing number of fish indicate higher natural capital and AC (vice versa).
AC			Perception of change in marine environment in past 5 years	62.3	Has the marine environment worsened or improved over the past 5 years?	Improved a lot = 4; Improved = 3; Worsened = 2; Worsened a lot = 1	Perception of improvement indicates higher NC. (if put 'same' then was given a score of 2.5).
AC		Decision making	Degree of involvement in community decision making	56.1	How involved are you in community decision making?	Very involved = 4; Involved = 3; Slightly Involved = 2; Not at all = 1	Involvement in community decision making yields greater interest in finding community rather than individual solutions.
AC			Degree of involvement in MPA management/ decision making	56.3	How involved are you in marine protected area management?	Very involved = 4; Involved = 3; Slightly Involved = 2; Not at all = 1	Involvement in MPA planning precipitates greater interest in protecting marine resources and activities

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
AC	Social Capital	**Networks**	Relative confidence in calling on someone for help financially	55.1	How confident are you that you can call someone if you need help financially?	Very = 4; Confident = 3; Slightly = 2; Not at all = 1	More confidence to call someone the better financial support to face adversity
AC		**Gender equity**	Number of women in leadership roles in the community and positions	36.1	Are any women in leadership roles in this community?	Yes = 4 ; No = 1	More women in leadership indicate greater community equity
AC		**Equity**	Degree of vulnerability to future harm among different community members	58.2	Would you say that everyone in this community is vulnerable or are some people more vulnerable than others in this community?	Everyone = 1; Most = 2; Some = 3; No one = 4	Higher levels of equality in community vulnerability indicate the potential for the community to work together to overcome future impacts
AC			Equality of access and control over livelihoods and resources between men and women	58.1	How equal is women's access and control of livelihoods and resources compared to men?	Totally equal = 4; Nearly equal = 3; Quite unequal = 2; Not at all equal = 1	Higher levels of equality indicate equal distribution of power and access between men and women
AC		**Leadership**	Strength of community leadership	57.1	How strong is your community leadership?	Very strong = 4; Strong = 3; Slightly strong = 2; Not at all = 1	Stronger leadership = greater the representation of the community
AC			Accessibility of community leadership	57.4	How often can you talk to a community leader if you need to?	Always = 4; Often = 3; Sometimes = 2; Never = 1	More access to community leader = greater community representation.
AC			Types of community organisations actively participated in	42.2	List any community organisations you are an active participant in:	None = 1; any mention of committees, churches, etc. = 4	more involvement in community organisations = more motivation to find solutions to problems.
AC			Main source of assistance when have financial, food or basic needs	35.1	When I need help financially or in terms of food or basic needs I ask for assistance from:	Family = 4; Neighbours/ Friends =3; Skipper/Boss = 2; Local money lenders = 1	Source of help can increase AC (family) or decrease AC (loan sharks). No one = 1 (less adaptive capacity).

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
AC		**Social capital, networks, and community cohesion**	Possibility to obtain cash for an emergency today	43.2	If you needed cash today for an emergency - would you be able to get that cash?	Yes = 4 ; No = 1	Greater possibility to obtain cash, better capacity to respond to change
AC			Relative confidence in calling on someone for help financially	55.1	How confident are you that you can call someone if you need help financially?	Very confident = 4; Confident = 3; Slightly = 2; Not at all = 1	Greater confidence to call for help, greater adaptive capacity to respond to change
AC	**Bridging social capital**	**Access to institutional safety nets and information**	Number of governmental safety nets for fishers	31.1	Would you say there are none or many government safety nets in case disaster strikes fishing activities in this community?	Many = 4; Some = 3; Few = 2; None =1	More of a government safety net = better response in case disaster strikes fishing activities
AC			Strength of links between fishers and institutions or government	31.2	How well linked is this community to government departments and/or academic institutions so you receive up to date information about fishing?	Very well linked = 4; Well linked = 3; Slightly = 2; Not at all = 4	Stronger link = better access to up to date information on fishing related matters
AC		**Built house**	Tenant or owner of house	48.1	Do you own or rent the house you live in?	Own = 4; Do not own = 1	Owning a house indicates greater physical capital
AC			Need for maintenance or renovations	48.5	Does your house need much renovation and maintenance?	No = 4; Yes = 1	The need for maintenance lowers physical capital and AC
AC			Main construction material of house	48.6	What is the outside of the house mainly made of?	Cement/Bricks = 4; Wood = 1	Permanent and long lasting materials = higher physical capital, temporary low quality materials = lower physical capital

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
AC	Physical capital	House Conditions	Relative condition of roof	77.1	Roof condition:	Very good = 4; Good = 3; Fair = 2; Bad = 1	Better condition = greater physical capital
AC			Relative condition of building	77.2	Building condition:	Very good = 4; Good = 3; Fair = 2; Bad = 1	Better condition = greater physical capital
AC		Boat assets	Possession of a boat	49.1	What sort of boat do you own?	No boat = 1; Recreational boat = 3; Ski boat = 4	Owning a boat means greater physical capital.
AC		Debt on main assets	Amount of money owed on main assets	61.1	How much money do you owe on your main assets?	Much = 1; Some = 2; Little = 3; None = 4	More money owed means less physical capital and lower adaptive capacity
AC		Condition of assets	Amount of possessions/ assets in good condition	61.2	How many of the things you own are in good condition and don't need to be replaced anytime soon?	All = 4; Most = 3; Some = 2; None =1	Better condition = greater physical capital
AC		Fresh Water Supply	Possession of freshwater tank	50.1	Do you have a water tank?	No = 1; Yes = 4	Water tank indicates access to fresh water and greater physical capital
AC			Main source of drinking water	50.2	What is your main source of drinking water?	Public system = 1; Stand pipe =3; Fresh water = 4	More reliable source of water indicates higher physical capital.
AC			Freshwater source affected by heavy rains or flooding	67.1	Does your water source get dirty during heavy rains/flooding?	Yes = 1; No = 4	Water sources affected by heavy rains indicates a lower physical capital
AC		Energy	Main source of energy	51.1	What is your main source of energy?	Mains connected = 4; No power = 1	more reliable source of energy indicates greater PC and AC
AC			Main source of water heating	51.2	What source of heating do you have?	Electric = 4; Kettle/Stove/ Fire = 1	More reliable source of water heating indicates higher physical capital and AC.
AC		Cooking Fuels	Main source of cooking fuel	52.1	What is the main source of fuels you use for cooking?	Electric = 4; Gas = 3.5; Wood = 2; None = 1	More reliable source of fuel = higher PC and AC.

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
AC		**Waste**	Possession of own toilet	53.1	Do you have your own toilet?	Yes = 4 ; No = 1	Own toilet = higher PC and AC
AC			Type of toilet	53.2	What type of toilet do you have?	Flush = 4; Pour flush = 3; Compost/Long Drop = 2; No Toilet = 1	more reliable/technologically advanced toilet = higher PC and AC
AC			Route of wastewater	53.3	What happens to the waste?	Disposal = 4; Septic Tank 3; Soak pit = 2; None = 1	More advanced route = higher PC and AC
AC			Disposal of rubbish	53.4	How do you get rid of most of your rubbish?	Collected = 4; Hole/Open Burning = 1	as above.
AC		**Material assets**	Assets	74.1-74.16	Do you own: vehicle, fishing gear, T.V., Gas/ Stove, Cell phone, Piped water, Fridge, Radio, Video, Generator, Electricity	Yes = 4 ; No = 1. Average the answers.	More material assets = better adaptive capacity
AC		**Infra index**		Infra	Filled by researcher: Indicate if the following infrastructure items are present or absent in the community (i.e. hospital, Medical clinic, Primary school, Hotel, Petrol station, Sewer, etc.)	Present = 4; Absent = 1. Add up & divide by 34 (34 structures were named) for the average.	Higher number of infrastructure items in a community = higher physical capital. (Note: each community will have the same score).
AC		**Insurance**	Types of insurance policies held	47.1	What insurance policies do you have at the moment?	Three plus policies = 4; Two policies named = 3; One type of insurance = 2; None	Existence of insurance policies indicate ability to withstand potential losses
AC		**Credit**	Loan provision for others in past year	46.2	Have you loaned money to anyone in the last year?	No = 1; Yes = 4	Respondents who provide loans to others indicate disposable incomes and higher financial capital and AC
AC		**Debt**	Mortgage repayments	45.1	Do you have a mortgage on your house?	No = 4; Yes = 1	Mortgage = lower financial capital

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
AC	Financial capital	Debt	Money owed excluding mortgage	45.3	Do you owe money to anyone?	No = 4; Yes = 1	Money owed indicates higher debt and lower FC
AC		Savings	Possibility to access financial reserves during periods without work	60.2	How possible is it for you to access financial reserves if you end up without work for a while?	Very = 4; Possible = 3; Slightly = 2; Not at all = 1	Access of financial reserves during workless period indicates higher FC
AC			Presence of savings for emergencies	44.1	Do you have any savings or money put aside for emergencies?	No = 4; Yes = 1	Presence of savings allows fallback money in times of emergency and thus, higher FC
AC		Household income	Monthly income	2.1	Is there much variation in your household income between the summer and the winter period?	Yes = 4 ; No = 1	Higher amounts of income = higher FC
AC		Socioeconomic Index	Monthly income	2.2	What is your average household income per month before tax and from all sources?	< 1000 R = 0.5 ; 1,000-2,000 R = 1.0; 2,001-4,000 = 1.5; 4,001-8,000 = 2.0; 8,001-15,000 = 2.5; 15,001-25,000 = 3.0; 25,001-50,000 = 3.5 ; 50,001 and above = 4	Ranges increase as income increases. Logic: as income lowers, the vulnerability rapidly increases. Example: an extra 1,000 R is a huge difference when earning 2,000 R monthly vs. earning 20,000 R monthly. (changed original scoring: could not make sense of it).
AC		Household sharing income	Contribution of each household members income to household expenses	43.1	Does each working household member contribute to basic household expenses?	Yes = 4 ; No = 1	More household members contributing = multiple income generators for house hold and higher FC
AC		Income shocks	Ability to endure some income shocks	60.1	How possible is it for you to endure some shocks if it should occur?	Very = 4; Possible = 3; Slightly = 2; Not at all = 1	Ability to endure income shocks = higher FC

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
AC	Personal flexibility	Perception of risk in approaching change	Level of habituation to changes in everyday life	21.1	How used would you say you are to the changes in everyday life?	Very used = 4; Used to it = 3; Not used to it = 2; Not at all used to it = 1	Those habituated to everyday changes are more likely to be adaptable in the future
AC			Perception of which user groups are most at risk to future changes	21.2	Would you say that only big companies or only small scale fishers will survive future changes in the industry?	Big companies only = 4; More big companies than small = 3; Small scale fishers only = 2; More small scale than big = 1	Higher perception of risk for themselves and others indicates higher ability to be aware of future risk (more perception of risk = better adaptive capacity).
AC		Ability to plan, learn and reorganise	Level of financial planning	22.1	How well have you planned for your financial security?	Very well planned = 4; well-planned = 3; planned a little = 2; no plan at all = 1	High levels of financial planning indicate higher ability to plan for the future
AC			Level of interest to learn new skills outside of fishing	22.2	How interested are you in learning new skills outside of your expertise?	Very Interested 4; Interested = 3; slightly = 2; not interested at all = 1	Interest to learn new skills indicates higher potential to develop alternative skills for future livelihoods
AC			Perception of possibility to personally improve the marine environment	22.4	How possible is it for you to make a personal difference in improving the health of the marine environment in this area?	Very possible = 4; Possible = 3; Slightly = 2; Not at all possible = 1	Higher perception of ability to improve marine environment indicates passion and stewardship towards the marine environment
AC		Perception of the ability to cope with change	Level of confidence that events will work out well regardless of everything else	23.1	How confident are you that things will turn out well regardless of the changes and challenges you confront?	Very confident = 4; Confident = 3; slightly = 2; not at all = 1	Higher confidence indicates a positive-minded , optimistic mind set about the future regardless of change.
AC			Perception of responsibility to protect the marine environment	24.1	How responsible do you feel to protect the marine environment?	Very = 4; Responsible = 3; Slightly = 2; Not at all = 1 (switched on the table)	Higher perception of responsibility to protect the marine environment indicates level of stewardship.

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
AC		**Level of interest in adapting to change**	Level of interest in changing employment	10.1	Right now, if you had a chance would you:	Change your job = 4; Stay doing what he is doing = 1	High interest in changing occupation indicates dissatisfaction in current employment and/or interest in alternatives if marine based occupations become untenable in the future
AC		**Employability**	Perception of finding work in alternative sector	10.2	At this time do you feel you could find work in a different sector?	Yes = 4 ; No = 1	High perception in ability to find work outside of fishing indicates higher adaptability
AC			Number of options for alternative work	10.3	How many options for a different type of job/ work would you say you have?	Many = 4; Some = 3; Few = 2; No options = 1	Greater number of options = greater adaptability
AC			Number of courses taken to improve employability	10.4	Have you done any courses to improve your employability?	Yes = 4 ; No = 1	Greater number of courses = greater chance of finding alternative occupations
AC			Level of interest in working for someone else	10.6	Would you be happy working for someone else?	Yes = 4 ; No = 1	Higher interest in working for someone else indicates greater adaptability
AC			Perception of utility of own skills to set up a business outside of fishing	26.1	How useful would your skills be in setting up a business other than in fishing?	Very useful = 4; Useful = 3; Slightly = 2; Not at all = 1	Higher perception indicates positive mindset in setting up a business and finding alternative income if fishing becomes untenable
AC		**Attitude to Change**	Perception of ability to adapt to change compared to others locally	25.2	How likely are you to adapt to change compared to others you know?	Very likely = 4; Likely = 3; Not likely = 2; Not likely at all = 1	Higher perception to adapt to change better will result in greater willingness to accept and adapt to change
AC			Perceived level of risk to community from environmental change	32.1	How much of a risk do you think environmental change poses to the community you live in?	High = 4; Medium = 3; Low = 2; None = 1	High level of risk perceived indicates a better capacity to anticipate and adapt to change.

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
AC	Attitude and perception		Degree of anxiety felt about environmental changes observed locally	32.3	How anxious/scared do you feel about the changes you are seeing in the environment in your area?	Very = 4; Scared/Anxious = 3; Little = 2; Not at all = 1	High anxiety indicates higher likelihood that community and individuals will take steps to adapt
AC		Attitude and perception to climate change	Awareness of Climate Change	72.1	Have you ever heard of climate change?	Yes = 4 ; No = 1	Awareness of climate change = more knowledge and higher capacity to anticipate change
AC			Experience of Climate Change	72.2	Do you think the climate has changed over time?	Yes = 4 ; No = 1	Awareness of climate change = more knowledge and higher capacity to anticipate change
AC		Interest in the Environment	Amount of knowledge good fishers possess about target fish biology	34.4	Would you say a good fisher knows a lot or a little about the biology of the main species they catch?	a lot = 4; Some = 3; Little = 2; Nothing = 1	Greater knowledge indicates greater interest in the environment and understanding of the system, which makes them more likely to wish to preserve the ecosystem.
AC			Number of ideas held to ensure sustainability of the target fish species locally	34.3	How many ideas would you say you have about how to ensure the sustainability of the main species you catch?	Many ideas = 4; Some = 3; Few = 2; No ideas = 1	High number of ideas = greater possibility to keep the activity for a longer time.
AC		Capacity to anticipate change and develop response strategies	Relative importance of tourism to community and natural resources to tourism	27.1	How suitable do you think your community is for tourism activities?	Very suitable = 4; Suitable = 3; Slightly = 2; Not at all = 1	Higher suitability indicates more promising opportunity for tourism as an alternative source of income = greater adaptability
AC			Health of the marine resources locally	27.2	How healthy are the marine resources in your area for tourism?	Very healthy = 4; Healthy = 3; Slightly = 2; Not at all = 1	Healthy marine resources = high potential for suitable tourism
AC			Relative importance of fishing as economic activity locally	27.3	How important is fishing as an economic activity in this community?	Very = 4; Important = 3; Slightly = 2; Not at all = 1	High relative importance of fishing indicates the importance to safeguard fishing industry.

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
AC	**Occupational flexibility**	**Occupational Mobility (attachment to fishing)**	Number of employment changes in past 5 years	11.1	Have you had a change of employment in the past 5 years?	Yes = 4; No = 1	Large number of employment changes = more skills to work in different sectors OR inability to work in one sector successfully for long periods of time. Here, employment change is positive for adaptive capacity.
AC			Level of interest in working in non-fishing sector	11.4	Would you be interested in doing a job other than fishing if you could earn as much as you do fishing?	Yes = 4 ; No = 1	High level of interest = greater interest in alternative livelihoods = greater adaptability
AC			Types of livelihoods found by fishers leaving the fishery	11.8	In which sector do people who have left fishing find work in this community	No other options = 1; One option = 2; Two options = 3; Three or more options listed = 4	Indication of the options available locally to those who have exited the fishery recently.
AC			Level of occupational diversity throughout the year	28.1	How often are you employed in more than one job per year?	Never = 1; Rarely = 2; Often = 3; Very often = 4	high level of occupational diversity = greater adaptability
AC			Response to hypothetical change in primary livelihood (fishing) - what will you do if it becomes too difficult to find fish?	70.2	What will you do if it becomes too difficult to find enough fish	Find other work = 4; Already difficult but remains = 3; Fish other species = 2; Keep fishing = 1	Indication of what it would take to get a fisher to stop fishing. Willingness to find other work = greater adaptability.
AC			Willingness to relocate for livelihood purposes	28.2	How willing are you to move to a bigger town or community for work if necessary?	Very = 4; Willing = 3; Slightly = 2; Not willing at all = 1	Willingness to relocate = higher adaptability
AC			Presence of natural resource management institutions in community	13.1	Does your community have any type of marine resource management?	Yes = 4 ; No = 1	Presence of natural resource management improves the possibilities to keep ocean related livelihoods long-term

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
AC	**Institutional support**	**Resource management institutions**	Type of management system	13.2	If yes, what kind of management system?	Government = 1; Community / Skipper = 4	Community participation = better capacity that the local issue be attended by marine resource management. (all answered Government).
AC			Level to which rules have changed due to environmental changes	13.3	Have rules, practices changed in the past in response to environmental changes?	Yes = 4 ; No = 1	Changing rules shows the institutions work to keep livelihoods and preserve marine resources in the face of climate change
AC			Degree of recording/ reporting of catches required	13.5	Do you have to report/ record your catches at a landing site or to an authority?	Yes = 4 ; No = 1	High degree of recording = better data for marine resource managers to make well informed decisions
AC		**Climate Change focused institutions**	Presence of climate change centred institutions or government departments in the area/community	71.1	Are there institutions or government departments working on climate change or facilitating adaption to change in the community	Yes = 4 ; No = 1	Presence of institutions = better adaptability
AC		**Fishing compliance and conflict**	Relative occurrence of illegal fishing locally	30.1	Would you say that illegal fishing does not occur or does occur in the community in which you fish?	Occurs a lot = 1; Occurs = 2; Occurs a little = 3; Does not occur at all = 4	High levels of illegal fishing indicates lack of compliance and an individualistic profit making mindset of local fishers.
AC			Number of people who know those who break the rules	30.4	Would you say that everyone or no-one knows the individuals are that break the fishing rules?	No one = 4; Few people = 3; Most people = 2; Everyone = 1	High numbers of people who know people who fish illegally indicates how overt or covert illegal behaviour is.
AC			Relative occurrence of conflict among fishers	30.6	How common are conflicts between fishers in this area?	Very common = 1; Common = 2; Not very common = 3; Never occurs = 4	High levels of conflict = high levels of conflict and inequality (in gear, space, and access).

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
AC	Institutional flexibility		Level of enforcement of fishing rules	30.5	How well enforced are the fishing rules that apply in this area?	Well enforced = 4; just enforced = 3; enforced a little = 2; Not at all enforced = 1	Indication of level of enforcement
AC		Markets	Number of markets to sell fish in the community	12.5	How many markets/ auction sites are there in your community where you can sell your fish directly?	No markets = 1; 1-2 markets = 2; 3-4 markets = 3; 5 markets and above = 4	Higher number of markets to sell fish provides more options to fishers and may contribute to better price competition
AC			Possibility of selling fish outside the community	12.6	Do you ever sell fish to a fish market outside your community?	Yes = 4 ; No = 1	higher possibility to sell fish outside of the community indicates higher adaptability.
			Stability of fish price	12.9	Have fish prices been relatively stable over the past three years?	Yes = 4; No = 1	Higher stability of fish can be good or bad. In this case, higher stability indicates greater adaptive capacity and reduced vulnerability.
			Number of markets to sell meat and vegetables	12.11	How many markets are in your community where you can buy/sell fresh meat and vegetables?	0 markets = 0.57; 1 market = 1.14; 2 markets = 1.71; 3 markets = 2.28; 4 markets = 2.85; 5 markets = 3.42; 6 markets or above = 4	High number of markets to sell fruits and vegetables reduces vulnerability and increases adaptive capacity for those who have farm animals and products to sell for cash when fishing is not good.
AC		Skills	Confidence in own skills resulting in success in fishing industry	59.2	How confident are you that your skills will mean that you are successful in the industry?	Very confident = 4; Confident = 3; slightly = 2; not at all = 1	Greater confidence in own skills, greater chance at being successful
AC			Perception of relationship of role of technology and skill of fishers	59.1	Would you say that, with the technology available to the industry now, that anyone or only certain people can be a skilful fisher?	Anyone = 1; Many people = 2; Some = 3; Very few = 4	The perception that with just technology anyone can be a successful fisher, indicates a decreased perception of importance of traditional fisher knowledge

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
AC	Human Capital		Possession of skill sets outside of fishing related activities	40.1	Do you have basic skills in the following fields: Gardening, Electronics, Emergency/first aid, Mechanics, Welding, other	None = 0.67; One skill = 1.34; Two skill = 2.01; Three skill = 2.68; Four skill = 3.35; Five skill and above = 4	More skills outside of fishing indicates lower dependence on fishing. (Self-Scored).
AC		**Health**	Presence of infirm or unwell person in household in the last year	38.1	Do you have anyone in your house that is or was infirm or needed assistance to undertake daily chores in the past 12 months?	Yes = 1; No = 4	Presence of infirm person reduces adaptive capacity.
AC			Presence of chronically ill person in the household	38.2	Is anybody in your family chronically ill?	Yes = 1; No = 4	Presence of chronically ill person reduces adaptive capacity.
AC		**Labour**	Degree of difficulty in finding alternative work if known as a fisher	42.1	Is it easy to find work outside of fishing if you are known to be a fisher?	Yes = 4 ; No = 1	The easier it is to find work, the easier it would be to find another source of income if the fishing sector is negatively impacted.
AC		**Migration**	Household members who live/work elsewhere during past 5 years	76.1	Did any of your household members live/work elsewhere in the past 5 years?	Yes = 4 ; No = 1	The more members of family living away, the lower the social dependence on the community and long term attachment to the place = higher adaptability.
AC		**Knowledge**	Possession of basic knowledge in environmental, marine, fishing, or business knowledge	41.1	Do you feel you have basic knowledge in any of the following areas: local environmental issues, local marine issues, fish biology, running a business, other	None = 0.8; Named one area = 1; two areas = 2; three areas = 3; four areas or above = 4	Basic knowledge = greater ability to be successful in the fishing industry.

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
AC		**Age**		household data	How old are you?	65 years or older = 1; 55-64 years old = 2; 45=54 years old = 3; Below 45 years old = 4	Vulnerability increases with age
AC		**Education**	Highest level of formal education attained	39.1	What is the highest level of education reached by you?	None to Grade 1 = 0.57; Primary school = 1.14; Grade 7 = 1.71; High school = 2.28; Matric = 2.85; College = 3.42; Above = 4	The higher the level of formal education, the better ability to cope with change.
E	**Environmental change**	**Sea level**	Increase/ Decrease/ Same	64.1	In the past 5 years, have you noticed any changes in Sea level?	Increase/Decrease = 4; Same = 1	Changes in sea level indicate exposure level
E		**Rain**	Increase/ Decrease/ Same	64.2	In the past 5 years, have you noticed any changes in Rain?	Increase/Decrease = 4; Same = 1	Erratic rain leads to loss of fishing days
E		**Wind**	Increase/ Decrease/ Same	64.3	In the past 5 years, have you noticed any changes in Wind?	Increase/Decrease = 4; Same = 1	Fluctuations in wind speed affects fishing operations and indicates higher exposure levels.
E		**Air temperature**	Increase/ Decrease/ Same	64.4	In the past 5 years, have you noticed any changes in Air temp?	Colder/Hotter = 4; Same = 1	Rising air temperature increases cost of living leading to higher exposure
E		**Wave height**	Increase/ Decrease/ Same	64.5	In the past 5 years, have you noticed any changes in Wave Height?	Increase/Decrease = 4; Same = 1	Changes in wave height affect fishing operations and increased wave height can lower the number of viable sea days.
E		**Current strength**	Increase/ Decrease/ Same	64.6	In the past 5 years, have you noticed any changes in Current Strength?	Stronger/Weaker = 4; Same = 1	Changes in current strength affects fish stock/ground.
E		**Rough seas**	Increase/ Decrease/ Same	64.7	In the past 5 years, have you noticed any changes in Sea roughness?	Increase/Decrease = 4; Same = 1	Increased sea roughness can lead to threats in sea safety and lead to overall higher exposure

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
E		**Sea temperature**	Increase/ Decrease/ Same (depth of fishing/ area of fishing increase)	64.8	In the past 5 years, have you noticed any changes in Sea temp?	Colder/Hotter = 4; Same = 1	Increase in sea temperature affects fishing efforts.
E		**Bottom temperature**	Increase/ Decrease/ Same	64.9	In the past 5 years, have you noticed any changes in Bottom temp?	Colder/Hotter = 4; Same = 1	Increase in bottom temperature indicates higher exposure level.
E		**Safety at sea**	Preference for presence of other boats at sea while fishing	63.1	Would you say for safety reasons you prefer to work with many boats around whilst at sea?	Many = 4; Some = 3; Few = 2; None =1	Preference of working with others at sea indicate the need to work with others to identify fishing ground and curb eventualities at a minimum level. This preference = dependence = higher exposure.
E			Perception of safety in current livelihood despite environmental/climatic exposure	65.2	How safe do you feel you are in your main occupation in the context of climate exposure?	Very safe = 0.8; Safe= 1.6; Somewhat dangerous = 2.4; Dangerous = 3.2; Very dangerous = 4	Better awareness on safety leads them to take more precautions and reduce exposure.
E		**Storms**	Occurrence of large storm in past 5 years (moment –adverse; long time – advantageous)	66.1	Has there been a large storm in the last 5 years?	Yes = 4 ; No = 1	Large storm = high personal exposure.
E			Personally, directly impacted by storm	66.2	Were you directly impacted by the large storm?	Yes = 4 ; No = 1	Direct impact and incidence of causalities/ fishing days lost = higher exposure
E			Degree of damage to household	66.3	If yes, how bad was the storm damage to your household?	No damage / not impacted directly = 0.8; Little damage = 1.6 ; Moderate damage = 2.4; Major damage = 3.2; Catastrophic = 4	Increased degree of damage to household from storms = high personal exposure
E			Action taken to prevent future large storm damage	66.4	Have actions been taken by the household to prevent large storm damage?	No = 4; Yes = 1; NA = 1	Any mitigation or adaption to prevent future large storm damage lessens exposure (NA answers also receive a 1).

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
E	Personal exposure		Number fishing days lost to large storms in past year	66.6	How many fishing days did you lose due to the large storms in the past year?	NA/None = 0.8; Less than 10 days = 1.6; 10-30 days = 2.4; 1-3 months = 3.2; Greater than 3 months = 4	Loss of fishing days = high exposure.
E		Floods	Household in area prone to flooding	67.1	Does your water source get dirty during heavy rains/flooding?	Yes = 4 ; No = 1	Household flooding increases likelihood of destruction to personal assets and overall exposure
E			Occurrence of floods in past 5 years	67.2	Has there been a Flood in the last 5 years in your area?	Yes = 4 ; No = 1	Occurrence of floods = high exposure
E			Personally, directly impacted by flood	67.3	Were you directly impacted by the flood?	Yes = 4 ; No = 1	Incidence of personal impact from flooding = high exposure
E			Degree of damage to household	67.4	How bad was the Flood damage to your household?	No damage = 0.8; little damage = 1.6 ; moderate damage = 2.4; major damage = 3.2; Catastrophic	Exposure levels increase as severity of damage increases
E			Action taken to prevent future flood damage	67.5	Have actions been taken by the household to prevent flood damage?	Yes = 1; No = 4	Any mitigation or adaption to prevent future flood damage lessens exposure (NA answers also receive a 1).
E			Number fishing days lost to floods in past year	67.7	How many fishing days did you lose due to the flood in the last year?	NA/None = 0.8; Less than 10 days = 1.6; 10-30 days = 2.4; 1-3 months = 3.2; Greater than 3 months = 4	Loss of fishing days = high exposure.
E			Occurrence of drought in past 5 years	68.1	Has there been a Drought in the last 5 years?	Yes = 4 ; No = 1	Droughts limit access to natural capital and overall livelihood activities and therefore increases
E			Personally, directly impacted by drought	68.2	Were you directly impacted by the Drought?	Yes = 4 ; No = 1	Personal impact = higher exposure

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
E		**Drought**	Degree of damage to household	68.3	How bad was the drought damage to your house?	No damage = 0.8; little damage = 1.6 ; moderate damage = 2.4; major damage = 3.2; Catastrophic	Exposure levels increase as severity of damage increases
E			Action taken to prevent future drought damage	68.4	Have actions been taken by the household to prevent drought damage?	Yes = 1; No = 4	Any mitigation or adaption to prevent future negative impacts of drought lessens exposure. (NA answers also receive a 1).
E			Number fishing days lost to droughts in past year	68.6	How many fishing days have you lost to the drought in the last year?	NA/None = 0.8; Less than 10 days = 1.6; 10-30 days = 2.4; 1-3 months = 3.2; Greater than 3 months = 4	Loss of fishing days = high exposure.
E		**Shoreline changes**	Occurrence of shoreline changes in past 5 years	69.1	Has the shoreline in your village/area changed over the years?	Yes = 4 ; No = 1	Changes in shoreline indicate higher exposure
E			Observation of shoreline erosion by the sea locally	69.2	Have you noticed places in your area where the shoreline has been eroded by the sea?	Yes = 4 ; No = 1	shoreline erosion leads to infrastructure losses and reduction of alternative options
E			Degree of beach erosion over last 5 years	69.3	How much of the beach has eroded in the last 5 years?	No damage = 0.8; little damage = 1.6 ; moderate damage = 2.4; big damage = 3.2; House/trees falling = 4	shoreline erosion leads to infrastructure losses and reduction of alternative options
E			Impact of shoreline erosion on livelihood	69.4	Have you noticed any changes to your livelihood as a result of shoreline erosion?	Yes = 4; No = 1	shoreline erosion leads to infrastructure losses and reduction of alternative options
E			Fishing frequency	1.2	How many days per week do you go fishing?	Less than once a week= 0.67; Once a week = 1.34; 1-2 days = 2.01 ; 2-3 days = 2.68; 3-5 days = 3.35; Everyday = 4.00	Higher frequency relates to lower fish availability OR higher dependency on fishing AND higher exposure to risk.

Category	Component	Sub-component	Indicator	Q No	Survey Question	Scoring Method	Rationale / Notes
E		**Fishing Activity**	Duration of Trips	1.3	What is the average length of a fishing trip?	less than 3 hours = 1; 3-8 hours = 2; 8-12 hours = 3; more than 12 hours = 4	Increased fishing duration relates to lower catch and increased vulnerability because of higher exposure to risk.
E			Directionality of any change in the distance from the coast where fishing takes place	1.7	Has the average distance increased, decreased, or not changed in the time you have been fishing?	Increased = 4; Stayed the same or Decreased = 1	Increased distance of fishing from coast indicates lower CPUEs, higher exposure, and increased vulnerability
			Observed change in main target species in past 5 years	1.11	Have you noticed any changes in your main target species in the past 5 years?	Yes = 4; No = 1	Changes in the occurrence / distribution / species composition indicates increasing exposure and vulnerability.
E	**Attitude and perception**	**Attitude to change**	Perceived level of risk to community from environmental change	32.1	How much of a risk do you think environmental change poses to the community you live in?	High = 4; Medium = 3; Low = 2; None = 1	High level of risk perceived indicates high exposure.
E			Degree of anxiety felt about environmental changes observed locally	32.3	How anxious/scared do you feel about the changes you are seeing in the environment in your area?	Very = 4; Scared/Anxious = 3; Little = 2; Not at all = 1	High anxiety indicates higher exposure.
E		**Perceptions of change**	Degree of difficulty in finding/catching fish compared to the past	33.2	How difficult has it become to catch fish in the areas you fish?	Very = 4; Difficult = 3; Slightly = 2; Not at all = 1	Difficulty to catch fish indicates less capacity to adapt and higher level of current exposure
E			Perceived level of danger to fishing from weather changes	33.1	How dangerous are changes in the local weather making fishing?	Very Dangerous = 4; Dangerous = 3; Slightly = 2; Not at all = 1	Danger in local weather increase exposure
E			Number of changes in marine species observed locally	33.3	How many changes would you say you have noticed in the marine species you see?	Many Changes = 4; Some = 3; Few = 2; None =1	High number of observed changes indicate better capacity to adapt AND higher exposure

D. ANOSIM Histograms

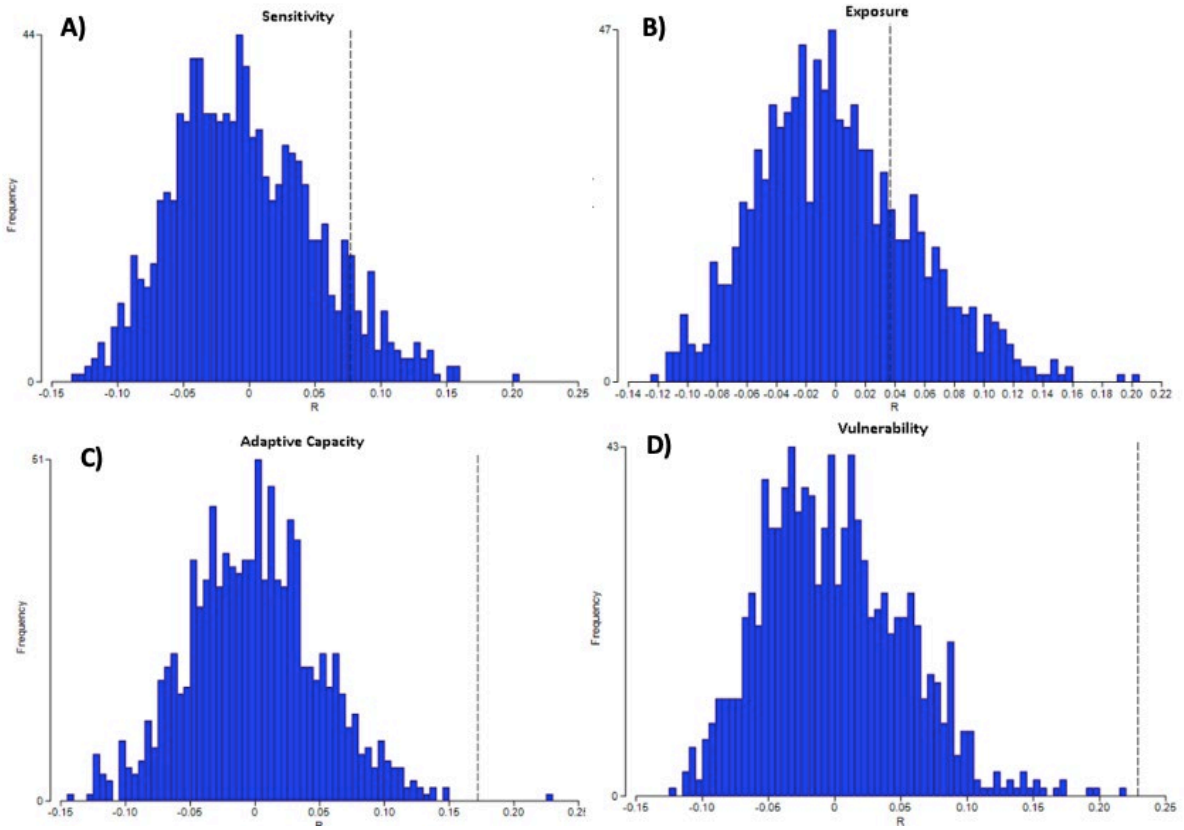

Figure D. ANOSIM results in the form of frequency distributions for A) Sensitivity, B) Exposure, C) Adaptive Capacity, and D) Vulnerability. The dotted line represents the test statistic (R-value). If the R-value falls within the histogram, the likelihood that you will obtain the groups (communities) by chance is unlikely. In other words, overlapping of the dashed line with the histogram bins indicate that groups (community differences) do not exist.

E. Results of the ANOSIM and Kruskal Wallis Post-Hoc Dunn's Pairwise Comparison Tests compared at the category level.

Table E.1. Table of ANOSIM and Kruskal Wallis pairwise comparisons amongst the communities in terms of their overall Social Vulnerability scores. Pairwise comparisons with significant differences are highlighted.

Social Vulnerability				
	ANOSIM		KRUSKAL WALLIS	
Groups	R	Significance Level (%)	Z-value	Significance Level (%)
M, V	0.169	5.00	-1.57	5.80
M, B	0.165	4.60	-2.45	0.70
M, S	0.086	29.3	0.40	34.50
M, MB	0.285	0.40	-2.25	1.20
V, B	0.544	0.10	-3.32	< 0.10
V, S	0.090	29.10	-1.28	10.00
V, MB	-0.006	44.10	0.41	34.20
B, S	0.211	12.60	-1.02	15.40
B, MB	0.386	0.20	-3.98	< 0.10
S, MB	0.054	32.30	1.60	5.50

Table E.2. Table of ANOSIM and Kruskal Wallis pairwise comparisons amongst the communities in terms of their Adaptive Capacity scores. Pairwise comparisons with significant differences are highlighted.

Adaptive Capacity				
	ANOSIM		Kruskal Wallis	
Groups	R	Significance Level (%)	Z-value	Significance Level (%)
M, V	0.133	5.60	0.40	34.60
M, B	0.155	3.80	0.96	16.90
M, S	0.324	1.60	0.22	41.30
M, MB	0.193	0.40	3.39	< 0.10
V, B	0.131	5.80	1.12	13.20
V, S	0.157	16.40	0.03	48.80
V, MB	0.141	4.80	-2.35	0.90
B, S	0.033	42.30	0.75	22.70
B, MB	0.266	0.10	3.62	< 0.10
S, MB	0.048	37.80	-1.64	5.10

F. Kruskal Wallis Results for Component Level testing.

Table F. Table of Kruskal Wallis pairwise results and pairwise comparisons amongst the communities in terms of their overall component scores, where the Component, test statistic (Chi-Squared), and P-value are shown. Upon significant findings, the p-value is highlighted in yellow and only the significantly different pairwise comparisons are shown along with their level of significance. One asterisk indicates a p-value of 0.01-0.05, two asterisks indicate p<0.01, and three asterisks indicate p<0.001.

Kruskal Wallis Sensitivity Component Result					
Component	**Chi-Squared**	**Df**	**P-Value**	**Pairwise Comparisons**	**Significance**
Social Dependence on Fishing (S.SDoF)	3.03	4	p>0.05	-	-
Historical and Cultural Dependence on Fishing (S.HCDoF)	6.55	4	p>0.05	-	-
Economic Dependence on Fishing (S.EDoF)	3.08	4	p>0.05	-	-
Economic Dependence on Other Resources	11.25	4	p<0.05	B-MB	*
				B-MK	*
				MB-V	*

Kruskal Wallis Exposure Component Results					
Component	Chi-Squared	Df	P-Value	Pairwise Comparisons	P-value
Environmental Change (EC)	8.00	4	p>0.05	-	-
Personal Exposure (PE)	5.59	4	p>0.05	-	-
Attitude and Perception (AaP)	0.37	4	p>0.05	-	-

Kruskal Wallis Adaptive Capacity Component Results					
Component	Chi-Squared	Df	P-Value	Pairwise Comparison	P-value
Natural Capital (AC.NC)	8.64	4	p>0.05	-	-
Human Capital (AC.HC)	11.07	4	p<0.05	B-MK	*
				B-MB	*
				MK-S	**
				MB-S	*
Social Capital (AC.SC)	8.05	4	p>0.05	-	-
Bridging Social Capital (AC.BSC)	14.33	4	p<0.05	B-MB	*
				B-S	*
				MK-MB	**
				MK-S	**
				S-V	*
Physical Capital (AC.PC)	16.86	4	p<0.05	B-V	***
				B-MB	**
				B-S	*

				MK-V	**
				MB-V	*
Financial Capital (AC.FC)	8.78	4	p>0.05	-	-
Personal Flexibility (AC.PF)	2.47	4	p>0.05	-	-
Attitude and Perception (AC.AaP)	9.17	4	p>0.05	-	-
Occupational Flexibility (AC.OF)	3.41	4	p>0.05	-	-
Institutional Support (AC.IS)	12.37	4	p<0.05	MK-MB	**
				MK-S	*
				MB-V	*
Institutional Flexibility (AC.IF)	4.19	4	p>0.05	-	

G. PCA Results

Table G. Table of PCA results for the A) Sensitivity scores, B) Exposure scores, and C) Adaptive Capacity scores. The cumulative variation for exposure and sensitivity shows that the PCA is a good representation of the data. For adaptive capacity, many PCs are required to explain a smaller percentage of the variation, therefore it is not a good representation of the data and is not used for the analysis. The variables that make up the PCs are highlighted.

A. ***Eigenvalues*** ***Eigenvectors*** *(Coefficients in the linear combinations of variables making up PC's)*

PC	Eigenvalues	%Variation	Cum.% Variation	Variable	PC1	PC2	PC3	PC4
1	0.192	39.1	39.1	**S.SDoF**	-0.286	0.631	-0.717	-0.078
2	0.14	28.5	67.6	**S.HCDoF**	-0.156	0.075	0.233	-0.957
3	0.091	18.5	86.2	**S.EDoF**	-0.245	0.667	0.657	0.252
4	0.0681	13.8	100.0	**S.ED**	0.913	0.389	-0.008	-0.121

B. ***Eigenvalues*** ***Eigenvectors*** *(Coefficients in the linear combinations of variables making up PC's)*

PC	Eigenvalues	%Variation	Cum.% Variation	Variable	PC1	PC2	PC3
1	0.625	57.4	57.4	**E.EC**	-0.937	0.306	-0.169
2	0.361	33.2	90.6	**E.PE**	-0.210	-0.108	0.972
3	0.102	9.4	100.0	**E.AaP**	-0.279	-0.946	-0.165

C. ***Eigenvalues*** ***Eigenvectors*** *(Coefficients in the linear combinations of variables making up PC's)*

PC	Eigenvalues	%Variation	Cum.% Variation
1	0.897	34.9	34.9
2	0.359	14.0	48.9
3	0.233	9.1	57.9
4	0.227	8.8	66.8
5	0.194	7.5	74.3

H. RELATE Results: Histogram of Possible Permutations for each Comparison.

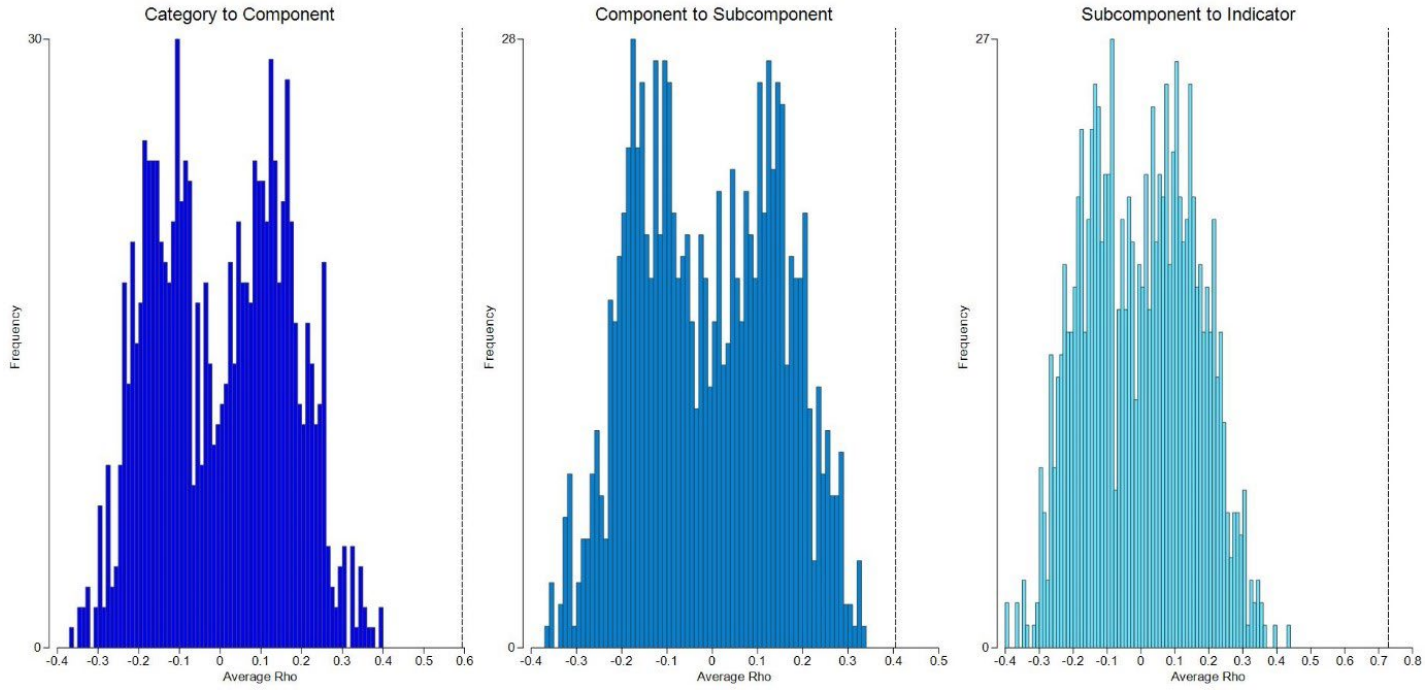

Figure H. Results of the Primer RELATE tests, showing the relationships between the vulnerability scores when calculated at different scales of the GULLS framework. The following comparisons are shown: a) Category and component, b) Component and Subcomponent, and c) Subcomponent and Indicator. There was no significant relationship detected between the category and component (RELATE, R=0.594, $p<0.05$), component and subcomponent (RELATE, R=0.405, $p<0.05$), and subcomponent and indicator datasets (RELATE, R=0.729, $p<0.05$).

I. Radar Plots for Overall Social Vulnerability, Sensitivity, Exposure, and Adaptive Capacity.

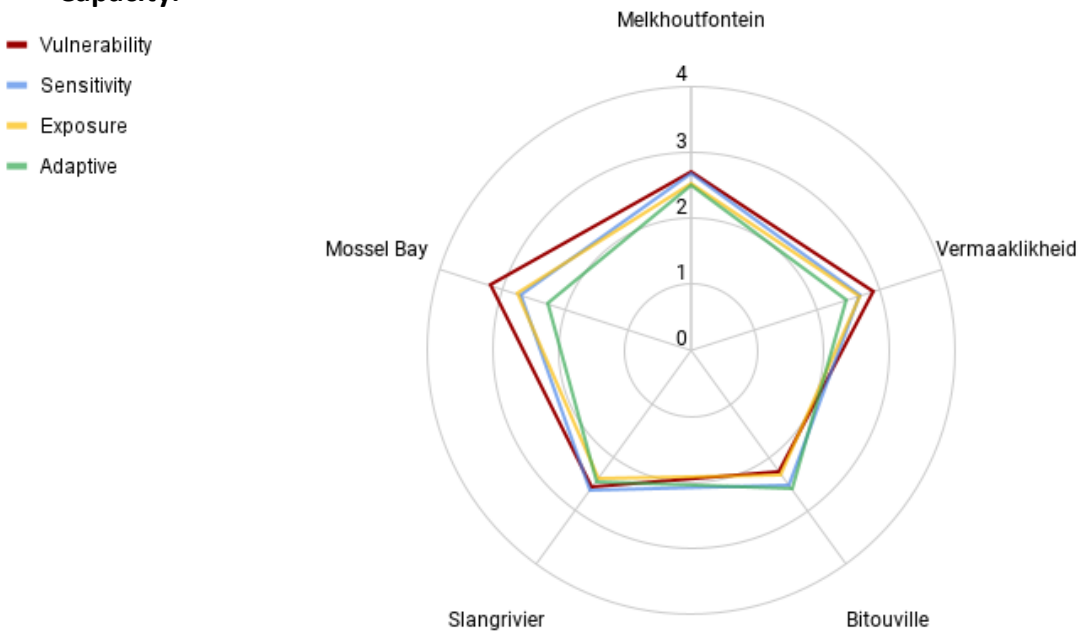

Figure I.1. Radar plot showing the Social Vulnerability scores and the comprising categories for each community. Minimum scores correspond to low sensitivity and maximum scores to high sensitivity.

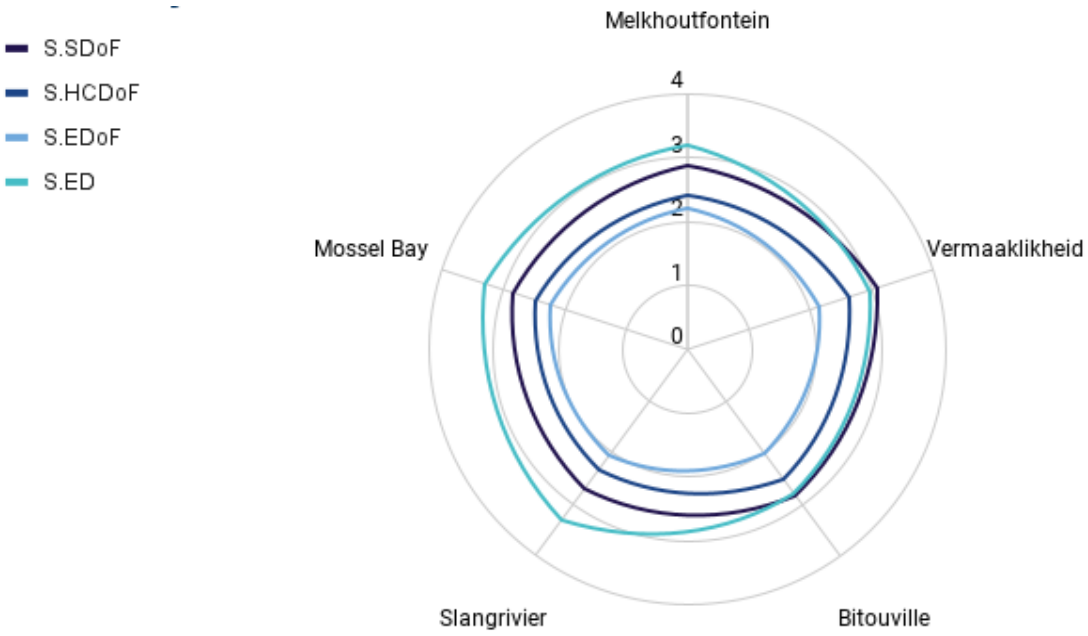

Figure I.2 Radar plot showing the Sensitivity components for each community, where Social dependence on fishing (S.SDoF), Historical and cultural dependence on fishing (S.HCDoF), Economic dependence on fishing (S.EDoF), and Economic dependence on other resources (E.ED), is shown to depict how the components influence the overall Sensitivity score for each community. Minimum scores correspond to low sensitivity and maximum scores to high sensitivity.

Appendix I continued

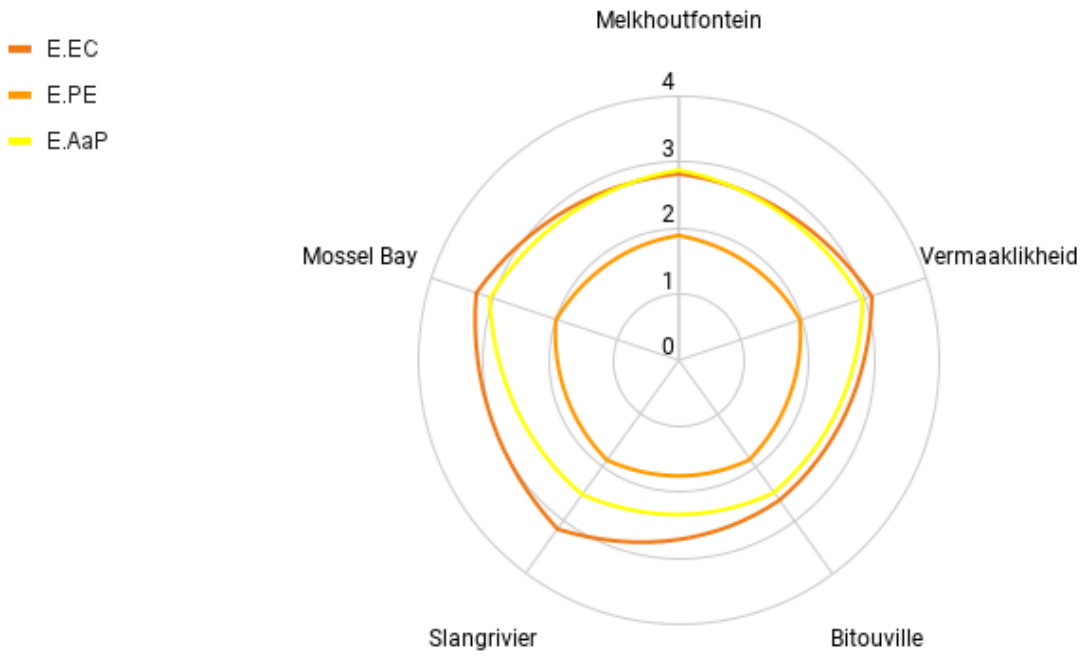

Figure I.3 Radar plot showing the Exposure category and its comprising components: Environmental change (E.EC), Personal exposure (E.PE), and Attitude and perception to change (E.AaP). Minimum scores correspond to low exposure and maximum to high exposure.

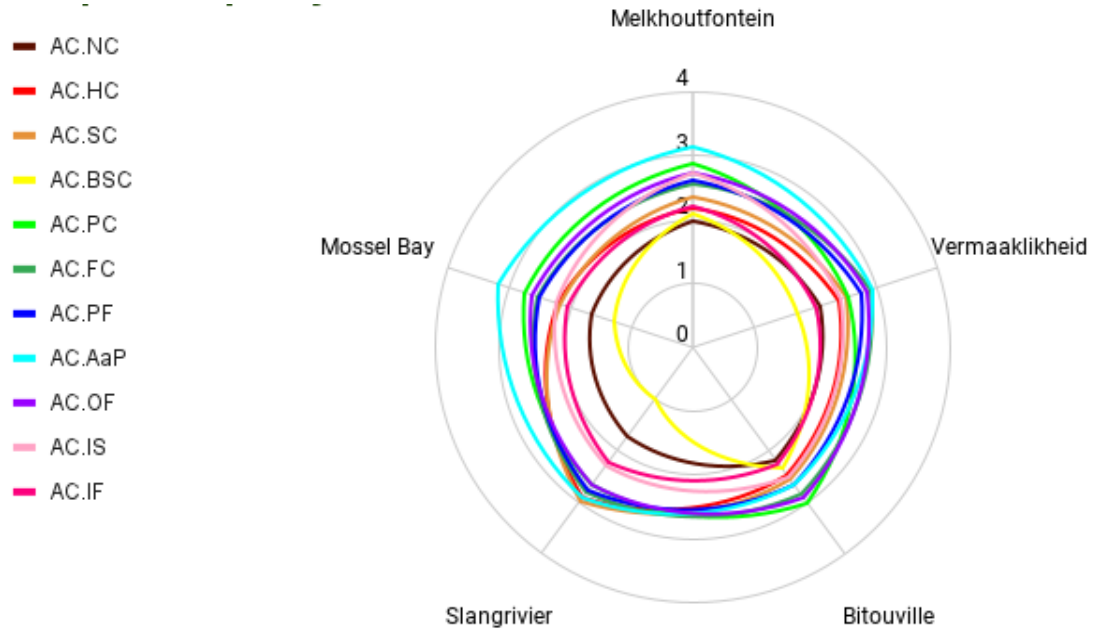

Figure I.4 Radar plot showing the each communities Adaptive capacity and its comprising components: Natural capital (AC.NC), Human capital (AC.HC), Social capital (AC.SC), Bridging social capital (AC.BSC), Personal Capital (AC.PC), Financial capital (AC.FC), Personal flexibility (AC.PF), Attitude and perception (AC.AaP), Occupational flexibility (AC.OF), Institutional support (AC.IS), and Institutional flexibility (AC.IF). Minimum scores correspond to low adaptive capacity and maximum to high adaptive capacity.