Climate and environmental change along the East Coast of South Africa: Perspectives from a local marine resource-dependent community and scientific researchers

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DECLARATION

I, **Tania Moyikwa**, declare that this work has not been previously submitted in whole, or in part, for the award of any degree. This dissertation is my own work. The contribution and quotation of others work in this dissertation haves been acknowledged, cited and referenced.

Signature: Signed by candidate

Date: 23 October 2019

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Most importantly, to God be the Glory!

DEDICATION

I dedicate this work to my little sister, Simamkele Bartman. Thank you for the humble reminders that every little mistake is an opportunity to learn great things.

ABSTRACT

Coastal areas are very susceptible to environmental problems such as sea-level rise, coastal flooding, increased frequency and intensity of extreme events, and changes in marine ecosystems that are arising from global climate change and variability. In the South African context, the Agulhas Current is important for its crucial role in regional climate and weather as well as the fishing livelihood of the coastal communities along the east coast of South Africa. Despite the efforts made to understand the Agulhas Current and the impacts of climate and environmental change, the shelf region remains poorly understood mostly due to the difficulties associated with observing and modelling such strong currents.

The marine resource users in the fishing communities along the east coast of South Africa show long term dependence on the neighbouring ocean going back at least three generations. These communities provide long term, rich, detailed, and contextualized environmental knowledge from their daily interactions with the sea. This study seeks to investigate the local climate and environmental change knowledge of the fishers based on their own observations, perceptions, and experiences. The convergence/divergence of the marine resource user's knowledge with the traditional scientific findings is explored using a broad, participatory methodology including desktop literature analysis, interviews and an adopted version of the Rapid Vulnerability Assessment (RVA).

Results show that fishers in Tshani-Mankosi have observed changes in the rainfall, sea surface temperature and wind patterns in their community. According to the fishers, sea surface temperature and annual rainfall seem to have decreased while winds and rainfall related extreme events have increased. Similar observations were noticed in the scientific research at a larger spatial and temporal scale. Key differences and similarities between the two types of knowledge come from factors such as knowledge construction processes, scales, type of data output and parameters of interest. Finally, the study reveals opportunities and challenges of research collaboration between the community and scientific researchers.

Key Words: Climate change, environmental change, local ecological knowledge, marine dependent community, scientific research, research collaboration

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LIST OF ABBREVIATIONS

BCLME –Benguela Current Large Marine Ecosystem

DAFF – Department of Agriculture, Forestry and Fisheries

DJF – December/January/Febuary

ECRL -East Cost Rock Lobster

ENSO – El Niño Southern Oscillation

JJA – June/July/August

LEK- Local Ecological Knowledge

MLR- Marine Living Resources

MLRU- Marine Living Resource User

MPA- Marine Protected Area

rRVA- reduced Rapid Vulnerability Assessment

RVA- Rapid Vulnerability Assessment

SIHP – South Indian High Pressure

SAHP – South Atlantic High Pressure

SSF – Small Scale Fisheries

SST- Sea Surface Temperature

WCRL- West Coast Rock Lobster

CHAPTER 1: INTRODUCTION

1.1. Background

The coastal and marine environment is associated with natural changes. Changes in rainfall, temperature, and wind patterns occur at daily, seasonal, and annual time scales. These changes may result in modification of the marine and coastal environmental conditions such as the sea roughness, freshwater input, species habitat, ocean circulation, and weather patterns (Potts, Götz and James, 2015; Whitfield *et al.*, 2016). The fluctuation of temperature, wind, and rainfall patterns on the interannual basis can be linked to climate variability. Incidences of extreme weather events such as tropical cyclones, dust storms, thunderstorms, heat waves, and drought may occur as a consequence of climate variability in the coastal environment (Kusangaya *et al.*, 2014). These events modify the coastal and marine environment differently according to the frequency and intensity of the event. The effect of these events can persist for years, decades, or centuries. The effects that persevere for centuries and longer are typically linked with global climate change.

Climate change is a global environmental problem affecting the livelihoods and economies of many countries. Scientific evidence suggests that human-induced global climate change is more pronounced in recent decades (IPCC, 2014). According to the statement for policymakers by the IPCC (2014), between 1880 and 2012 the combined global average of land and sea temperature has increased by 0.85 [0.65 to 1.06] °C. This has resulted in sea ice melting in the arctic region and a mass loss of the ice sheets in Greenland and Antarctica (IPCC, 2014). In addition, since the 1950s changes in extreme weather and climate events have been noted (IPCC, 2014). The frequency and the intensity of extreme weather events seem elevated especially along the coastal regions (Preston, Yuen and Westaway, 2011; Abiodun *et al.*, 2017; Kruger and Nxumalo, 2017; Jury, 2018) making coastal communities more susceptible to the impacts of climate variability and change (Preston, Yuen and Westaway, 2011; Cinner *et al.*, 2012; Aswani and Lauer, 2014; Jarre *et al.*, 2015). Ultimately, issues arising from climate change and climate variability have a considerable impact on the fisheries industry that supports a growing human population of about 7.4 billion people in 2016 (FAO, 2018).

Global fish production (fisheries and aquaculture) reached 171 million tonnes in 2016 with the first sale value of 362 billion USD (FAO, 2018). The global capture fisheries in marine waters were approximately 79.3 million tonnes, which showed a decrease from 81.2 million tonnes catches in 2015 (FAO, 2018). More than 50% of this decrease is associated with the significant decrease of anchoveta catches by Chile and Peru, which are usually substantial contributors to total catches (FAO, 2018). At the same time, anchoveta catches in the aforementioned countries have been reported highly variable due to the influence of El Niño. In the Benguela Current Large Marine Ecosystem (BCLME), which stretches between Angola (Luanda) and South Africa (Cape of Good Hope), species geographical shifts, changes in abundance and biodiversity linked to physical environmental forcing were noted (James *et al.*, 2013; Blamey *et al.*, 2015; Kirkman *et al.*, 2015). These changes may have an impact on the total catch in this region and southern Africa's fishery industry at large.

South Africa is comprised of a relatively large coastal population that is dependent on marine living resources for food and livelihood. Thus a large portion of the population is exposed to the effects of climate and environmental change within the coastal region (Sowman, 2006). Although other African countries, such as Kenya, Mozambique, and Tanzania, are associated with higher coastal and marine resource-dependent populations, the fisheries sector contributes significantly to the economy of the South Africa (Kerri and Reviva, n.d). According to the *South African Government*[1] , the worth of the fisheries industry in South Africa is estimated at R6 billion per annum (Moreover, about 27 000 people are directly employed in the South African commercial fisheries sector while other industries linked to fisheries provide an estimate of 81 000 - 100 000 employment (Kerri and Reviva, n.d). Also, more than 29 000 people, who can be considered as small-scale fishers, are dependent on the Marine Living Resources (MLR) for basic necessities of life. According to the definition provided by the Food and Agricultural Organisation (2012) small-scale fisheries are:

> *"traditional fisheries involving fishing households (as opposed to commercial companies), using a relatively small amount of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, mainly for local consumption. In practice, the definition varies between countries, e.g. from gleaning or a one-man canoe in poor developing countries, to more than 20-m. trawlers,*

[1] https://www.gov.za/about-sa/fisheries

seiners, or long-liners in developed ones. Artisanal fisheries can be subsistence or commercial fisheries, providing for local consumption or export."

The small-scale fishers in South Africa spend most of their lives working on the coasts for food and basic needs. At the same time, challenges arising from climate change such as sea-level rise, flooding, coastal erosion, and marine species migration persist (Mather, Garland, and Stretch, 2009; Whitfield *et al.*, 2016; Martins and Gasalla, 2018). Principles and frameworks for adaptation planning to climate and environmental change have been suggested in the small-scale fisheries context (Hobday *et al.*, 2016; Sowman and Raemaekers, 2018) and much attention has been given to the inclusion of fisher's knowledge and the documentation of such for advanced environmental management and inclusion of resource users in policymaking (Berkes, Colding, and Folke, 2000; Badjeck et al., 2010; Aswani et al., 2015). However, the local knowledge of the fisherfolk in South Africa is underexplored. Consequently, the inclusion of small-scale fishers' knowledge into decision making and the implementation of fisher-informed adaptation action plans are still a work in progress in the country.

Literature suggests that fishing communities seem to be observing changes in the climate and their associated impacts (Moreno *et al.*, 2007; Aswani and Lauer, 2014; Martins and Gasalla, 2018). The ways in which the local resource users in the coastal communities learn about these changes is unique compared to the traditional scientific methods used in climate and environmental studies. The natural resource users rely on empirical evidence accumulated through their experiences, perceptions, and observations to build on their knowledge about the biophysical environment surrounding them (Inglis, 1993; Neis *et al.*, 1999). This highlights the inductive nature of the natural resource user's knowledge. On the other hand, scientific studies are more deductive and employ deliberate and systematic ways of learning to accumulate knowledge. As a result, environmental knowledge of natural resource users is usually in the form of narratives based on life experiences while scientific information may include quantitative studies. Nonetheless, both sources of knowledge are crucial and applicable to fisheries science and environmental management (Ruddle and Davis, 2013; Aswani *et al.*, 2015).

Since the early 1980s insight about the value of the local fishers' knowledge in marine science studies has been shared (e.g. Johannes 1981, Ruddle and Johannes 1985). Upon the completion of the "putting Fisher's knowledge to work" international conference of 2001, the use of MLR user's knowledge has been discussed (Hagan, Brignall and Wood, 2002). The use of the locals' knowledge at the research level has been encouraged. Consequently, Partnerships between the MLR users, scientists, government officials, and members of non-governmental organisations are forming for collaborative environmental research and management worldwide (Ruddle and Davis, 2011). Subsequently fishers knowledge has supported marine ecology and conservation studies, investigating resource behavior (Aswani and Hamilton, 2004), assisted in identifying threatened species (Bender, Floater, and Hanazi, 2013), involved in co-designing marine protected area (Aswani and Lauer, 2006) and detecting the impacts of climate and environmental change (Aswani and Lauer, 2014).

The involvement of local MLR harvesters in fisheries research and management not only assists in building the resilience of fishers at the community level but also helps remedy the segregational and exclusionary history of South Africa under Apartheid government. Collaborations between local resource users, researchers and managers give a "voice" to those who may have been historically disadvantaged and excluded from the benefits of these resources and decision making (Gasalla and Diegues, 2010; Sowman and Raemaekers, 2018). Also, the accelerating changes in climate and the environment demand a sustainable use and management of these resources. Uncovering the perceptions, experiences, and observations of fishers in the fishing communities along the coastline of the country is a crucial step to developing sustainable management plans under climate change without undermining the context of the social and cultural norms of such communities.

The fishing communities along the South African coastline are unique. In some countries small scale fisheries are usually associated with recreation, the small-scale fisheries sector in South Africa represents the marginalized and poor population of the country (Sowman *et al.*, 2014). The fishing communities along the East Coast of South Africa are poverty-stricken and have found a cornerstone of food security and an occasional source of income in marine living resources. They are remote, less technologically advanced, segregated and traditionally governed. In addition to the social aspects of these communities, the physical environment here is largely influenced by the fast, warm and nutrient-poor Agulhas Current flowing southward along the coast. This western boundary Current influences the global climate but is also impacted by climate change, such as warming of the surface temperature and changes in the current structure, with the ongoing global climate change and variability (Rouault, Penven and Pohl, 2009; Backeberg, Penven, and Rouault, 2012). Notwithstanding the scientific efforts put in place to study this intense western boundary current, information on the small scale climatic and oceanographic processes remain sparse due to limited *in situ* measurements and constraints of satellite and model data near the coast (Davis- Reddy and Vincent, 2017; Kruger and Nxumalo, 2017). The small scale and inshore processes that are driven by the Agulhas Current, have an effect on the fisheries livelihood along this coast and understanding the fisher's local knowledge in this region may aid in filling knowledge gaps.

1.2. Study Area: Tshani-Mankosi

Tshani-Mankosi is a traditionally governed, technologically limited and isolated fishing community on the hills of the Transkei, in eastern South Africa. This community is situated along the wild coast (31.93°S; 29.18°E) in the Eastern Cape province of South Africa under the Nyandeni Municipality (Figure 1.1). The population size of this rural community is estimated to be at least 6000 people in about 1000 households (*Statistics South Africa*, 2011). Records show that the community was established more than 100 years ago (Mbatha, 2011) and the people here have subscribed to the fishing livelihood for as long as this community existed (Raemaekers, 2009). The village is bordered by the Mdumbi and Mthatha Rivers, to the north and south respectively, as well as the Indian Ocean to the east (Figure 1.1). Different kinds of fishing practices occur in the three different marine and coastal environments available to the people of this community, namely, estuaries, the rocky shore, and the beach.

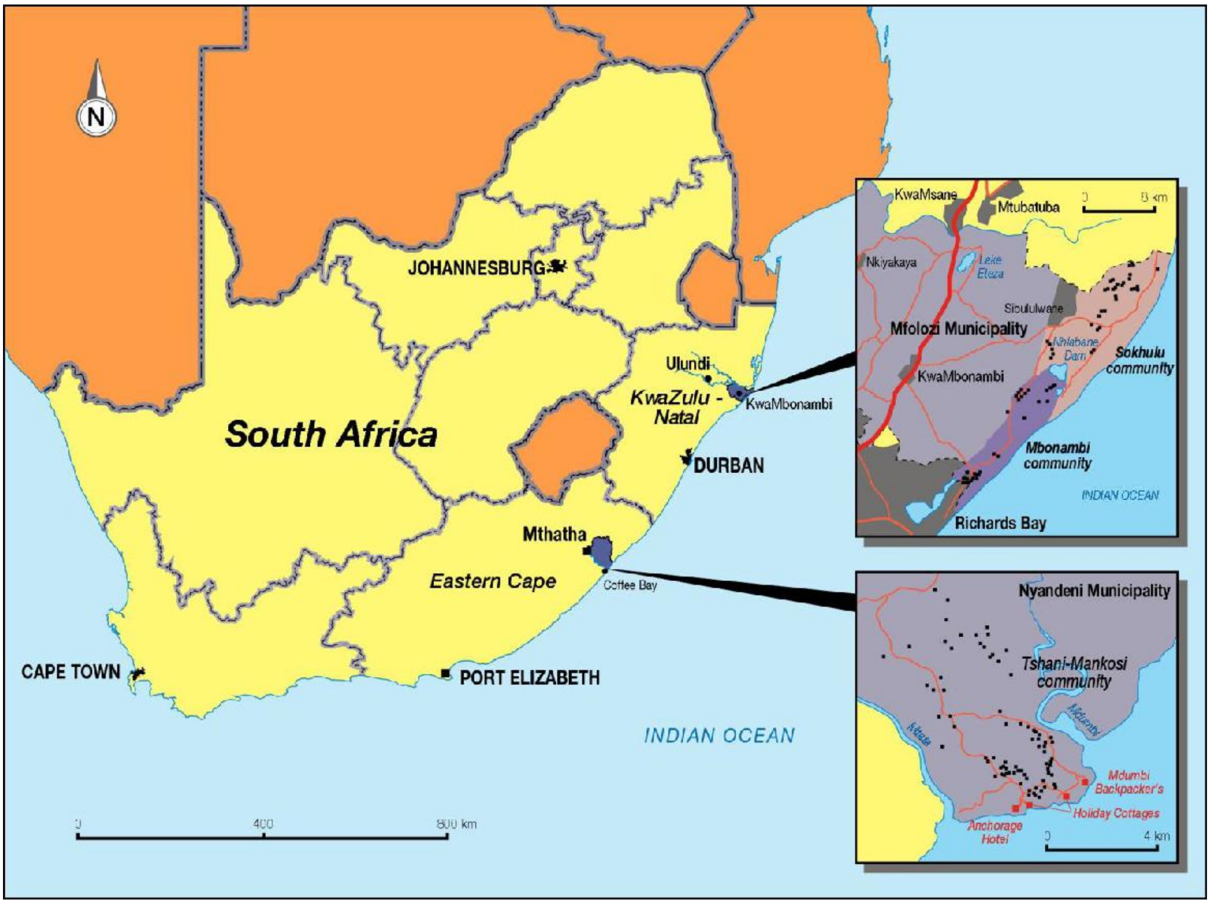

Figure 1.1: Position of Tshani-Mankosi (bottom right) in relation to South Africa; Image of Tshani-Mankosi community under the Nyandeni Municipality in the Eastern Cape of South Africa. Holiday accommodation sites are marked with red dots while households are marked with black dots, and the gravel road in orange lines (taken from Mbatha, 2011)

This community is one of many fishing communities concentrated along the wild coast. It was particularly chosen for this study because of its unique exposure to various coastal environments such as the rocky shore, beach, and estuaries. These spaces possess distinct physical and biogeochemical qualities and, as a result, they make habitat to specific and/or generic species. Therefore, environmental responses to a particular change in this locality would emerge from different habitats, providing several lenses through which the impact of the change can be studied. Moreover, previous research about fisheries and tourism systems were carried out in this community, providing good background information about the community to judge whether or not it would be suitable for the investigated question of this study (Raemaekers, 2009; Mbatha, 2011; Kaminski, 2012; Hitchcock, 2013). It is also important to note that the Tshani-Mankosi community has not been affected by the implementation of Marine Protected Areas (MPAs) - zones in the marine and coastal areas that are legally reserved from all or some human activities for the conservation of all or some enclosed natural environments (Kelleher and Kenchington, 1991). This implies that interactions between people and the natural environment have not been formally interrupted. This is particularly important for this study as it focuses on the knowledge of the local people about their surroundings accumulated over time, through experiences and observations. A more detailed description of the study site is provided in Chapter Three while a general outlook of Tshani-Mankosi was given here.

1.3. Rationale and Research questions

Many coastal communities are faced with challenges arising from climate and environmental changes worldwide (Aswani *et al.*, 2015). Climate and environmental change are both naturally and anthropogenically driven phenomenon. Anthropogenic change is described by the IPCC (2014) as the human influence on the climate system. The anthropogenic greenhouse gas emissions have been increasing, more drastically in recent decades. Between 1750-2011 about 50% of the carbon dioxide emitted by humans was emitted in the last 40 years of this 261 year period (IPCC, 2014). Although the fourth IPCC assessment report (IPCC, 2007) had shown the extent to which human gas emissions contribute to climate change, evidence of an increase in the anthropogenic influence on the climate system has been shown in the IPCC Fifth Assessment Report (IPCC, 2014). This suggests that even with the efforts made to research climate change and its impacts, the human influence on climate change has continued to grow. The consequences of climate change are more pronounced firmer on natural systems globally (IPCC, 2014). In the southern African region, the physical systems such as rivers, lakes, precipitation, and biological systems such as wildfire and marine ecosystems have been affected the most by climate change (IPCC, 2014). Anticipations about alterations in the coastal biological productivity (Hoegh-Guldberg and Bruno, 2010), species migration (James, Whitfield and Cowley, 2008; Blamey *et al.*, 2012; Jarre *et al.*, 2015), and localised extinctions (Potts, Götz and James, 2015) are presented as a result of climate variability or change. Furthermore, suggestions for higher risks of more intense and frequent extreme weather events in the coastal areas are suggested (Abiodun *et al.*, 2017). These negative consequences of climate and environmental changes on the coastal areas pose a significant threat to the vulnerable coastal communities associated with fishery livelihoods.

Many uncertainties are associated with climate and environmental change including the related impacts on society. As a result, precise and localized impacts of environmental change on fishery systems are poorly understood; coercing the communities whose livelihoods are based on fisheries to face the direct impacts of climate change (Sowman and Raemaekers, 2018). Ultimately, these communities are pressured to come up with localised adaptation and mitigation strategies to maintain their benefit from fisheries. Understanding the socio-ecological vulnerability of such communities to climate change has been prioritized with much attention to the sensitivity (responsiveness to certain degrees of change) and building of community resilience (Mason and Jury, 1997a; Preston, Yuen and Westaway, 2011; Rasheed, Abdulla, and Zakariyya, 2016). Notwithstanding the significance of these studies, a focus on exploring the understanding, perceptions, and observations made by these communities about climate and environmental change would assist in dissolving some of the uncertainties associated with such change (Aswani *et al.*, 2015; Musinguzi *et al.*, 2016; Tiller and Richards, 2018).

In South Africa, fisheries management procedures have been largely driven by natural science over the past (Hauck and Sowman, 2001; Ngqongwa, 2015). However, with the increasing social science research in marine studies (Raemaekers, 2009; Mills *et al.*, 2013; Sowman *et al.*, 2013, Gasalla and Diegues, 2010, Aswani and Lauer, 201) and the formulation of the recent small-scale fisheries policy[2] in South Africa, the South African Government has demonstrated a willingness to adopt novel approaches such as co-management by involving the small-scale fishers in the decision-making processes. The recognition of local and indigenous knowledge of fishers is promoted in the new policy as it states that there is a need to *"recognise the complementary value of indigenous and local knowledge*" under the principles established to guide the government in accomplishing the vision and the objectives of the policy[2]. This suggests that the government is open to the inclusion of human systems at research level even though this has not been demonstrated yet. This is not only essential in making sure that opportunities for conflicts between resource users and managers/scientist are mitigated by encouraging environmental stewardship but also to make sure that the science is transformed to something that is of mutual value between the scientific researchers and society (Bennett *et al.*, 2018; Sowman and Raemaekers, 2018).

[2]The South African small scales fisheries policy:https://www.nda.agric.za/docs/policy/policysmallscalefishe.pdf

Prior to developing collaboration plans for information gathering and monitoring of the coastal and marine environment between researchers and resource users to inform decision-makers, some considerations need to be made in South Africa. Firstly, there is a need to recognize the strengths and limitations of LEK and scientific findings to establish the kind of questions that each knowledge type can / cannot answer in collaborative research between scientific researchers and fishers. Also, the coastline of South Africa is associated with very different marine environments with the warm Agulhas Current flowing along the east coast and the cold Benguela Current along the west coast. Secondly, the socio-economic issues in the coastal provinces are not the same, partially due to the history of the country as described in the background section. Therefore, collaboration plans along the west and east coast cannot be entirely even. Along the west coast, there is increasing progress in implementing this collaboration as the fishing communities have been involved in the development and are using an information-gathering tool called *Abalobi App*[3] even though it may not be integrated into governments co-management plans yet. This study seeks to pave a way for the use of such tools along the East Coast, taking into account the socio-ecological context of this coastline. Thus, the following research questions are addressed in this thesis:

- How variant and comparable is fisher's local ecological knowledge (LEK) to available scientific findings of climate and environmental change along the East coast?
- Are there opportunities for research collaboration between the scientific community and resource users?

1.4. Research aims and objectives

This study aims to assess and explore the local ecological knowledge (perceptions, experiences, and observations) of marine living resource users at the community level with a focus on climate and environmental change. In parallel, this study investigates scientific findings and reviews recent knowledge about the aforementioned topic. In doing so this project probes to identify critical opportunities for research collaboration. To address these aims a participatory approach is utilized, guided by the following fundamental objectives:

[3] http://abalobi.org/

I. Explore the LEK of marine living resource users in Tshani-Mankosi community;
II. Provide a review of scientific literature and current knowledge (through direct interviews) about environmental change and climate variability or climate change along the East Coast of South Africa
III. Critically compare and contrast LEK and scientific findings where relevant
IV. Evaluate linkages and opportunities for collaboration between researchers and resource users

A participatory methodological approach will be used to achieve these objectives, based on the work of the FAO (2015) that conducted a community-level socio-ecological vulnerability assessment to climate and environmental change along the west coast of South Africa for small-scale fisheries. One of the aims of this research is to explore key pressures and threats to livelihoods of the coastal fishing communities according to their perceptions and experiences, with a focus on climate and environmental-related factors (FAO, 2015). A specific method was developed to ensure that the vulnerabilities identified were not established from science-based facts but from the local knowledge of the MLR users. This method was designed to accomplish this over a short period of time and thus called the Rapid Vulnerability Assessment (RVA). The RVA method is more holistic in obtaining the fisher's experiences, perception and observations about climate and environmental change ensuring that the socio-ecological, governance and environmental aspects of these communities are accounted for during the knowledge sharing process of the RVA. Results from the work suggested that regardless of the differences in scales between the fisher's local observations and the regional patterns noted in the scientific literature, some related trends in the two epistemologies occurred. Similar results may be expected along the East Coast of South Africa. However, the lessons learned about climate and environmental change from the west coast fishers may differ from those of the east coast due to the contrast in biophysical and socio-economic contexts of these areas.

CHAPTER 2: LITERATURE REVIEW

Many theories from multidisciplinary marine research have been provided to find solutions to social and environmental issues arising from climate and environmental change in the small-scale fisheries sector. This chapter focuses on the core themes that emerge recurrently in the literature reviewed. These include resilience strengthening and the use of Local Ecological Knowledge (LEK) which are integral parts of Ecosystem-Based Management. While the literature covers these ideas over diverse contexts, this review is centered around the importance and opportunities to use LEK in the South African small-scale fisheries industry in light of climate and environmental change for the development of resilient socio-ecological systems. The first subsection provides an overview of the South African fisheries industry. In the second subsection, the importance of climate and weather as role players in the marine ecosystem and the lives of the fisher community is examined together with the issues encountered in conventional climate studies. The third subsection highlights the vulnerabilities associated with climate and environmental change in Small-Scale Fisheries (SSF) and provides fitting frameworks for assessing these vulnerabilities. The last section of this literature review outlines the similarities/ differences between using LEK compared to that of scientific knowledge, discussing how LEK can be a steering wheel in ensuring the contribution of society to research and management.

2.1. Overview of the South African small-scale fisheries industry

The fisheries industry is one of the leading sectors in ensuring food security, employment opportunities and diminishing poverty globally (Mills *et al.*, 2011). It is reported that this industry provides employment to men and women involved in fisheries worldwide, 90% of this comes from developing countries (FAO, 2010). In South Africa, the fisheries industry supports not only the national economy but also has significant value in the social structures of many communities along the coast (Sowman and Raemaekers, 2018). The industry is divided into three sectors, namely, commercial, small-scale, and recreational fisheries (DAFF, 2013). Although the commercial sector has historically dominated the industry, the small-scale fisheries sector contributes significantly towards the livelihoods and food security of the coastal fishing communities (Glavovic and Boonzaier, 2007).

The unique biophysical conditions of the South African marine environment have played a significant role in how commercial and small-scale fisheries sectors are arranged along the coastline of the country. The commercial fishing industry is prolific on the west coast due to the high biological productivity of the Benguela Current flowing along this coast, while the South Coast is a key spawning ground for some species (Griffiths *et al.*, 2010). Although the East coast is associated with rich marine biodiversity, it is not as biologically productive due to the warm, nutrient-poor water that flows southward from the tropical Indian Ocean (Griffiths *et al.*, 2010). As a result, the east coast has a considerably smaller commercial fishing industry. Regardless of this, the local living marine resources, which are mostly intertidal, are exploited by the small-scale fishers in the poor coastal communities who depend on these resources for the necessities of life (Clark *et al.*, 2002; Sowman *et al.*, 2014). Predominantly in South Africa, fisheries livelihood is an integral to rural and remote coastal communities (Clark *et al.*, 2002; Sowman *et al.*, 2014). Along the west coast, this livelihood is rather incorporated in more urban or peri-urban communities. This geographical characterization of South African fishing communities is attributable to the history of the country.

During the apartheid era (1948-1994), the state forcefully captured the land and natural resources from local people through systematic exclusion governance that led to the criminalization of local harvest and forced removals of locals from their residences (Hauck and Sowman, 2001; Sowman, 2006; Sowman *et al.*, 2014). This had a negative impact on the socio-ecology and livelihood in coastal areas (Glavovic and Boonzaier, 2007). Communities lost their customary access to gathering marine living resources for food, medical purposes, and spiritual practices. Whilst small scale fishers were neglected, the white-owned fishing companies grew, and an export-orientated fishing practice was developed and promoted (Branch and Clark, 2006; Raemaekers, 2009; Sowman *et al.*, 2014). The Marine Living Resources Act signed off in 1998, and the more recently introduced small-scale policy[4] aims to address these imbalances created and ensure the appropriate management and accommodation of small-scale fishers in the industry.

South Africa has committed to securing the marine and coastal ecosystem quality of the country without compromising the necessary transformation needed to settle historical injustices in the small-scale fisheries sector (Sowman, 2006). Firstly, small scale fisheries have not only been recognized as a sector with the industry after the apartheid era but

[4] https://www.nda.agric.za/docs/policy/policysmallscalefishe.pdf

management plans and procedures, suited for this sector, are under development. Traditionally, fisheries management plans were resource-centered, informed by natural science findings and mandated by managers upon the resource users (Raemaekers, 2009; Sunde and Raemaekers, 2010). The development and current implementation of the recent small-scale fisheries policy is evidence of a paradigm shift in marine living resource management of this country as it is more inclusive of the human dimension. This policy proves "*willingness from Government to embrace modern governance approaches such as the human-rights approach, co-management and an ecosystem approach to fisheries*" (Ngqongwa, 2015: 3) as well as a holistic approach to sustainability.

Remedying the historical injustices of the small-scale fishers by granting better opportunities for sustainable socio-economic benefit while maintaining the integrity of the marine and coastal environment remains a challenge and a work in progress in South Africa. Tools and techniques in line with the small-scale fisheries policy need to be developed to ensure effective implementation of this policy. These tools may need to consider all components of fisheries systems including research (data), communities and governance. Superimposed to the above-mentioned challenge is the issue of the changing environment. Climate and the environment are constantly changing, and management plans are required to be adaptive to these changes. Nowadays, threats from global climate change in fisheries systems are elevated (James *et al.*, 2013; Potts *et al.*, 2014).

2.2. South African climate and weather and its role in fisheries

The climate of South Africa can be described using a range of climatic classifications, namely: the Mediterranean on the southwestern side, temperate in the interior regions and subtropical on the northeastern side. This is attributable to the influence of four main factors; the neighboring oceans and their currents, the geographical location of the country, atmospheric circulation patterns, and local topography (Reason and Mulenga, 1999; Jury, 2013) The country lies between 20° and 35°S and 15° and 32°E and, consequently, it is subjected to the influence of high pressure cells which form part of the subtropical high belt. These atmospheric pressure systems are called the South Atlantic Anticyclone (SAA), Continental anticyclone (CA), and the South Indian Anticyclone (SIA) which are positioned in the Atlantic Ocean, over the continent and the Indian Ocean, respectively (Figure 1.1).

In winter these pressure cells are located further north, increasing the influence of frontal systems on the southern parts of the African continent. Moreover, South Africa is surrounded by the Indian, Southern and Atlantic Oceans with each containing different physical properties. The cooler, upwelled waters of the Benguela Current flow northward along the west coast, while on the East coast the Agulhas Current carries warm, salty water poleward. The combination of these factors plays a significant role in determining the temperature, wind, and rainfall patterns experienced across the different regions in South Africa (Reason and Mulenga, 1999).

Although Southern Africa has a distinguished large-scale climate, there is considerable spatial variability across relatively short distances. The eastern side of South Africa receives more rainfall than the western side due to the moist air that rises from the warm Agulhas Current through the process of convection (Reason and Mulenga, 1999; Jury, 2013). The dominating winds along the east coast are north-easterly (NE) whereas the south-easterly (SE) prevails along the west coast (Schumann, 1992; Blamey *et al.*, 2012; Vizy and Cook, 2016). In addition, the east coast and inland regions receive their maximum rainfall in the summer months - December-January-February (DJF), while the southwestern part of the country receives most of its rainfall during the winter months of June-July-August (JJA) (Jury, 2013). The southern part of the country receives rainfall nearly all year round. In terms of temperature, the coldest days are experienced during JJA (austral winter) and the warmest during DJF (austral summer). These patterns continue to show variability at different temporal and spatial scales in conjunction with the global climatic variability and long-term changes.

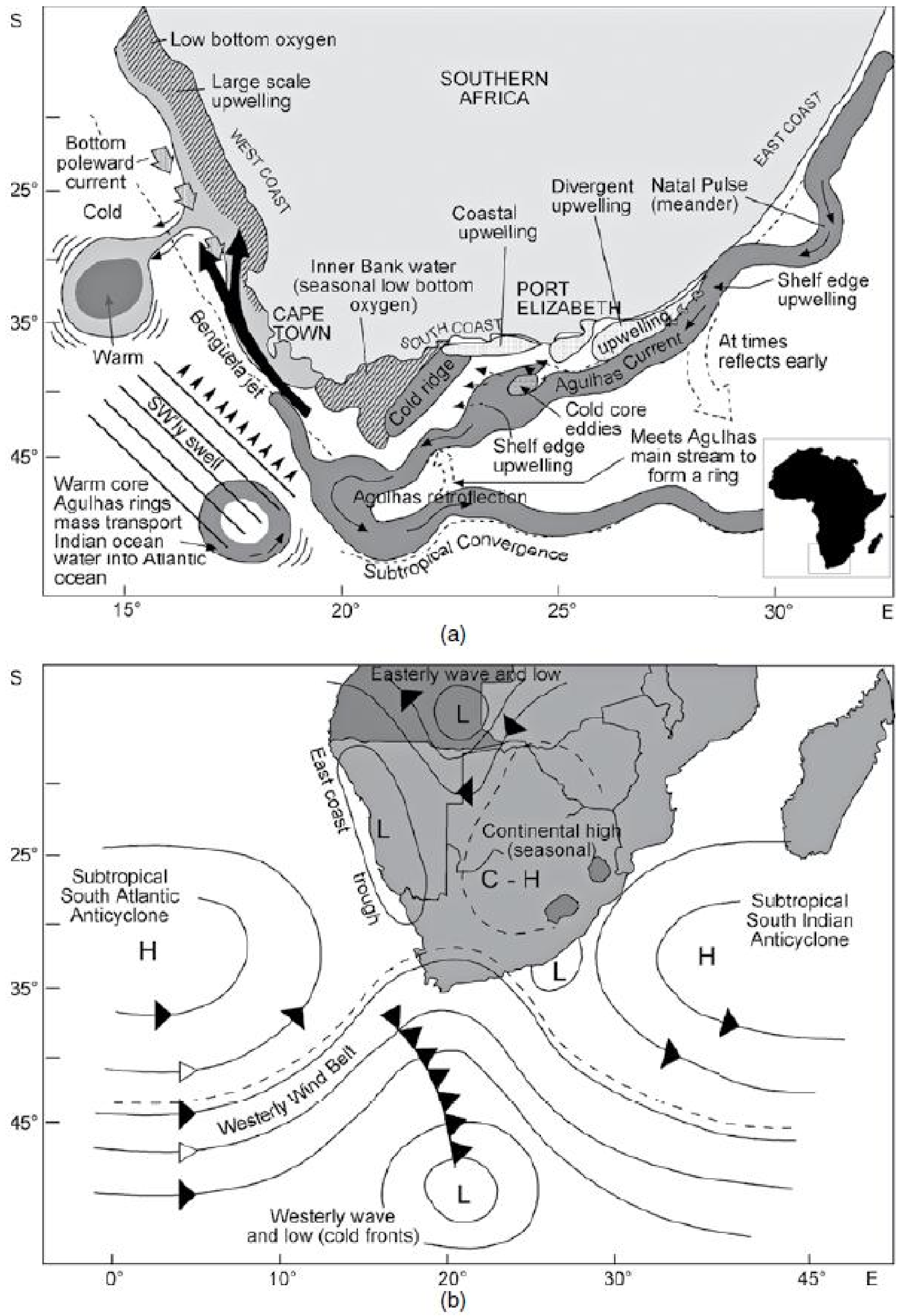

Figure 2.1: The complexity and variability of the marine and atmospheric environment around southern Africa. (a) The key oceanographic features; (b) An overview of the atmospheric forcing systems. [After Augustyn *et al*. (2018)]

2.2.1. Climate variability and change in the South African marine and coastal environment

In the context of this thesis, climate change is considered as the significant, long term change in the weather patterns over a significant period of time, in particular, that caused by anthropogenic activities happening in the 20th century, such as the prolonged emission of greenhouse gasses. Other typical drivers of climate change include natural processes such as volcanic activities and veering in earth's orbit and plate tectonics (Doney, 2010), but these are not relevant here. Climate change is complex given the shorter-term (seasonal to inter-annual) fluctuations or climate variability that are also experienced. A natural phenomenon, such as the El Niño-Southern Oscillation (ENSO), can cause climatic conditions to fluctuate in many places around the world. Often, it becomes a difficult task to disentangle whether the cause of certain unconventional atmospheric conditions is due to climate change or climate variability (Bakun *et al.*, 2010).

I. Climate variability

In southern Africa, the dominant mode of the natural inter-annual climate variability is ENSO (Reason *et al.*, 2000). ENSO is a three-phased climatic phenomenon that is linked to certain oceanographic and atmospheric conditions naturally occurring in the tropical Pacific Ocean. During ENSO events, the SST and atmospheric circulation patterns (see Figure 2.1) are modulated to be above (Positive phase) or below (negative phase) or normal (neutral phase) conditions, affecting the climate in the tropical and subtropical regions around the world (Mason and Jury, 1997b; Reason and Rouault, 2002; Reason and Jagadheesha, 2005, Trenberth 1997, Power *et al* 2018). Generally, ENSO events take time to build up, occurring every 3-7 years and are typically mature during the austral summer months (DJF) (Reason *et al.*, 2000). These events have been occurring for centuries and may be affected by global climate change.

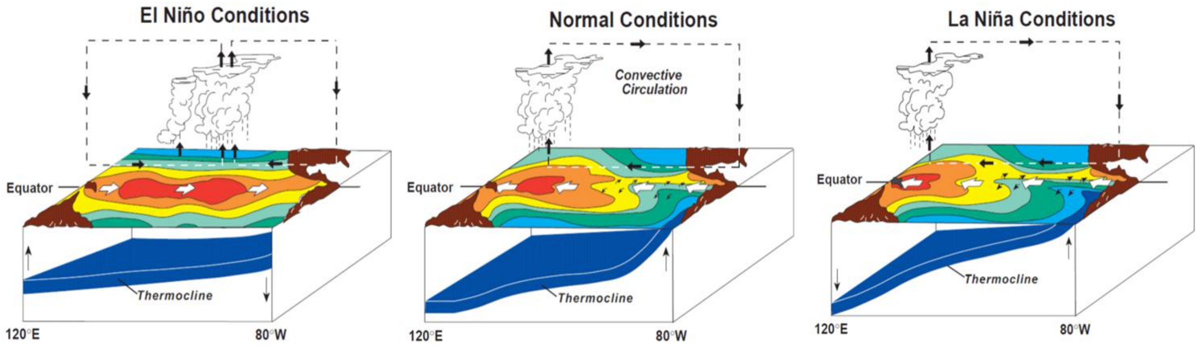

Figure 2.2: Diagram showing a model of surface temperatures, winds, areas of rising air, and the thermocline (blue surface) in the tropical Pacific during El Niño, normal, and La Niña conditions. Taken from *Reef Resilience Network*[5]

The influence of ENSO on South African climate is most noticeable in the months December-March (i.e. when ENSO peaks), when the country, excluding the southwestern Cape, is expected to be experiencing the highest rainfall amounts (Lutjeharms and de Ruijter, 1996; Jury, 2017; Kruger and Nxumalo, 2017). During the summer of a positive phase (El Niño) of an ENSO event (i.e. warm water in the tropical Pacific Ocean), the SST decreases in the mid-latitude Indian Ocean and mid-latitude central South Atlantic Ocean (Reason *et al.*, 2000; Dieppois, Rouault and New, 2015). Moreover, the amount of rainfall received in the summer of an El Niño event in the southern African region may be less than usual, evident in the 1982/83 and 2015/16 event (Tyson and Preston-Whyte, 2000; Reason *et al.*,2000). This impact can persist through the winter season (Phillipon et al., 2011). In addition, the South African wind systems, which are dominated by the subtropical high-pressure cells, have been subjected to the influence of ENSO. During the austral summer an El Niño event, a weakening of the dominating southeasterly winds was witnessed along the west coast of South Africa leading to warmer SST conditions (Rouault, Pohl and Penven, 2010). The reverse patterns occur during negative or cold ENSO, known as La Niña, events. Kruger (1999) has shown evidence that La Niña events are concurrent with above-normal rainfall events in South Africa.

The predictability of ENSO events and how they may evolve in the future remains a scientific challenge. The 1993/94 El Niño event was not expected and the impact of the 1991/92 and 1997/98 El Niño was unsuccessfully forecasted (Reason and Rouault, 2002; Reason and Jagadheesha, 2005). The comparatively weak El Niño event of 1991/92 was associated with

[5] https://reefresilience.org/climate-and-ocean-change/el-nino-southern-oscillation/

extreme drought in large parts of the South African region, yet only mild dry conditions were experienced in connection with the relatively stronger warm ENSO event in 1997/98 (Lyon and Mason 2007). The lack of skill in seasonal forecasts of rainfall patterns across southern Africa during ENSO events, or perhaps changes in the mechanisms that apprise the intensity and frequency of ENSO events is of great concern with regards to understanding climate change or variability in the southern African region (Mason and Jury, 1997; Mason, 2001; Reason and Rouault, 2002). Subsequently, there is a lack of certainty in predicting the impacts on marine and coastal environments.

II. Climate change

There is growing evidence of climate change in the key factors, such as the Agulhas Current along the east coast and mid-latitude wind systems, shaping the climate and weather of South Africa. Using satellite data, Rouault *et al.* (2009) have shown a warming trend of the Agulhas Current from the 1980s to the 2000s, including waters on the continental shelf. In a more recent study, it was noted that the Agulhas Current has been warming at a rate of 0.03°per decade since the 1980s. Moreover, the strengthening of trade winds in the tropical Indian Ocean has resulted in the acceleration of eddy propagation, particularly in the Mozambique Channel and south of Madagascar, highlighting the intensification of mesoscale variability in the Agulhas Current (Backeberg, Penven, and Rouault, 2012b).

Recently, over the Agulhas bank, a negative regime in winds correlated with the reduction of the overlaying atmospheric pressure (Malan *et al.*, 2019). Furthermore, changes in atmospheric circulations have been noticed (Mills et al., 2013; Vizy and Cook, 2016) and evidence suggests that the South Atlantic High Pressure (SAHP) appears to have been displaced southward/poleward from the early 1980s to 2014. However, the exact mechanisms behind the changes seen in the SAHP and the Agulhas Bank are not clear and it is also not known if this is part of natural variability, such as ENSO, or anthropogenic climate change (Schumann, Cohen, and Jury, 1995; Kruger and Nxumalo, 2017; Endris *et al.*, 2018).

III. Impacts of climate change on Marine Living Resource

Changes in the SSTs of the Agulhas Current are expected to trigger responses in the regional climate and weather, marine biodiversity, resource abundance, and the distribution of marine organisms (James, Whitfield and Cowley, 2008; Rouault, Penven and Pohl, 2009). Rouault, Penven, and Pohl (2009) concluded that an increase in SSTs would result in an anomalous movement of heat from the ocean to land creating a warmer land surface than usual. The authors explained that the impact on precipitation and cloud cover would be relatively smaller than the impact on the ocean-land heat. Therefore, a warming trend of SSTs in the Agulhas Current can be associated with an increased heat influx from ocean to land and a possible increase in precipitation. Furthermore, Potts, Götz and James (2015) investigated the impact of temperature change on coastal fish species behavior and concluded that migratory fish species with lower thermal limits, such as yellowtail *Seriola laland*, would most likely move poleward in an event of warming ocean temperature, causing a distributional shift.

The impact of changing winds on fisheries has been mostly linked with the resulting upwelling dynamics. The coastal upwelling favorable winds along the east coast are northeasterly winds that flow poleward, parallel to the east coast of South Africa. As a result of Ekman transport (whereby the overall movement of water is at 90 degrees to the left of the wind movement in the Southern Hemisphere), the surface water gets pulled away from the coastal inshore zone, which is then replaced with cool and nutrient-rich water from the deeper ocean. Generally, upwelling zones are associated with high plankton biomass and productivity (Blamey et al., 2012). Change in wind strength and/ or direction would either enhance or reduce biological productivity in coastal areas. Stronger (weaker) upwelling has a positive (negative) effect on the fisheries (Potts, Götz and James, 2015). Moreover, upwelling affects thermal gradients in the coastal zones, and this may have an alternative implication on certain fish species, especially those which are estuary dependent, with optimal thermal conditioning (James et al., 2013).

The amount of rainfall received also has a significant implication on the amount of freshwater input in estuary systems and the marine environment. The input of freshwater into the coastal zone during a runoff introduces sediment and nutrients in estuary systems and the marine environment (Lamberth, Drapeau, and Branch, 2009; Augustyn *et al.*, 2018). The nutrients are crucial in the primary production of phytoplankton, which is consumed by zooplankton. These organisms are an important source of food for many fish species at their different stages of life (Lamberth, Drapeau, and Branch, 2009; Potts, Götz and James, 2015). Therefore, an increase or decrease in the freshwater inflow would modify the abundance of fish. For example, in Thukela Banks along the east coast of South Africa, a forecast of 36% decline in the catch of Slinger (Chrysoblephus puniceus) was made under a scenario of a 16% to 44 % decline in the current freshwater input (Lamberth, Drapeau, and Branch, 2009).

Finally, a large gap in scientific knowledge about the underlying processes of climate change and its impacts exist, and the ability to make mitigation and adaptation plans to climate change vulnerabilities is thus limited. Thus, there is an urgent need for more evidence about climate change-related events to build the resilience of those who may be impacted the most including coastal communities and to inform decision-makers.

2.3. Vulnerability and vulnerability assessment

Coastal communities are not only vulnerable to consequences of long-term changes in climate such as sea-level rise; they are also vulnerable to extreme events such as storm surges, floods, erosion, etc. (Dolan and Walker, 2006). These extreme short-term events seem to be worsening over time and many coastal communities are already experiencing these changes (Doney *et al.*, 2012; Hobday *et al.*, 2016). The frequency and magnitude of these climate change impacts differ from one place to the other (Badjeck *et al.*, 2010; James *et al.*, 2013) and it becomes fundamental to drawing up responses to these changes at community level to account for the experiential learning of the particular community about their environment (van Aalst, Cannon, and Burton, 2008; Sowman and Raemaekers, 2018). Climate change vulnerabilities are often addressed through the development of mitigation or adaptation strategies. Mitigation plans, which are grounded in behavioral change across global to local scales, tend to be prioritized in dealing with climate change (IPCC, 2014). However, adaptation responses are vital for communities who are already affected by climate change impacts as they provide a locally contextualized action plan. In South Africa, coastal fishing communities have shown an ability to come up with their own specific adaptation strategies and areas where support is needed in dealing with the evident climate change impacts along the west coast (FAO, 2015). This proves that these communities are efficient in picking up climate change environmental problems to which they can later adapt by themselves.

Vulnerability studies have been very instrumental in addressing numerous research aims including enhancing community resistance (Raemaeker and Sowman, 2015), vulnerability mapping (Preston, Yuen, and Westaway, 2011), and improving vulnerability assessment frameworks (Mills et al, 2011). In the past, vulnerability frameworks were developed with a major focus on natural hazards and very little consideration of the context of vulnerability (Eakin and Luers, 2006). However, when applied in the socio-ecological systems context, such as fisheries, the frameworks have become more holistic and inclusive of socio-economic, political and cultural aspects (Aswani *et al.,* 2018; Sowman and Raemaekers, 2018). This may be due to the increasing recognition of the multiple drivers of stress and change to the socio-ecological system; and the challenge with associating particular stress (e.g. resource declination) to a specific driver of change (e.g. increase in SST) based on conventional science evidence only.

Moreover, various interpretations of vulnerability exist in climate change discourse. The major interpretations that exist can be traced back to scientific framing and human security-framing of vulnerability (O'Brien *et al.,* 2007). Scientific research has produced a distinct and significant type of knowledge that has influenced and informed specific climate change response policies. This type of knowledge is outcomes-based and includes magnitudes and rates of change in climate to determine vulnerability (O'Brien *et al.,* 2007). Here the emphasis is on the projected impacts of climate change on either a biophysical or social unit as shown in the schematic A in Figure 2.3. On the other hand, human- security framing is more processual and relies on multidimensional views of climate-society relationships (O'Brien *et al.,* 2007). Here changes in climate are considered to occur in the context of political, economic, institutional and social changes that correlate with contextual conditions of the exposed unit. In turn, the contextual conditions affect exposure to climate change and response to it as shown in schematic B in Figure 2.3. Therefore, due to this difference in vulnerability interpretations and their underpinning discourses, it has been argued that they are not integrated but treated as complementary (O'Brien *et al.,* 2007). Even though human-security framing of climate change and contextual vulnerability was less visible than the outcome vulnerability, this has seen a change in the recent past.

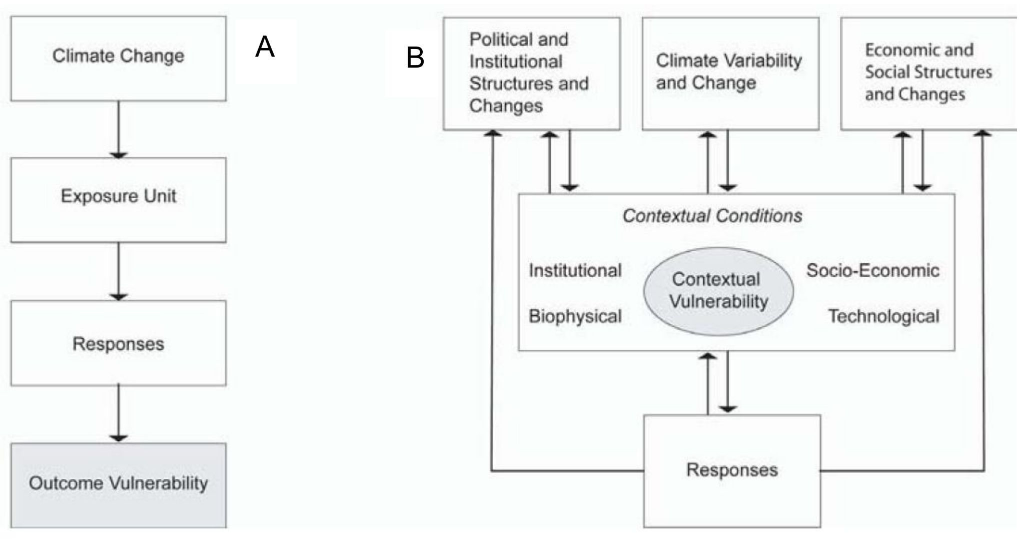

Figure 2.3: Frameworks depicting two interpretations of vulnerability to climate change: A outcome vulnerability; B Contextual vulnerability (taken from O'Brien *et al*., 2007)

More recently, a focus on the perceptions and knowledge of environmental change of coastal resource users has been seen crucial in vulnerability studies since adaptive capacity is not only determined by the capital of the vulnerable individual or group but by their understanding and perception of these changes (Figure 2.3) (Sievanen, 2014; Limuwa *et al.*, 2018; Tiller and Richards, 2018). Nonetheless, essential approaches and methodologies for vulnerability studies have been developed. This includes the incorporation of qualitative and quantitative data as well as coupled human-environment systems analysis across various spatial, geographical and temporal scales (Barsley, De Young and Brugère, 2013). Moreover, participatory approach has been strongly argued in vulnerability assessments for its benefits in ensuring local framing and ownership of environmental problems and solutions, selection of locally relevant methodologies and application of frameworks.

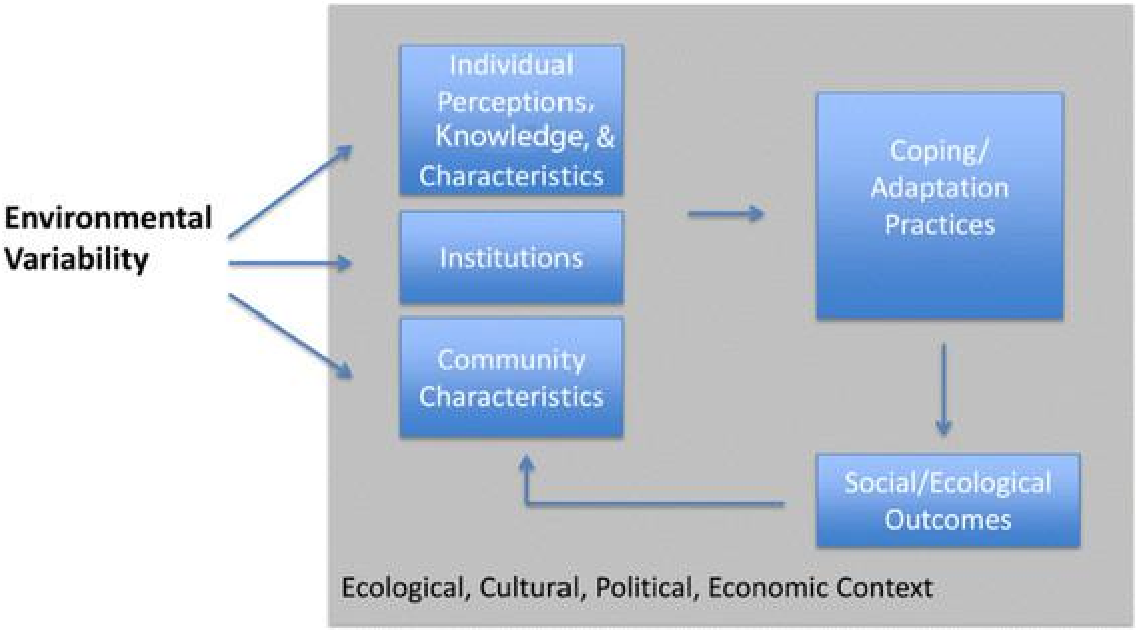

Figure 2.4: Conceptual framework illustrating how fishers adapt to environmental variability (taken from Sievenan 2014)

2.4. Local ecological knowledge

2.4.1 Definition and characteristics

In this study, Local Ecological Knowledge (LEK) is defined as the evolving body of knowledge about ecosystems, which is underpinned by social attitudes, beliefs and historical experiences (Inglis, 1993; Ruddle and Davis, 2013). It is accumulated over time through continual relationships between people and their environment (use of resources); and may or may not be generationally passed on through cultural transmission in prominently less technologically progressive societies (Inglis *et al.*, 1993, Agrawal, 1995). "Resource users" is one of the groups that can hold LEK. In the context of small-scale fisheries studies, it becomes important for local marine resource living users to acquire highly specific information through experiences, observations and perceptions to develop necessary skills for their livelihood (FAO, 2015). This is referred to as an "accumulation of facts by trial-and-error" (Inglis *et al.*, 1993) and can be best reflected in the behavioral change of fishers under circumstantial changes or variability (Berkes, Colding and Folke, 2000). Natural resource-dependent communities often experience severe socio-economic or environmental conditions that may put the resources they depend on under pressure (Bodin and Crona, 2008). This allows for an intimate relationship and an advanced understanding between resource users and their surroundings. Fundamentally, LEK is regularly transformed and holds a large concentration of archival and recent socio-ecological understanding (Menzies and Butler, 2006). The accumulation of such knowledge is made possible by the long-term series of information gained from daily livelihoods on specific locality (Inglis *et al.*, 1993, Agrawal, 1995).

2.4.2. LEK with the more conventional science

The significance and practicality of LEK with and within the more conventional scientific research have been increasingly argued around the world. A major recognition of the ability of LEK to supplement and remedy challenges endured by scientific fisheries studies is evident (Huntington, 2000; Green and Raygorodetsky, 2010). Despite building the scientific knowledge on fish behavior and distribution patterns related to climate change worldwide, this knowledge is rather lacking at the local scale (Potts *et al.*, 2014; Potts, Götz and James, 2015). Furthermore, ecological mechanisms underpinning behavioral feedback of fish is still limited (Potts, Götz and James, 2015). This is owing to the procedural challenges encountered by marine biologists and ecologists to successfully monitor crucial environmental processes occurring on a daily, weekly and sometimes seasonal basis at a high spatial scale (Silvano *et al.*, 2006; Aswani and Lauer, 2014). However, fish distribution and behavioral patterns at local scale are of importance to fishers as they have an implication on their fishing efforts, food security and income. Consequently, fishers tend to extensively observe and study the physical environmental conditions that lead to variation in the local distribution of fish to avoid maximizing fishing efforts while catches remain minimal (Neis, *et al.*, 1999; Moreno *et al.*, 2007). These physical conditions include, but are not limited to, wind direction and speed, tides, sea surface temperature, water clarity and flow of current.

Although there is significant literature on the integration of fishers' knowledge in scientific fisheries studies such as fish ecology (Moreno *et al.*, 2007; Silvano and Valbo-Jørgensen, 2008), spawning aggregation (Silvano *et al.*, 2006; Hamilton *et al.*, 2012) and marine species trends (Neis *et al.*, 1999) worldwide, literature on the use and contribution of fishers' knowledge in coastal and marine physical science processes such as ocean circulation, current speed and transport is limited. Recently, studies have shown the value of LEK in weather prediction in the coastal villages of Tanzania, fishermen were found to be able to predict productivity seasons and weather conditions by observing the behavior of seawater, plants, animals, sand, sun, and the stars (Shalli,2016).

The use of sophisticated tools and instruments for *in situ* data collection is challenging along the coastlines where sea conditions can be very rough and hostile. To assist with knowledge generation, marine scientists often turn to numerical models. However, there are still numerous issues with coastal modeling, especially over the South African Exclusive Economic Zone, considering the lack of observations and the inaccuracies of satellite data that are essential in validating models. (Veitch, Penven and Shillington, 2010). Most models do not include tides or rivers runoff in their simulations even though they are a vital component of the coastal physical systems, often due to a lack of data. Additionally, with regards to ocean models, the resolution must be increased in coastal regions to capture the complex small-scale processes, which is not always feasible given the computation power needed to do this. Boundary conditions must also be accounted for within a regional modeling context, especially given the influence of the global systems on our coastlines. Hence there are capabilities for good regional estimates of the ocean but processes occurring along the coast are not well resolved (Veitch, Penven and Shillington, 2010).

2.4.3. Utility of LEK

The use of LEK as a contribution to the knowledge base on our environment has been promoted internationally although universal methodological procedures of documenting this knowledge have not been established. The Rio 'Earth summit' of 1992 saw a development in the promotion of international admission of LEK for climate change studies and accomplishing other environmental goals. The Intergovernmental Panel on Climate Change (IPCC) on its fourth assessment report accepted indigenous knowledge as '*an invaluable basis for developing adaptation and natural resource management strategies in response to environmental and other forms of change'* (IPCC, 2007). This was later reaffirmed in the documentation of the 32nd session of the IPCC that "*traditional and indigenous knowledge may prove useful for understanding the potential of certain adaptation strategies that are cost-effective, participatory and sustainable'* (IPCC, 2010a).

Methods of acquiring LEK are less established than the scientific practices and, as a result, there tends to be a desire to describe LEK in terms of the more conventional science. On the contrary, Huntington (2000) argues for the use of social science methods such as questionnaires, workshops, and informal interviews, to gather LEK data. This may allow a multidisciplinary application of this data. The data gathered in these instances is mostly qualitative, however, there is evidence that responses from the social science methods can be used in models as linguistic statements to produce both qualitative and quantitative information (Mackinson, 2010). Nonetheless, in accordance with the definition of LEK in this study, certain groups of people hold this kind of knowledge and the choice of study site area or the background of participants becomes important (Agrawal, 1995).

In conclusion, marine and coastal ecosystem services are regulated by the oceanographic and climatic processes in the coastal areas. The regulatory feature of the climate in marine ecosystems can be seen in the feedbacks that exist between the physical environment and life at sea. An example would be the observed poleward shift of fish species along the west coast of South Africa as a potential response to a changing climate (Blamey *et al.*, 2012; Jarre *et al.*, 2015). The impact of such changes in the communities of those who directly benefit from the marine ecosystem services differs geographically. Moreover, there is uncertainty associated with climate change trends, especially when considered at a local level. This makes it difficult to draw up adaptive fisheries management plans that are sensitive to the locality. At the same time, the observations of those who spend their lives at sea remain undocumented.

CHAPTER 3: STUDY AREA -TSHANI-MANKOSI COMMUNITY

This chapter introduces the Tshani-Mankosi fishing community as the study area of this research and gives an overview of the historical, socio-economic and biophysical context of this community

3.1. Historical overview

The wild coast is located along the east coast of South Africa (see Figure 3.1). According to the *wild coast*[6] historical background, this area was initially settled by a group of Bushmen who lived in the coastal valleys and kept livestock in addition to their agricultural livelihood. Archaeological evidence suggests that the human influence on this environment dates back to the late 7th century AD. This group was later replaced by Nguni people in the 17th century coming down from the Natal coast. From the late 18th century to the early 19th century, the southward migration of the Nguni created prolonged tribal wars within this group. The wars were intensified by the British settlers who were also in search of a settlement. The region gained a martial reputation which is thought to have been the reason why the Eastern Cape was not densely populated by the European settlers but left to the highly mobile indigenous people[5]. It is suggested that the society became more static and permanent settlement in the wild coast started during the mid-1800s (Beinart, 1982).

The occupancy of this region by mostly native people was further advanced by the apartheid government, which declared the Transkei as one of the homelands. Even though homelands were the isolated areas far from the major centers such as Cape Town and Johannesburg, the Transkei had its own towns such as Mthatha, Gcuwa, Idutywa, etc. These towns were mostly founded by missionaries or well-known historic battlefield sites. Many villages were established around these towns. Furthermore, the segregated homelands were the source of labor for a migrant workforce- mostly consisting of men who would temporarily relocate into the major cities. Due to the insufficient income received by the men, they could not send a portion home each month hence those who were left behind needed to find alternative means

[6] https://www.wildcoast.co.za/historical-background

of living (TMCT[7], personal communication, 2017). As a result, these villages consisted of people who were heavily reliant on natural resources for living and maintained traditional ways of living. The historical segregation of the country seems to have had the most influence in ensuring the minimal influence of a foreign lifestyle to the traditional way of life in the homelands such as those in the Eastern Cape Province. Direct dependence on natural resources for necessities of life is still evident (Mbatha, 2011). The people have a protracted interaction with the coastal and marine environments.

During an interview with a local villager, it was shared that the shoreline is believed to have been mostly used as a cattle grazing area with minimal dwellings (TMCT, personal communication, 2017). In the engagement with the locals it was also shared that during grazing periods of the day, the cattle herders would consume marine living resources for lunch since their homes were relatively far from the field. Marine living resources quickly gained recognition, and this may have been the genesis of the fishing livelihood among the amaXhosa group who lived along this coastline (TMCT, personal communication, 2017). Consequently, the Tshani-Mankosi village is one of the many villages scattered immediately alongside the South African coastline. Feilding (1995) documented that there are about 8 of the fishing communities along the wild coast stretch (~ 250km) of the South African coastline (Figure 3.1).

According to *Statistics South Africa,* [8] this community has a population size of more than 1000 people and more than 200 households (*Statistics South Africa*, 2011). However, the more recent survey[9], at a municipal level, revealed that the population size of the district municipality (O.R Tambo) this community falls under increased by 6.7 % from the previous consensus (*Statistics South Africa* 2016). In this community, at least one person in every second household is involved in the use of marine living resources for either consumption or trade (Mbatha, 2011). Although it seems that more than one livelihood exists in this community, some livelihoods seem to be more dominant than the others and a geographical pattern can be seen regarding the preferred livelihood. Generally, agricultural practices are still considerably valued here. However, livestock keeping seems to be the main practice for households that are further away from the shoreline. The households near the coast are tailored around the fishing livelihood. A 78-year-old retired fisherman who was born in this

[7] TMCT is a coded reference of the meeting the author had with Tshani-Mankosi Community Trust representatives during the scoping visit in August 2017.
[8] http://www.statssa.gov.za/?page_id=4286&id=4824
[9] http://cs2016.statssa.gov.za/wp-content/uploads/2018/07/EasternCape.pdf

community (household near the coast) claimed that his parents were one of the early settlers in this community, suggesting that the village existed more than 90 years ago (SVMLRU[10], Personal communication, 2017). Moreover, it is possible that the fishing livelihood started around about the same time.

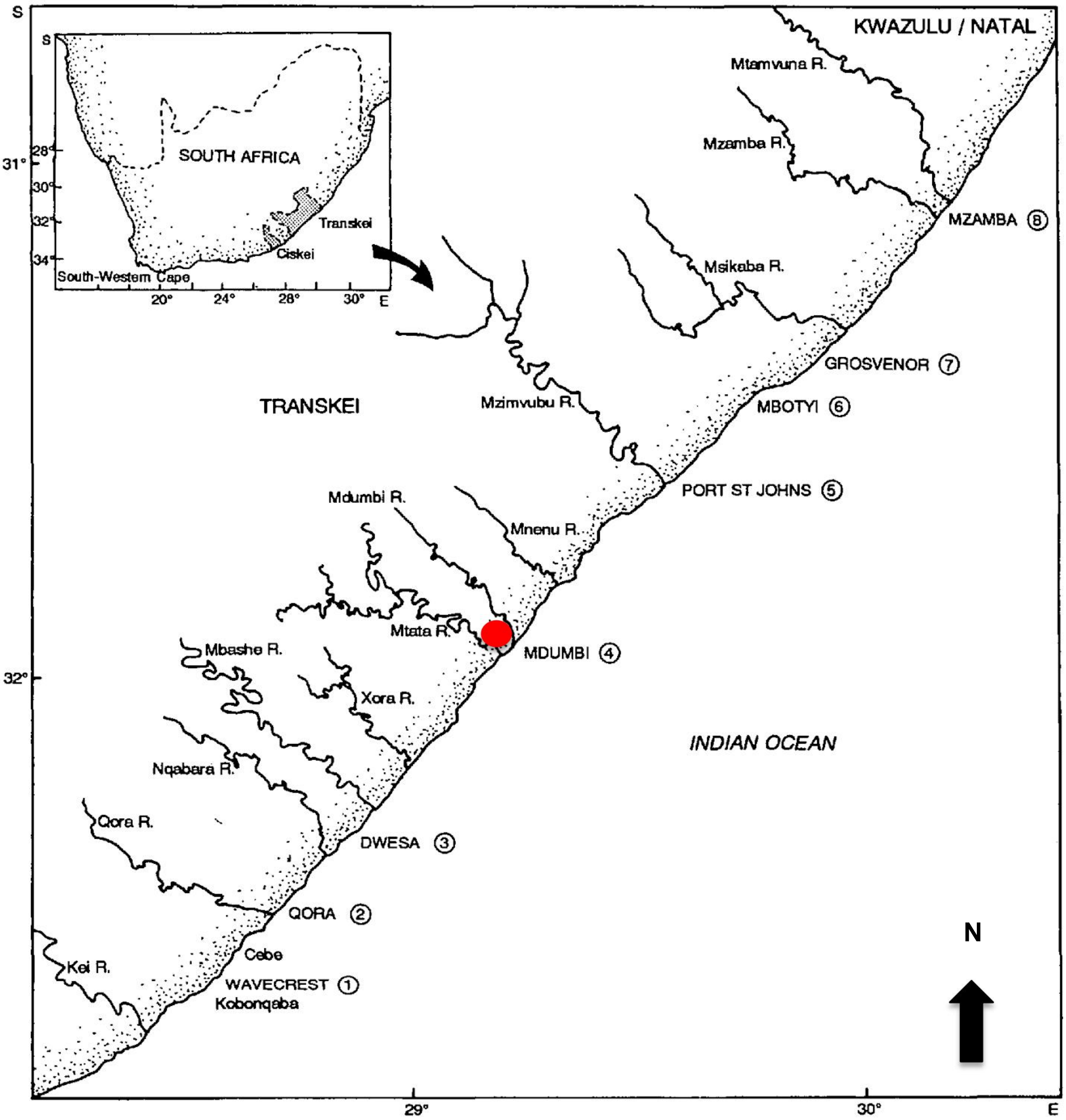

Figure 3.1: Image of the wild coast and key rivers (from Kei to Mntavuma River) along the east coast of South Africa. The location of Tshani-Mankosi village is shown as the red dot [adapted from Fielding, 1995]

10 SVMLRU is a coded reference of the engagement between author and the local Marine Living Resource Users during the scoping visit in August 2017

3.2. The Socio-economic overview

Typical living conditions of a coastal Transkei community are represented in Tshani-Mankosi. Dusty gravel roads are evident with traditional dwellings (locally known as rondavels) built from clay sand and mud bricks with grass roofs (Figure 3.2). Basic services are lacking in the region with the electricity supply being irregular and sanitation facilities being very informal. The highest percentage of young adults (20 years old and older) with no history of schooling in South Africa is in the Eastern Cape, dominated in the O.R Tambo municipality- the district municipality of Tshani-Mankosi community (*Statistics South Africa*, 2016). In conversation with community members, it was indicated that employment opportunities are very limited (TMCT, personal communication, 2017). Government social grants make up more than 60% of the households' income in this community, the rest of the income tends to come from fisheries, tourism and other activities (Mbatha, 2011). Due to poverty, many are forced to either migrate to urban areas for better opportunities or turn to natural resources to at least ensure that the necessities of life are secured (TMCT, personal communication, 2017.

Figure 3.2: A photo depicting the typical landscape of the Transkei coastal community (Tania Moyikwa, August 2017)

A strong historical tie between fisheries and tourism is evident, as tourism seems to create the demand for marine living resources (Raemaekers, 2009; Mbatha 2011). The holiday accommodation establishments around this community have created a marketplace for the marine resource harvesters to occasionally trade. This makes tourism an integral part of this livelihood. Moreover, tourism has an influence on other socio-economic aspects of this community. For example, Mdumbi backpackers[11] which are co-owned between community members and the two founders had a subtle yet significant role in the development of this community. This backpacker was formed in 2002 and later, in 2004, the founders initiated a Transcape NPO[12] to provide support to the community. Transcape has achieved health, education, livelihood and income projects such as the upgrade and improvement of the community healthcare facilities, providing high school and tertiary education scholarships, as well as formal early childhood development services. Moreover, the backpackers seem prosperous and essential to the community as it provides genuine and purposeful support for the development of the community (Hitchcock, 2013). The backpackers source local food (fresh seafood) and labor and they encourage tourists to spend on small local businesses such as restaurants, taverns, fishing and surfing classes, hiking guides and clothing shops as well as donating tools that fishers can borrow for their livelihood (TMCT, personal communication, 2017). Furthermore, the backpackers encourage environmental inclination by hosting tree planting projects and refraining from purchasing marine living resources during their closed season or when they do not meet the size limit. The role of tourism in the fishing livelihood and the general socio-economy of this community is noticeable. Such that, besides social grants, the pivot of the socio-economy of this local community seems to be the fisheries sector coupled with tourism.

Local government and traditional authorities are other role players in the fishing livelihood and socio-economy of this community. For the local traditional authority of the village, a headman is selected together with his council to oversee the administration and daily activities of the village (TMCT, personal communication, 2017). The headman is then expected to report to a Chief who is represented in the leadership structure of the Nyandeni municipality. In parallel to this, the local government has its leadership hierarchy consisting of a ward councilor and ward committees who also hold a seat in the Nyandeni leadership

[11] https://www.Mdumbi.co.za/
[12] http://www.transcape.org/about/about-us

(TMCT, personal communication, 2017). A further complication to this dual leadership is that certain departments of the national government such as the Department of Agriculture, Forestry and Fisheries (DAFF) establish their own separate working committees in the community (TMTA[13], personal communication, 2017). This often causes power conflicts in the community when fisheries development and management plans are brought forth (TMCT, personal communication, 2017). In addition to this, the MLRU is expected to have permits and be aware of the governmental controls in the fisheries sector. The coastal law enforcement officials, referred to as "Nature" by the locals, have monitored the use of marine living resources since the 1970s. The local traditional authorities who strongly embrace cultural values, seem to have a dominating role in the governance of this community. For example, overexploitation of resources is not encouraged as fishers opt to share their catches should one catch more than what they can keep, given that there are no refrigerators in their homes (SVMLRU, personal communication, May 2017). The fishers argue that one should always show the spirit of "ubuntu" to live in harmony.

3.3. Biophysical overview

The *wild coast climate*[14] is characterized by a warm rainy summer season (DJF) while the winter season (JJA) is cool and dry. The annual rainfall received over this region is estimated at around 1000 mm per year. The average summer temperature can reach 28°C with a low of 17°C. During winter, temperatures decrease to a mild average of 21°C with an average minimum of 10°C. Considerable climate variations between the northern and southern parts of the wild coast exist. The northern part tends to be relatively warmer than the southern part while the mid-region is usually mild. The prevalent winds along this coast are northeasterly, although southwesterly winds can also occur frequently. These climatic conditions are influenced by the neighboring ocean and atmospheric circulations in this region, for example, it has been suggested that during the summer months, the east coast is sensitive area to potential extreme convective activities due to the high latent heat influxes produced by the adjacent Agulhas Current (Blamey et al, 2017).

[13] TMTA is a coded reference of the meeting had with the Tshani Mankosi Traditional Authority representatives during the scoping visit in August 2017
[14] https://www.wildcoast.co.za/environment/wild-coast-climate

The coastal environment of Tshani-Mankosi can be distinguished into three major domains: sandy beach, rocky shore and estuarine (Figure 3.3). Sandy beaches are usually characterized by a surf zone, the beach, and dunes. The relatively small system of dunes in Tshani-Mankosi is stable and fully covered by vegetation. While the surf zone provides habitat to algae (providing a food source to microscopic animals such as zooplankton), the beach area is dominated by burrowing animals such as sea snails, which depend on tides for their movement (Cockcroft *et al.*, 2002). The sheer cliff headland and wave-cut platform characterize the rocky shore of this coastal community. Life in the rocky shores can be characterized into three classes, namely the high tide, intertidal and low tide zone. Sea plants and animals here are organized in these classes according to their needs and adaptation to water, heat, and air (Porri *et al.*, 2008). Those adapted to exposure to air and heat tend to be located in the low tide region. Lastly, Tshani-Mankosi is bordered by the Mthatha and Mdumbi estuaries which are permanently open. These two estuaries are an essential habitat and nursery area for many species (Whitfield, 2010).

Figure 3.3: Image showing the terrain of the Tshani-Mankosi community boarded by the Mthatha and Mdumbi Estuary and the sea. The beach and rocky shore environment are also shown (image created using GoogleEarth software)

The wild coast is celebrated for rich marine biodiversity and unique marine ecological processes such as the sardine run. This is characterised as the sporadic migration of sardines up the east coast of South Africa followed by predators such as dolphins, sharks, birds, and whales (Caputo et al, 2017). This phenomenon generally occurs between the late autumn and winter months of May and July. The processes underlying the sardine run are not fully understood, however, some ecological changes on the east coast waters have been noted such as they increase nitrogen levels, competition and migratory patterns of species such as humpback whales (Hutchings et al., 2010; Caputo et al, 2017). Also, for the sardines to be moving against the dominant Agulhas Current suggest that there are some mesoscale features occurring on the shelf edge of the current (Krug, Swart & Gula, 2017). This highlights how the limited knowledge of the shelf and coastal features off the wild coast contributes to the lack of sufficient understanding of the processes behind the sardine run.

CHAPTER 4: METHODOLOGY

4.1. Research design

This study seeks to investigate climate and environmental change based on scientific research as well as the interpretation of life events, values, and beliefs of marine resource users. Therefore, the meaning assigned by humans to their observations and experiences in their socio-ecological space is important. In Local Ecological Knowledge (LEK) related research it is important that the way in which people make sense of the experiences and how their world is constructed is understood (Neis *et al.*, 1999; Huntington, 2000). Therefore, social science methods will be used to gather climatic and environmental data from local resource users while information from scientific efforts will be gathered from scientific literature and direct interviews with scientists. Qualitative data will be interpreted concurrently with the quantitative data utilizing a mixed-method research design.

4.2. Research approach: Participatory Research

A participatory research approach is incorporated to peruse knowledge about climate and environmental change along the east coast of South Africa. This research is a reflective process of gradual improvement in understanding climate change at a local scale and environmental change from various perspectives, namely scientific researchers and local MLRU. This approach encourages collaborative knowledge production from various stakeholders (Murray, Bavington and Neis, 2005; Baum, MacDougall and Smith, 2006). Participatory research approach is suited for this study as it includes an engagement between the researcher and those whose lifeworld is being investigated. An engagement with the MLR users is therefore important to ensure that cognitive power of the research participants is prioritized to investigate and interpret their perspective on climate and environmental change.

This research will use the case study strategy to investigate the question. Cases studies provide a good lens through which an in-depth investigation of a particular phenomenon is undertaken (Baxter and Jack, 2008). It is a useful research strategy to accumulate and evaluate empirical evidence of change based on real-life experiences. Even with the selection of this strategy, this research would be close-minded without the consideration of "*patterns of behaviors, language, and actions of an intact cultural group in a natural setting over a* *prolonged period of time"* (Creswell, 2014). Thus, the importance of a scoping visit to the community is paramount to familiarise the researcher with the social norms of the community and is discussed in more detail below. Moreover, an in-depth scientific literature review was also completed to gain a better understanding of the local processes at play.

4.3. Data collection: Methodology and methods

Considering multiple perspectives or co-existing 'truths' to expand knowledge around climate and environmental change requires careful consideration of how the information is constructed from the source and the methodology applied. As a result, this study follows a dialectical methodological stand and uses mixed methods to collect data from various sources (Enosh and Ben-Ari, 2010; Fairclough,2009). Figure 4.1 shows the different methods used in association with the research objective.

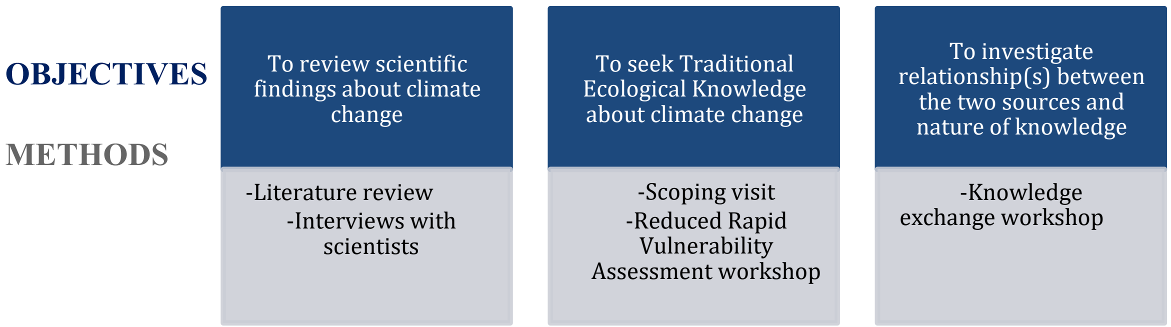

Figure 4.1: The Research objectives with the associated research methods

The sampling methodology used in this study is a non- probability, snowballing sampling method. This method is based on the referral for the selection of research participants (Schreuder, Gregoire, Weyer., 2001). As a result, the participants were selected in various stages. A sampling procedure in a form of an advertisement was used to ensure, with confidence, that all marine resource users in Tshani- Mankosi had an equal probability of participating in this research. During the scoping visit, permission to conduct research in the community was acquired from the village chief with the help of a local research assistant who was referred to the researcher and has been used for scoping exercises in the past.

During an interview with the local research assistant, it was suggested that an invitation letter is sent out to the community to invite interested marine resource users to participate in this research. The letter was posted around the community (Spaza shops, backpackers- the fisher's marketplace) during the scoping visit (2 months prior to the research workshop) to allow the community members to view the invite at least once. Word of mouth was also used to raise awareness about this research and its objectives in the community. From the participants of the workshop, a few key informants were selected for further 'experts' interviews. A total of 49 informants participated in this research. Finally, this sampling methodology was chosen because the population was not known and hard to reach.

4.3.1. Scoping visit

The scoping visit is a crucial initial step to this research as it allows familiarization of the researcher with the case study area and community. A scoping visit can facilitate decision making and planning of the methodological process that would be used to document data later in the research. During this time (Table 4.1), an evaluation of fishing livelihood and how it may be influenced by culture, land/seascape, politics, and social factors are key in capturing the context at some satisfactory level of depth. Here, informal interviews with fishers, school visits, and village tours were carried out. The visit plays a significant role in introducing the aims and objectives of the research to the community prior to commencing the research and to gauge the interest of the community in participating in the research. Furthermore, an acquaintance within the community as part of the research team is essential to give support in getting the chief's permission to conduct research, organizing suitable meeting venues, to provide translation services, assess the influence of environmental conditions such as a tidal system on fishing livelihood and identify local fishing experts. Additionally, spending time in the community prior to the research gives the researcher some time to earn the trust and acceptance of the people. Furthermore, it is important that there is contact between the researcher and the community after the scoping visit and foregoing the research. A discussion about timeframes for a workshop was initiated with the community members to avoid any interruption of fishing activities or other societal meetings. Upon the decided dates and times, a research team of four was organized, invites to the workshop were sent to the community, and a program for the two-day workshop was developed (Appendix A).

Table 4.1: A schedule of research fieldwork as well as dates of various meetings with different stakeholders and scientists from respective organizations or institutions. The code is generated to reference data that was gathered from these meetings.

Date	**Type of meeting**	**Attendees**	**Code**	**Organization**
10 July 2017	Informational interview	2 Scientific researchers	SR1	University of Cape Town
25 July 2017	Informational interview	2 Scientific researchers	SR2	DAFF
03 August 2017	Informational interview	1 Scientific Researcher	SR3	DEA
17 August 2017	Informational interview	3 Scientific Researchers	SR4	SAIAB
18 August 2017	Informational Interview	1 Scientific Researcher	SR5	Rhodes University
22 August 2017	Scoping Visit	2 Representatives	TMCT	Tshani-Mankosi Community Trust
23 August 2017	Scoping Visit	2 Representatives	TMTA	Tshani-Mankosi Traditional Authority
25 August 2017	Scoping visit	2 Fishers & 1 ECRL diver	MLRU	Tshani-Mankosi Marine Living Resource Users
16 November 2017	rRVA workshop	19 Men	RWMMLRU	Tshani-Mankosi Marine Living Resource Users
17 November 2017	rRVA workshop	23 Women	RWFMLRU	Tshani-Mankosi Marine Living Resource Users
1-10 May 2018	Data Verification	6 Locals who participated in rRVA	DVMLRU	Tshani-Mankosi Marine Living Resource Users

4.3.2. Interviews with coastal and climate change research specialists in South Africa

Semi-structured interviews form part of participatory fieldwork where the researcher engages participants in an informal discussion guided by some questions (Creswell *et al.*, 2003; Creswell, 2009). Key specialists in the disciplines of marine science and climate change from a variety of South African institutes were interviewed. The questions prepared for the interview, which were inspired by an extensive literature review, were open-ended and permissive of flexibility. This allowed spontaneity during the conversation and presented an opportunity for participants to come up with guiding measures to the research. The participants were encouraged to generate ideas or themes, which may have been otherwise missed by the researcher. This is particularly important in this investigation since it covers a range of disciplines and scientists with various expertise were interviewed. The selection of the researchers to be interviewed was based on whether they have worked on the east coast marine environment or a similar environment and were specialists in climate change, marine ecosystems, local knowledge, or fisheries systems. To avoid bias in the information acquired, the scientists chosen were affiliated with different institutions (Table 4.1) with different research mandates. For example, academic, government or research institutions have unique mandates and agendas for the kind of research they conduct. Meetings with the scientists were formally requested, and opportunistic prospects were also taken advantage of through talks with scientists met at conferences and seminars.

The primary aim of these interviews was to:

- Gain a general understanding of the main climatic concepts in southern Africa (particularly of non-published work)
- Explore some scientific theories in the context of fisheries studies
- Initiate scientific documentation of major environmental incidents along the wild coast such as storm surges, floods, and marine ecological changes
- Receive guidance to some of the recent work related to climate change and fisheries

While this data was being prepared for analysis, it played a significant role in providing direction for the secondary data (i.e. literature).

4.3.3. A review of the scientific literature

The purpose of a further review of literature as part of the data, and not only as a theoretical base for this research was to follow up on intellectual progress made on marine and coastal environment topics related to fisheries, specifically along the east coast of South Africa. The literature reviewed here is specifically the literature recommended by the researchers during the informational interviews. Literature was essential for this research since there are currently no scientific experiments/*in situ* observing platforms or numerical modeling performed in the study area to provide interdisciplinary scientific findings this environment. Thus, the existing literature was used to derive the current scientific understanding of the region.

4.3.4. A reduced Rapid Vulnerability Assessment (rRVA) workshop with Tshani-Mankosi Village fishers

This research uses an adapted version of the Rapid Vulnerability Assessment (RVA) process developed by the FAO (2015) for the Benguela Current Large Marine Ecosystem (BCLME) as a tool to document LEK of the fishers along the wild coast. The original RVA (Figure 4.2) contains exercises that may not be useful for the purpose of this study. As a result, some of these exercises were eliminated in this study and a reduced Rapid Vulnerability Assessment (rRVA) process was used (Figure 4.3).

Figure 4.2: Image of the original RVA process with 9 exercises (FAO, 2015)

It is critical that preparations are made by the fieldwork team prior to the workshop hence the rRVA information was rolled out to two research assistants and one local expert by the research leader. The team worked together in contacting the community members before the workshop, deciding on time frames that do not conflict with the fishing activities and facilitating the workshop. The rRVA was achievable in an intensive one-day workshop, run by the facilitator in plenary sessions and small groups that would then provide feedback to the plenary. It was learned that cultural dynamics play out in how a certain gender tends to dominate more than the other in a similar gathering. Hence, the workshop was stretched over two days (separating men and women) to accommodate possible gender sensitivities within the community (Table 4.1). The seven steps of the rRVA highlighted in Figure 4.3, as adapted from FAO (2015), are described below.

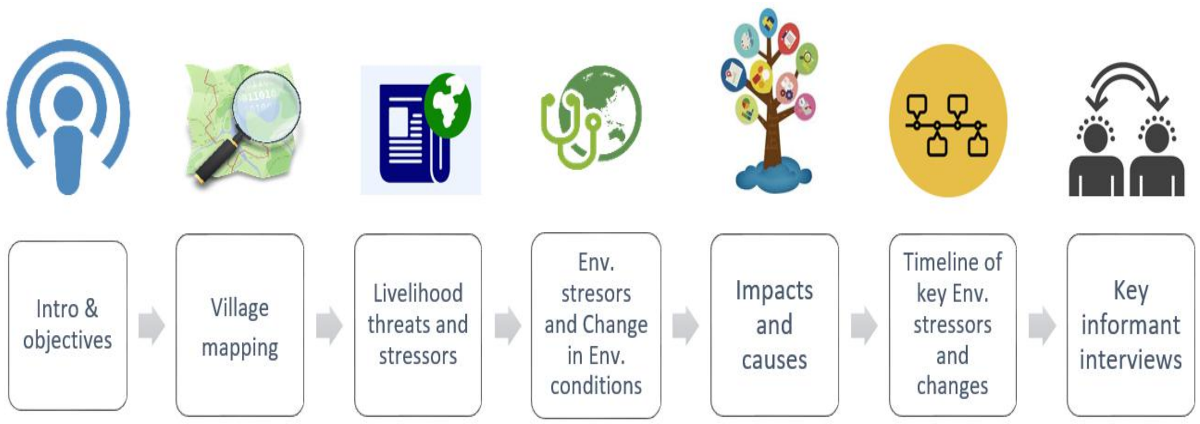

Figure 4.3: The 7 steps of the reduced Rapid Vulnerability Assessment process (designed by Tania Moyikwa, 2017)

Step 1: Introduction and Objectives

Workshops can be intimidating, and it is therefore important that a warm, relaxed learning atmosphere is created at the beginning of the workshop to put participants at ease. After everyone has introduced themselves, an icebreaker is used as part of the introductory exercise. Furthermore, the objectives and agenda of the project are presented in a manner that encourages participants to ask questions, describe, and explain the phenomenon of their livelihood. For example, "*the objectives for this workshop are to hear your voices, to learn about your lives and livelihoods as fishing communities, and the threats/stressors that you experience, especially the environmental and climate-related changes you experience, the impacts of these environmental changes/stressors on your livelihood''* Finally, it is crucial that the participants are aware that the outcomes of the research will be communicated back to them upon completion and later contribute to a knowledge base to assist decision makers during decision making process.

Step 2: Village mapping

Participants are encouraged to map the socio-ecological system of their community, highlighting important social, economic and instructional spaces and their value to the fishing livelihood. An example of such a map is shown in Figure 4.4 (see appendix C for more maps). This exercise is to allow a discussion around the worldview of the community, an overview insight of the culture and behavioral patterns in the community.

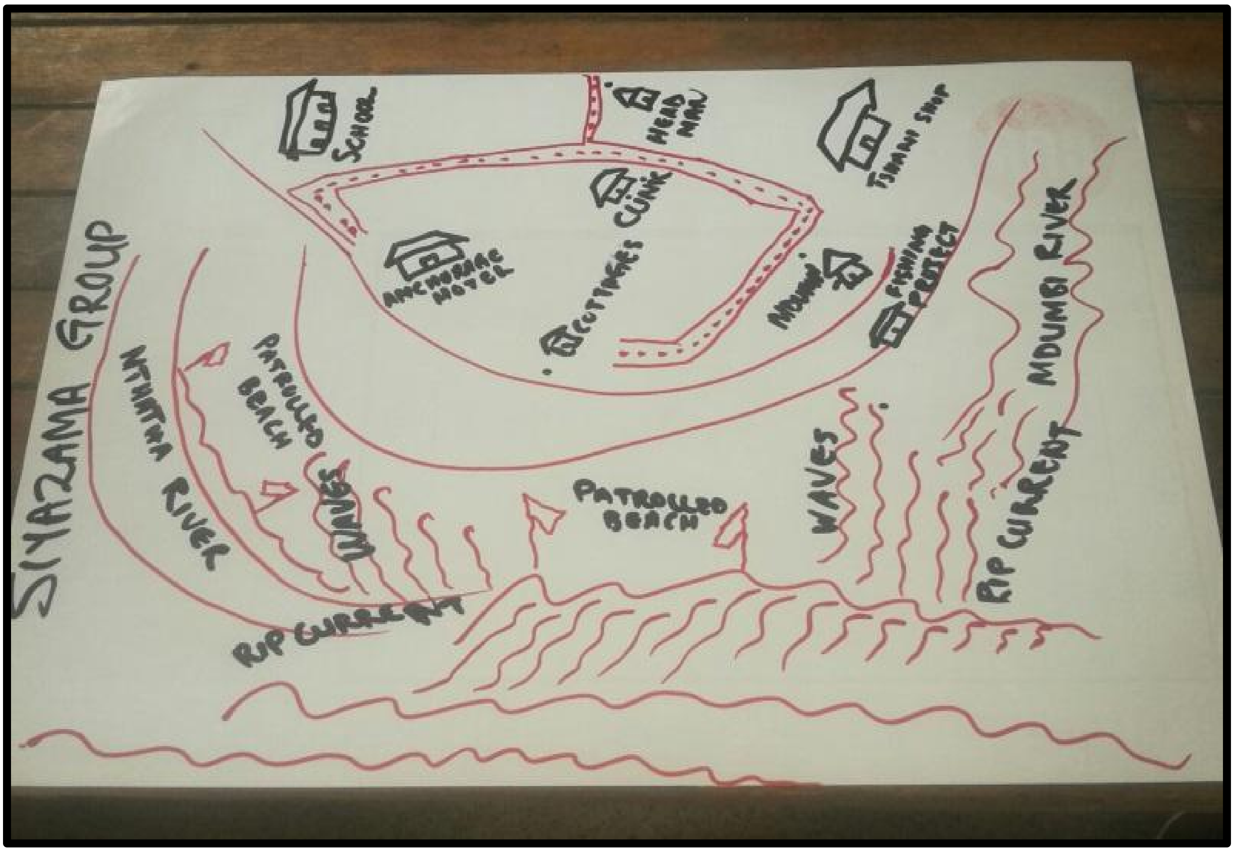

Figure 4.4: An example of a socio-ecological map of Tshani-Mankosi drawn by fishers highlighting areas of significance in relation to their fishing livelihood during an rRVA workshop in Mdumbi Backpackers between the 16th and 17th November 2017 (Photo taken by Ella-Kari Muhl, November 2018)

Step 3: Livelihood threats and Stressors

This exercise focuses on identifying social, economic, governmental and environmental (including climatic) processes and events that affect the fishing livelihood negatively (Figure 4.5). This allows a contextualized and in-depth understanding of the phenomena that may prompt a response from the community or individuals or even alters their worldview.

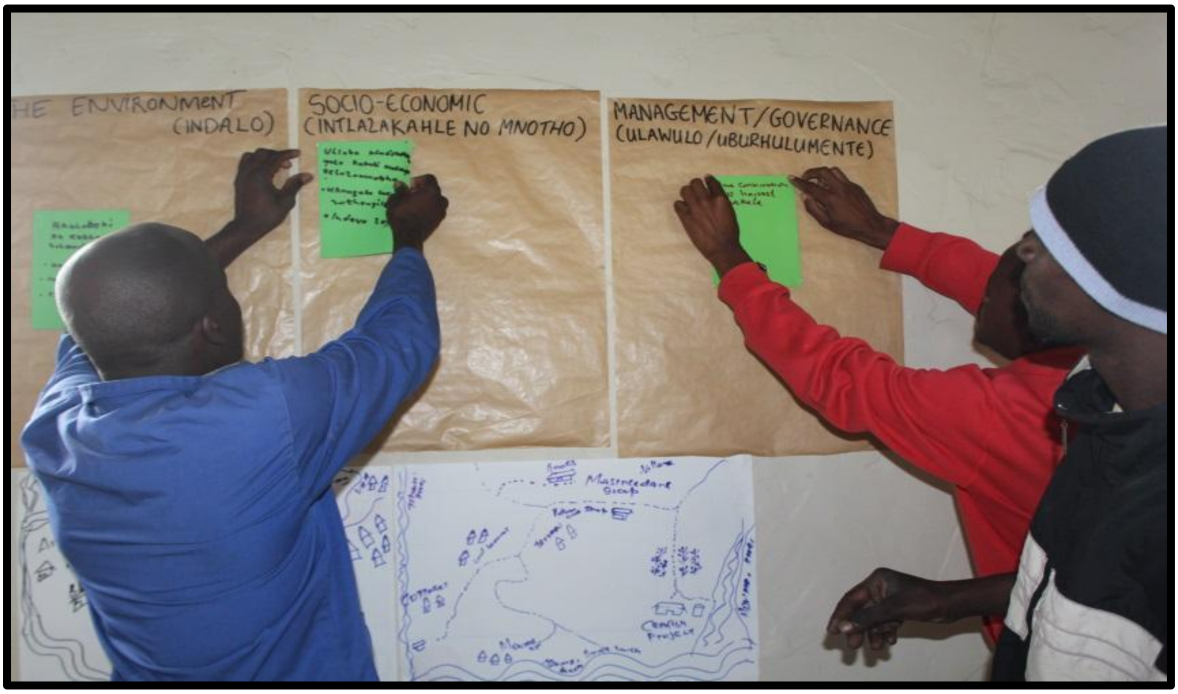

Figure 4.5: Image of fishers classifying the threats and stressors to their livelihood (photo taken by Tania Moyikwa, at the rRVA workshop, November 2017).

Step 4: Environmental stressors and changes in environmental conditions

Participants are encouraged to unpack the environmental stressors and how they manifest in their everyday lives. What those experiences mean to them and the kind of understanding associated with the mentioned changes. The aim of this is to probe further into environmental stressors identified and whether there is any link to the changing biophysical conditions.

Step 5: The impacts and causes

The aim here is to explore what kind of environmental changes mean the most by ranking them and the perceived causes for those changes.

Step 6: Timeline of key environmental stressors and changes

Organize the environmental events and changes in chronological order with the participants to trace any changes in the interpretation of these events.

Step 7: Key informant interviews

The key informant interview stage does not occur immediately after the timeline exercise because the key informants will need to be identified collectively by the research team from the workshop participants. Key informants are the specifically selected individuals who possess first-hand knowledge of the phenomena or issue/s being investigated. The two key informants in this study were individuals who were never formally employed for any period but have been unceasingly dependent on marine living resources. The two (male and female) were born and raised in the community and had never lived in the city. Interviews with them were arranged and done a day after the completion of the two workshop days (Figure 4.6). These interviews were used to supplement findings from the workshop and gain a greater level of depth in understanding the motivation and beliefs of fishers about the environment.

Figure 4.6: Image showing the interview stage of the rRVA (Photo blurred intentionally to adhere to ethical research practice, taken by Thomas Mtontsi, November 2017)

4.3.5. Knowledge exchange workshop: fishers and scientists

A team of researchers affiliated with institutions such as the University of Cape Town African Climate & Development Institute, ABALOBI, Food, and Agriculture Organization, and independent environmental consultants with expertise in transdisciplinary climate adaptation in a fisheries context, organized a fisher- scientist knowledge exchange workshop. Most of the fishers came from communities along the west coast, including Doorings Bay, St Helena Bay, Lamberts Bay, and Struis Bay. From the traditional scientific community, scientists with oceanographic and meteorological specialization attended the workshop from institutions like the Council for Scientific and Industrial Research, University of Cape Town Oceanography Department, and Climate System Analysis Group. Attending this workshop was useful in shedding light on the areas where fishers and scientists' knowledge coincide, the opportunities and limitations of the different forms of knowledge about climate variability and change. The workshop was used to explore how fishers and scientist relate pertaining climate in the fisheries context and helped to interpret findings from Tshani-Mankosi.

4.4. Data analysis

To ensure theoretical coherence and consistency, the process of data collection and analysis are considered as interdependent in this study (Creswell *et al.*, 2003). As a result, data analysis was directed by the content of the data and the emerging ideas or themes from the analysis were integrated back into data collection (Aronson, 1995). The type of information sought in this study, i.e. people's experiences, observations, views, and perceptions, requires a rigorous analysis to safeguard the meaning embedded in the dataset without any contamination. Hence, the thematic analysis strategy that has been used widely across social science was employed in this study. The analysis process is shown in Figure 4.7.

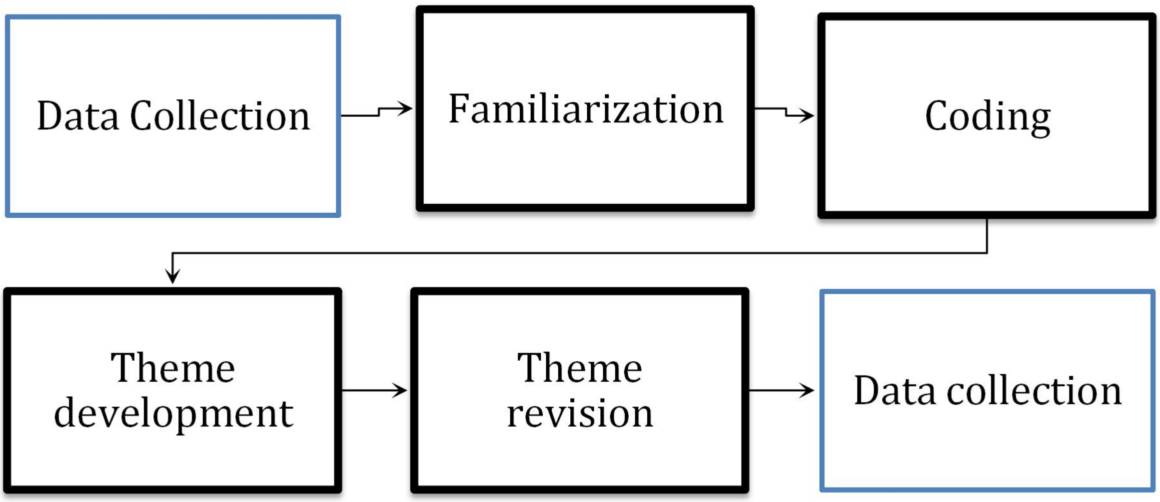

Figure 4.7: The overview of the thematic analysis process

After the data collection, the thematic analysis began with the process of ***familiarization***, where the data was repeatedly viewed and reviewed to familiarize the researcher with data to uncover a pattern in the experiences and observations shared by the participants. This is written as a set of general statements or direct quotes deconstructed from field notes and transcripts. This was followed by the ***coding*** process, where linked experiences are classified into narrower coded topics such as rainfall, winds, and sea surface temperature. Thereafter, codes that appeared meaningless when viewed alone were merged with other related codes to generate bigger ***themes*** such as climate variability. This was mainly important "*to form a* *comprehensive picture of their collective experience*" (Aronson, 1995). Finally, the ***themes are revised*** by engaging a key informant in an interview to obtain feedback. From the interview, more questions emerged, and the response was incorporated back into the analysis. To draw an inference, analytic narratives from interviews and workshops, as well as literature were interwoven according to the objectives of the study.

4. 5 Research ethics

Due to the involvement of human participants, this project applies ethical moral conduct guided by the University of Cape Town research ethics code. The researcher committed to conducting this research with "Scholarly integrity and excellence, socially sensitivity and responsibility, and with respect for the dignity and self-esteem of the individual" (UCT, 2006:46). In the course of this study, voluntary participation, confidentiality, objectivity, and transparency are encouraged. Agreements and commitments between the researcher and participants are in the form of a signature from participants upon the presentation and explanation of the consent form (Appendix B). No photos are used in which the person can be recognised unless explicitly permitted. It is also important to note that, the findings and implications of the work in this thesis have been reported back to the community.

CHAPTER 5: RESEARCH FINDINGS

Chapter 5 presents the key topics that emerged during data collection and analysis in accordance with the research objectives. The first section covers the scientific perspective about climate and environmental change along the east coast region of South Africa obtained from direct interviews with scientific researchers and from the associated literature. Section two provides the observations, experiences, and perceptions of Tshani-Mankosi MLRU about the climatic and environmental changes witnessed in their community. Finally, key evidence of change in climate and the environment are provided based on scientific efforts and fishers LEK in Section 3.

5.1. Scientific findings

One of the key research objectives is to assess the LEK garnered from the rRVA workshop in parallel with the available scientific knowledge. In doing so, an investigation of whether there are differences or similarities between the two sources of knowledge is possible. For the purpose of the scientific review, the studies suggested by the interviewed researchers are prioritized.

5.1.1. General physical environment and climate of the east coast of South Africa.

The climate of the east coast of South Africa is majorly influenced by the warm Agulhas Current, the South Indian High Pressure (SIHP), and the mid-latitude (30°-60°S) wind systems (westerly wind belt). The Agulhas Current is a western boundary current flowing poleward from close to the Mozambique border, along the South African continental shelf to the tip of South Africa where it then completes an anticyclonic loop around the Agulhas bank (termed the "retroflection") and heads eastwards into the South Indian Ocean (Figure 5.1). This warm, salty, and fast-flowing current is driven by wind fields over the Indian Ocean and the rotation of the Earth. Some significant physical processes occur in this current as it was shared that "a westward propagation of inshore boundary eddies occurs occasionally in the Agulhas Current (Figure 5.1). This includes the Natal pulse occurring 4-5 times per annum. The presence of these eddies can result in northward flow nearshore" (SR1, personal communication, 2017). Their work has shown that in a region associated with a strong southward current, there are sporadic times during the year when there is a nearshore countercurrent with the strong southward current being further offshore. This northward-flowing coastal countercurrent may have an impact on the transportation of marine organisms near shore. Ultimately, the fisheries' livelihood in the communities along this coast would be affected.

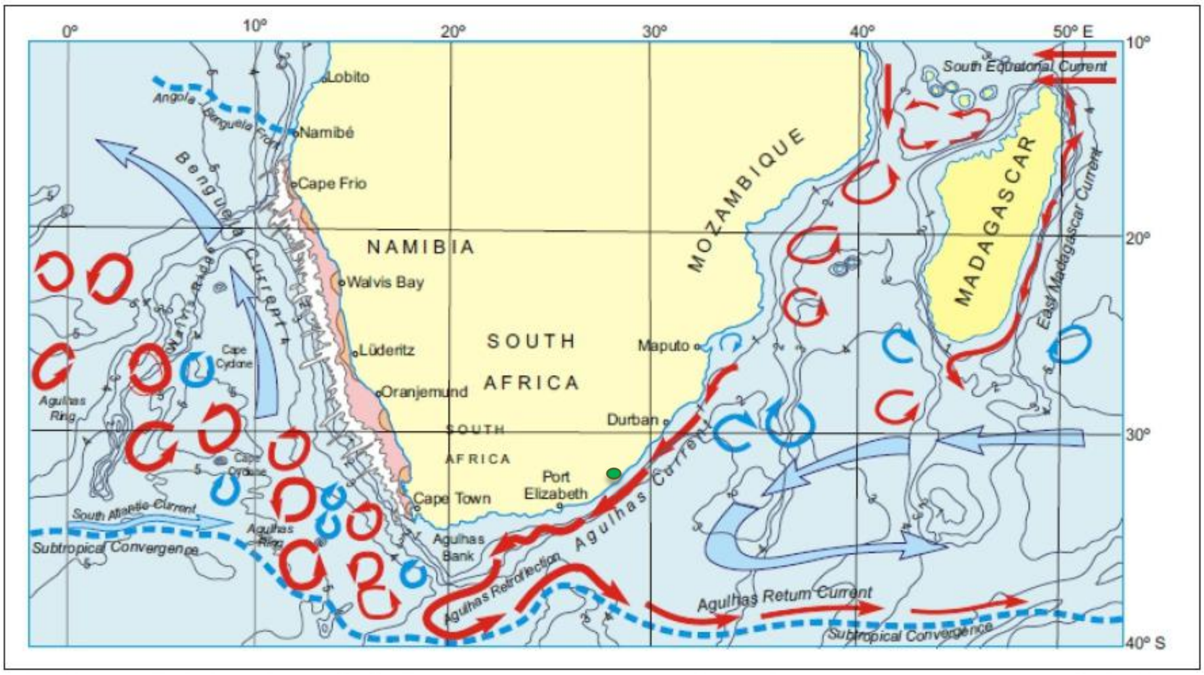

Figure 5.1: Image showing the greater Agulhas Current and the propagation of water from the Mozambique Channel. The red (blue) straight and circular (eddies) arrows represent the warm (cold) water coming from the equatorial (polar) region. The location of Tshani-Mankosi community is shown by the green dot. (adapted from Morris et al, 2017)

The wind systems along the east coast are mostly controlled by the longitudinal and latitudinal migration of the SIHP cell and the ridging of the SAHP to the south of the country. During the summer season (DJF), the pressure cells are allocated south of the southern African continent (Figure 5.2), reducing the dominance of the westerly wind belt in the region and resulting in north-easterly winds. In winter, the continental high-pressure cell is formed and is migrated northward with SAHP and the SIHP. This results in a latitudinal stretch of the westerly wind belt (temperate zone) and the cold fronts to the southern tip of the Southern Africa continent affecting the wind patterns here (Figure 5.2). Moreover, A researcher suggested that interannual climate systems such as ENSO could affect the atmospheric pressure systems dominating this region and may confound a significant modification of wind systems in the region (SR1, personal communication, 2017). Given that winds play a significant role in driving oceanographic phenomena such as upwelling, where cold and nutrient-rich water is brought to the surface, changes in the usual pattern of winds along the coast may trigger changes in the availability or abundance of certain fisheries resources.

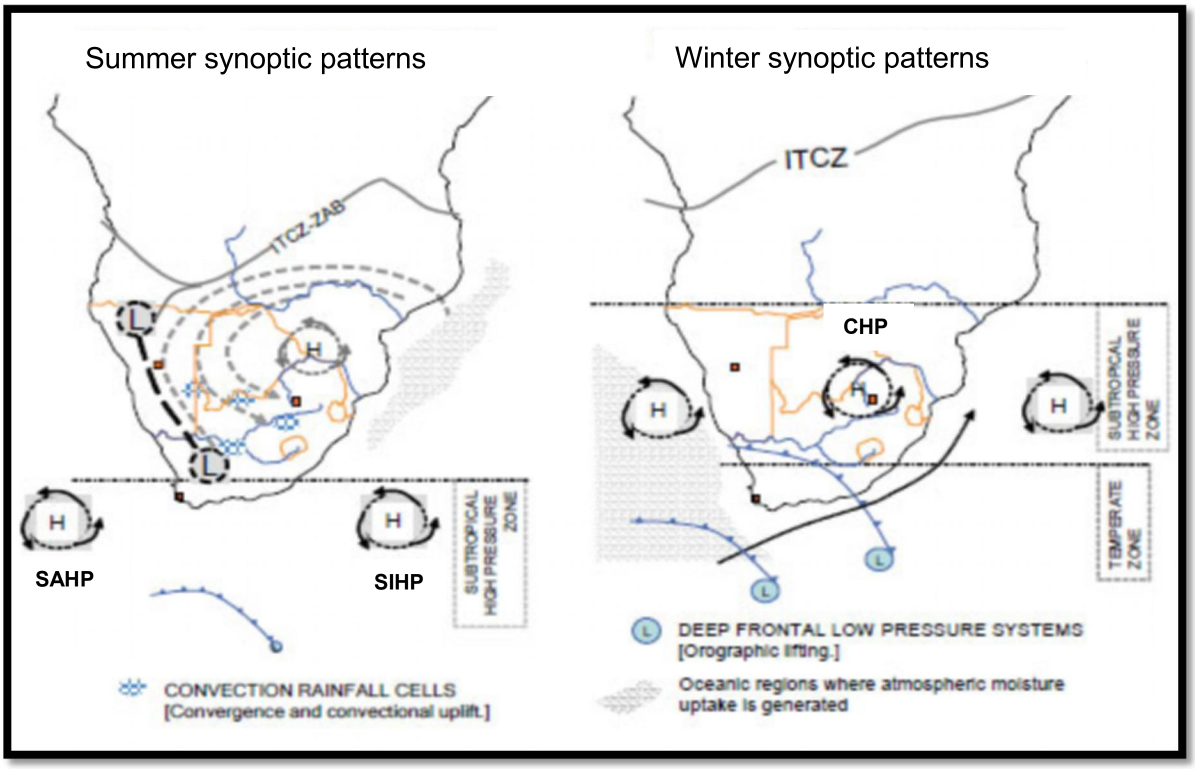

Figure 5.2: Chart showing southern Africa synoptic patterns during the summer and winter seasons. [adopted from van Wyk, van Tonder, Vermeulen (2011)]

A summary of the changes in the climate and coastal marine environment along the east coast of South Africa, in accordance with the more systematic scientific efforts, outlined as follows:

I. Sea Surface Temperature (SST)

Despite the deficiency of *in situ* long-term monitoring of SST along the east coast of South Africa, there is a growing amount of evidence around changes and trends in SST of the Agulhas Current using satellite data. In a conversation with researchers, they admitted that there is a lack of observational data along the east coast to verify the satellite data and ocean models, however, satellite data has still been useful to pick up potential trends in SST (SR1, SR3, personal communication, 2017). Using satellite data, Rouault, Penven, and Pohl (2009) showed that the warming trends of the Agulhas Current, including the continental shelf, from the 1980s to the early 2000s were up to 0.5 ºC. Such SST anomalies can occur as a consequence of inter-annual climate variability such as ENSO, where the abnormal periodic changes in temperature and wind patterns over the tropical Pacific Ocean influences the climate in the tropics and subtropical region (Figure 5.3). In a more recent study, it was indicated that the Agulhas Current has been warming up at 0.03 ºC per decade since 1980 (Jury, 2018).

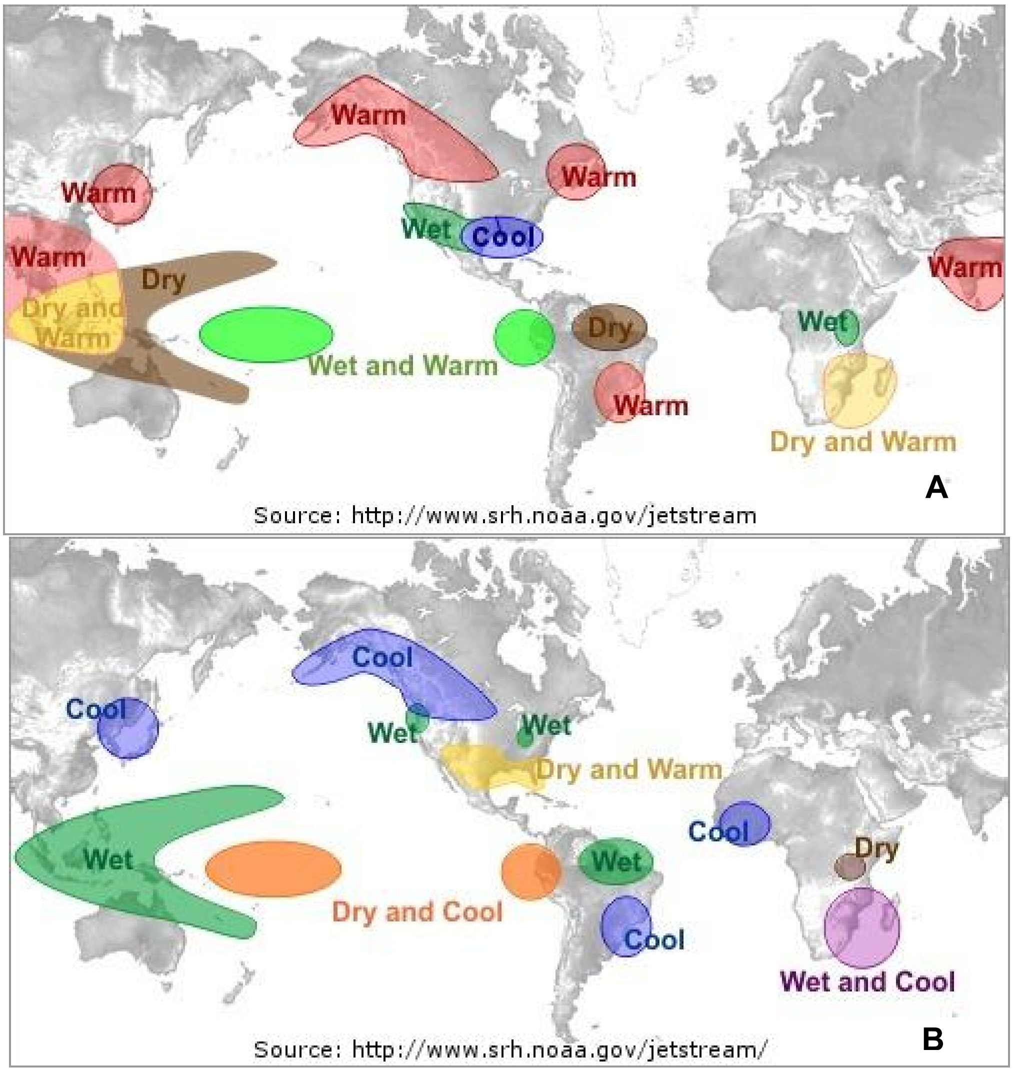

Figure 5.3: Images showing the global effect of El Niño (A) phase and La Niña (B) phase during the summer (December to February) period. Taken from *North California Climate office*[15]

However, during an interview a scientific researcher shared that even though the Agulhas Current plays a significant role in coastal processes, it is important that coastal ocean dynamics are studied at a higher spatial resolutions to account for important environmental factors that may influence ocean process at a local scale, such as the influence of land (SR1, personal communication, 2017). The researcher also stated that notwithstanding the

[15] https://climate.ncsu.edu/climate/patterns/enso

importance of long time series of SST to provide a long-term perspective of change, the variability within the long-time series becomes significantly crucial when considering livelihoods and human life span. Malan *et al* (2019) noted that coastal ocean temperatures (entire water column) along the Agulhas Bank have shifted from a warm to a cold regime in the mid-1990s (Figure 5.4) and this was in agreement with the works of Roy *et al* (2007) who use SST (ocean surface) data from satellite. This suggests that changes in temperature at the surface of the ocean water could represent changes through the water column (less than 200m).

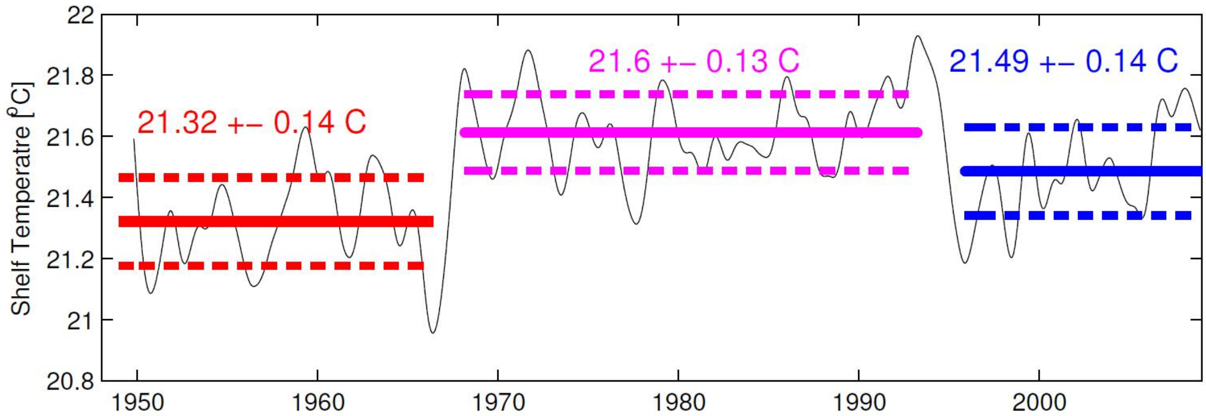

Figure 5.4: Depth-averaged temperature for Agulhas Bank waters shallower than 200m between 20^0E and 27^0E. The filtered 5-daily output is shown by the thin black line, with the three periods representing cold and warm regimes shown in colour. [(After Malan *et al*.,2019)]

In a conversation with a researcher, it was stated that marine ecosystems respond to physical environmental change. For example, in their work, Roy *et al* (2007) and Malan *et al* (2019) suggested that the mid-1990s eastward distributional shift of Cape anchovy *Engraulis encrasicolus* in the Agulhas Bank was associated with the environmental change. In a conversation with scientific researchers, fish were described as thermoconformers, meaning that their bodies cannot regulate temperature, but alter as a function of the external temperature and thus they are very sensitive to temperature (SR4, personal communication, 2017). It was further explained that fish respiration is also affected by the temperature change of the water. In their work, Potts, Götz, and James (2015) highlighted that warmer waters may result in oxygen limitations in the water, affecting the respiration of fish and the species distribution. It has been predicted that migratory fish species along the east coast of South Africa would respond to warming SST by migrating poleward (being replaced by the tropical migratory fish species) once the thermal tolerance limit of these species is reached (Potts, Götz and James 2015). Some of the migratory fish species found along the east coast of

South Africa include steenbras, dusky kob, elf, and adult white musselcracker. It is predicted that the resident fish species (such as yellowfin bream, yellowtail kingfish, black seacat and juvenile white musselcracker) here would be able tolerate and thrive in warmer SSTs compared to the migratory species, however warmer environmental conditions that exceed the critical thermal limit of these species may have a negative impact.

During an interview, a researcher explained that there is evidence of marine ecological change along the east coast of South Africa which can be linked to physical environmental change (SR2, personal communication, 2017). They further explained that a distributional shift in tropical fish species has been documented in temperate estuaries such as Breede, East (south of Mdumbi) Kleinemonde and Mngazana (~ 25km north of Mdumbi). For example, there has been fish range expansion of species such as spotted grunter (*Pomadasys commersonnii)* along the east coast (Whitfield *et al.*, 2016). This subtropical species has become a resident species in the transition zone (Breede) between warm temperate and cool temperate for the past two decades, where it was initially a seasonal visitor (Whitfield *et al.*, 2016). Moreover, the scientist emphasized that marine ecological changes such as distributional shifts should not be limited to a single driver of change but to a broad range of climate change effects (SR2, personal communication, 2017)

II. Wind patterns

In a conversation with a researcher, it was stated that the Agulhas Current has a significant influence on the overlying atmosphere and the general ocean surface winds (SR1, personal communication, 2017). To justify this statement, the researcher explained that the large-scale circulations such as high pressures and frontal systems play a significant role in determining the winds found here. As a reminder, the southern Africa high-pressure cells are subjected to and north -south migration (Figure 5.2) causing a migration of the zero line between easterly and westerly mean winds over the South African continent as well as the influence of frontal systems over this region. Furthermore, this fast-moving and warm current are believed to produce evaporation up to five times more than the surroundings (Rouault, Penven and Pohl, 2009). As a result, winds blowing over this current are relatively stronger than the surrounding (Krug *et al.*, 2018).

During an interview, a researcher stated that there are general dominating winds over the east coast region at different seasons of the year, playing a significant role in modulating processes such as coastal upwelling (SR1, personal communication, 2017). In this interview session, the average ocean surface winds over the Agulhas Current were described as generally blowing towards the southwest (down current) in winter (JJA) and northeast (up to current) in summer (DJF). In related literature, stronger winds (exceeding 15 m/s) are commonly experienced during winter, whilst in summer, the wind speed here is within the range of 5-15 m/s (Krug et al., 2018). The researcher described the northeasterly winds (blowing to the southwest) as coastal upwelling favorable winds along the east coast, due to Ekman transport, bringing up cool and nutrient-rich water to the surface and creating a more biologically productive region (SR3, personal communication, 2017). However, general wind conditions are subjected to change as a result of changes in the ocean-atmosphere relationship under climate change and variability as well as large-scale regional changes linked to the subtropical high pressures.

The growing evidence of change in the wind field over the Agulhas Current at various scales was highlighted during an interview with a scientific researcher, some of these changes in wind direction and speed attributable to the warming of the Agulhas Current. A poleward shift in the westerly wind belt in the South Indian Ocean was also noticed in an earlier study (Rouault, Penven and Pohl, 2009). Furthermore, Swart (2012) noted through climate models that over the period of 1979-2010 the annual wind stress of the westerly winds in the Southern Hemisphere has been strengthening in all seasons but more predominantly in summer (DJF). The author associated these changes with shifts in frontal systems in the Southern Ocean and the warming of the Agulhas Current. The IPCC (2014) has projected that this may continue into the future.

Along the east coast of South Africa, in Port Elizabeth (33.9608° S, 25.6022° E), a trend in wind direction between the early 1950s and the early 1980s showed an increase in the eastward component (Schumann, 1992). Wind speed trends were observed by Roy (2007) over the Agulhas Bank as decreasing between the period of 1983-1992 and 1994-2005 due to a reduction in atmospheric pressure. In a more recent study, Malan et al (2019) showed 3 regimes of increased and decrease zonal wind speed and direction as well as Ekman transport between 1950 and 2007 over the Agulhas Bank (Figure 5.5). An intensification of winds was observed in the inshore front of the Agulhas Current in close proximity to the SST maxima (Krug *et al.*, 2018). However, Krug (2018) highlighted the limitations of satellites in making adequate observations at certain spatial resolutions. Finally, a scientist shared that winds over the Agulhas Current have been mostly considered using satellite and model data due to challenges arising from making observations in this fast current. In addition, investigating coastal wind using satellite and model data is challenged due to the consideration of boundary layer conditions. Ultimately these research interviews highlighted that although scientists are aware of significant changes in large scale wind processes, they are still at the beginning of research downscaling this information to the coastal regions.

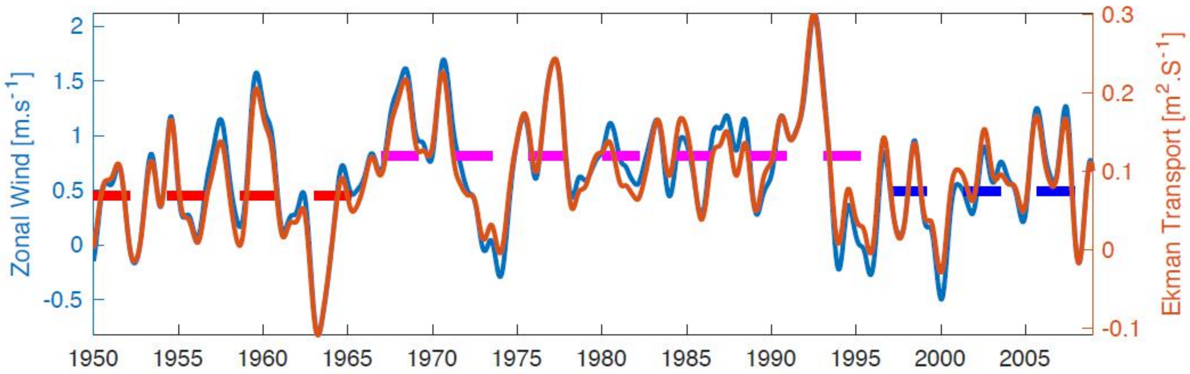

Figure 5.5: Zonal CORE winds (+ve is eastward and therefore downwelling) and Ekman transport (+ve is northwards) for coastal Agulhas Bank the coloured dashed lines indicate the 3 different regimes. After Malan *et al* (2019)

III. Rainfall

One scientific researcher stated that there is a high degree of variability, both spatially and temporally, in South African rainfall amounts from historic observational data, computer models, and satellite data (SR1, personal communication, 2017). However, the annual and seasonal trends in rainfall amounts, specifically those linked to the number of wet days, seem inconsistent across the country. In literature it has been documented that the total number of wet days per year (days where precipitation amount is exceeding 1 mm) seem to have increased over the southern interior part of South Africa while the extreme north and northeast parts seem to experience a negative trend in the number of wet days (Mackellar, New, and Jack, 2014; Kruger and Nxumalo, 2017). In an analysis of seasonal rainfall total, insignificant downward trends during autumn were noticed throughout the country (Groisman *et al.*, 2005). Figure 5.6 shows evidence of a decrease in seasonal rainfall totals of wet days during spring in the eastern region of South Africa (Kruger and Nxumalo, 2017). In addition to the annual and seasonal characteristics of South African rainfall over the 20th century, trends in rainfall-related extreme events exist.

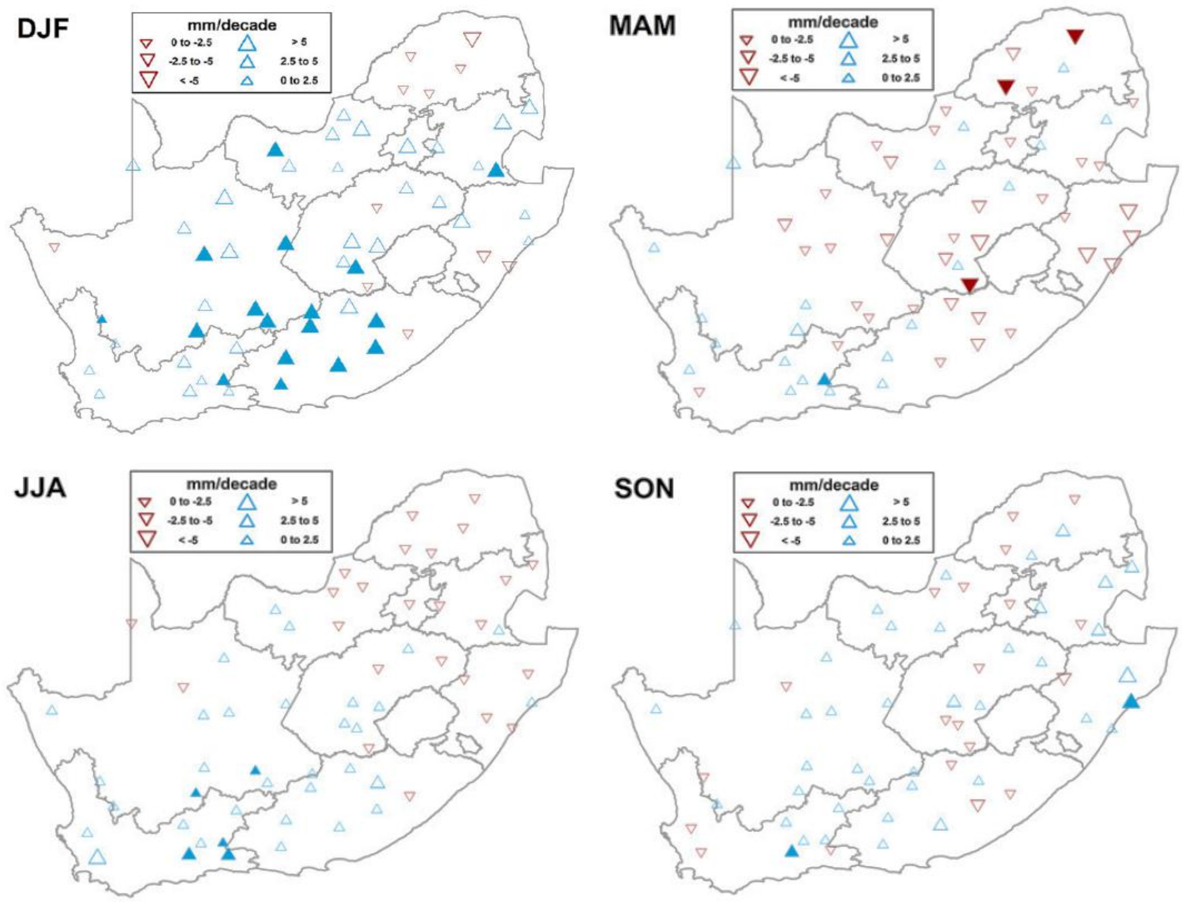

Figure 5.6: Trends in seasonal rainfall totals (1921–2015) (DJF: December to February – summer, MAM: March to May – autumn, JJA: Jun to August – winter, SON: September to October – spring). Shaded symbols indicate significant trends at the 5% level. High and extreme daily rainfall events. After Kruger and Nxumalo (2017).

The researchers emphasized that it is not only in recent times where South African rainfall shows a high degree of variability (SR1, personal communication, 2017). The literature clearly shows the country experiencing decadal variability in rainfall. For example, from 1906-1997, heavy rainfalls seem to have been more frequent (Easterling *et al.*, 2000; Groisman *et al.*, 2005) and more intense between the 1930s and 1990s (Mason *et al.*, 1999; Kruger, 2006) on the eastern side of South Africa. Due to spatial incoherence in trends over the southeastern sides' rainfall data, the latter studies could not be confirmed in the recent study (Mackellar, New, and Jack, 2014). This is in agreement with observations made by Kruger and Nxulamo (2017) who noted a possible inhomogeneity in the local rainfall time-series. The number of stations with similar trends in the same region might be less. However, a significant increase in high daily totals of rainfall from the isolated station in the northeastern region is evident between 1921 and 2015 (Kruger and Nxumalo, 2017). Finally, the occurrence of extreme events can be further explored by investigating traits including duration (the number of continuous days of heavy rainfall in a year/season/event) and the daily intensities during the event to determine risks of disasters such as flash floods.

A scientist shared that high probabilities of flash floods are calculated from counts of high rainfall days over time (SR1, personal communication, 2017). In the work of Kruger and Nxumalo (2017), a high, daily rainfall analysis is defined as the annual mean of the number of days where the precipitation received is equal or more than 20mm. The authors calculated the probability of flash floods in the Eastern Cape and found them to be 0.2 days /decade. Furthermore, there is a positive trend in the number of continuous wet days per year over the eastern region of South Africa (Kruger and Nxumalo, 2017). Finally, many authors (Kruger, 1999; Mason, 2001; Reason and Rouault, 2002; Dieppois *et al.*, 2016) have emphasized the influence of ENSO events on South African rainfall. More recently the consequence of the expansion of the SAHP cell into the mid-latitudes, namely moist southeasterly along the south to the east coast of South Africa, may have a significant implication on climate trends here (Blamey et al., 2019).

In a conversation with a scientist, it was said that rainfall fluctuations along the east coast trigger a response in the local marine and coastal ecosystems (SR3, personal communication, 2017). Freshwater input transports nutrients and sediments into the coastal zone, affecting marine living resources both directly and indirectly in coastal zones (Potts, Götz and James, 2015). The nutrients get absorbed by the phytoplankton, which gets consumed by zooplankton and together becomes food for fish. The availability of more nutrients may increase biomass (Bakun *et al.*, 2010), however, suspended sediments may reduce visibility conditions providing protection of fish from prey but also increasing their catchability (Lamberth, Drapeau, and Branch, 2009). Finally, an inflow of freshwater may provide cues of migration to estuarine-dependent fish and ultimately affect the abundance of fish in the coastal areas (Potts, Götz and James, 2015). Thus, the importance of local rainfall trends is evident even though such analysis can be limited by the availability of observation stations.

5.2. Fishers LEK about climate and environmental change

5.2.1. History of the Tshani-Mankosi community and the development of LEK in a fisheries context

In Tshani-Mankosi, the LEK of the fishers appears to have evolved with the need and use of MLR over time. During the early years (~ the 1800s) of this community, marine resources were solely valued for dietary and medicinal benefits (TMTA, personal communication, 2017). The community members ate MLR for animal protein and used them as medicine (see example Box 5.1). As a result, LEK about the marine environment quickly grew around the medicinal and nutritional benefits of seafood. Also, the generational experience of working at the sea saw advancement in the knowledge and understanding of the marine environment in this community (SVMLRU, personal communication, 2017). The more experienced MLRU can link environmental conditions to the availability of resources (elaborated in Section 5.2.2.). More recently, tourism has an influence on how the locals perceive the MLR and the environment in general.

Example Box 5.1. Belief on properties of Oyster in Tshani-Mankosi community

From the early years of Tshani Mankosi, it has been generally understood that oysters are useful for the reproductive health of men (SVMLRU, personal communication, A2017). As such, a local name given to oysters in the community is "*imbatyisa*" which means "sexual stimulator" (respectfully known as *Zwembe*) as it is believed that this resource improves the sexual drive of men. This belief was self-taught and became accepted in the community when the parents of the young men who harvested and consumed this resource noticed that their children seemed more sexually inclined compared to their peers who did not consume this resource. The elders at the time took it upon themselves to test this by controlling who consumed this resource and watched their behavior (SVMLRU, personal communication, 2017). Ultimately, the elders were convinced of the medical and benefit of oyster. This self-taught belief seems to be conserved within a certain age group as the fishers were cautious of sharing this information with children around and the term "mbatyisa" seems to be used only among the elders (RWMLRU, personal communication, 2017). According to the locals, the oyster case is one the many examples showing how sea resources, such as seaweed, plough snails and estuary clay, have held medical value in the community. As of now, oysters are generally considered as aphrodisiacs even in medical science (Ridzwan et al., 2013).

Picture of local oysters sold to Mdumbi backpackers guest taken from https://www.solsalute.com/blog/off-beaten-track-wild-coast

As highlighted, the community has holiday accommodations such as Tshani cottages, Mdumbi and Vukani Backpackers and tourists from different parts of the world visit this community. In interactions with the locals, it was shared that the tourists who are interested in fisheries and care for people would spend some of their time to learn and teach the locals a few things around fisheries as part of their holiday activities (TMCT, SVMLRU, personal communication, 2017). In those teaching-learning social meetings that the local fishers and tourists would have, the locals learnt about the nutritional benefit of the East Coast Rock Lobster (ECRL)- a traditionally forbidden[16] resource for food consumption. Some of the locals ate this resource from long ago because they were never convinced of the reasons why this resource was forbidden, however, there are more now eating it due to the information they have learned from the tourists (DVMLRU, personal communication, 2018). After learning and being convinced about the nutritional benefits of ECRL, the demand for food and knowledge of this previously despised resource increased (DVMLRU, personal communication, 2018). More recently, some of those who consume this resource noticed that it settles diarrhea, especially when consumed at its late-life stages (DVMLRU, personal communication, 2018). Therefore, the influence of tourism in the consumption of ECRL is not only limited to nutritional value but also provided an opportunity for the locals to learn about the possible medicinal value of this resource. Those who were not interested in ECRL prior to the arrival of tourist admitted that they had little knowledge about the underwater environment before they started diving for this resource (RWMLRU, personal communication, 2017). The growing interest in ECRL gave the more locals an opportunity to learn about the underwater and rocky environment. Hence, the enrichment of LEK in Tshani-Mankosi.

Another influence of tourism in the fisheries livelihood in Tshani-Mankosi is related to the socio-economic state of this community. MLR gained its economic value with increasing tourism in the mid-1970s (Hitchcock, 2013). The relatively older fisher (~50 years of age) explained that tourists would ask to purchase their catches and the community saw this as an opportunity to make an earning (SVMLRU, personal communication, 2017). He further explained that it was important in their generation to go with their fathers to sea, missing out on school, to learn ways of catching different resources to be compatible with his peers and

[16] The ECRL was historically perceived as *iphela lolwandle* (translating to sea cockroach) and not ordained by God to be eaten by human (SVMLRU, personal communication, 2017). This perception is so strong that it has not completely faded, even after experiencing the growing popular trend within tourism for consuming ECRL. Some community members still refuse to eat ECRL due to their belief about not being a suited for consumption (DVMLRU, personal communication, 2018).

be able to provide some income for their families. At present, boys from the age of 6 consider themselves skilled, and well trained by their family members (who are involved in fisheries) to make catches (DVMLRU, personal communication, 2018). During our conversation by the rocks, the young fishers shared that they can spend their afternoons at the shoreline fishing in the absence of a mentor (Figure 5.7). This shows that the demand for fresh and locally caught seafood by the tourists who visited this community played a significant role in making sure the elderly trained and shared their knowledge with the succeeding generation for them to make occasional sales to the tourist and have some income.

Figure 5.7: Image of two boys fishing for on the rocky shores of the Tshani-Mankosi community during occasional participant observation. (Photo was taken by Tania Moyikwa May 06, 2018).

The long-term dependence on MLR as a source of food and medicine has developed an important connection between the people and the biophysical environment. This connection is shown by the appreciation the locals show for the variety (Table 5.1) of MLR they get at sea as a cornerstone for food security -which needs to be sustained for future generations (RWFMLRU, personal communication, 2017). The community members exhibited an understanding of overfishing and the need not to fish out species early in their lifecycle. In conversation with the local MLRU, they shared how they had taken the responsibility of monitoring the fishing activities of tourists in a subtle and friendly way (the teaching-learning engagements mentioned earlier) in fear that the tourists may not know what is sustainable to catch (RWMMLRU, personal communication, 2017). Moreover, the community members of Tshani-Mankosi refer to MLR in their indigenous language- IsiXhosa (Table 5.1). Indigenous names of fish species exist in other countries with resource-dependent communities, for example, in Namibia over 150 species have local indigenous names from various tribes (Okeyo *et al.,* 2004). Indigenous names of seafood species are typically known to describe the species in more detail, whether it is by naming the species based on its geographical origin, physiology, or socio-economic value (Barendse & Francis, 2015). For MLRU to be able to have a local naming system of the fish species, it is expected that they would have had a prolonged relationship with the marine ecosystems and the services provided to gather the knowledge about the different fish species and give the fish species suited names. Therefore, the indigenous names of fish species in Tshani-Mankosi may be the underlining factor of the prolonged relationship between local and the marine and coastal environment.

Table 5.1: Commonly caught species with socio-economic value by Tshani-Mankosi fishers. The common English names are given with the traditional isiXhosa names in parenthesis and scientific names in italics.

Estuaries	**Rocky Shore**	**Sandy beaches**
Spotted grunter (Nkonkolo) *Pomadasys commersonnil*	Blacktail (Ntimna) *Diplodus capensis*	White Steenbras *Lithognathus lithognathus*
Dusky kob (impolo) *Argyrosomus Hololepidotus*	Bronze bream (Nyazala) *Coracinus Capensis*	Three spot swimming crab (iThefu) *Ovalipes trimaculatus*
Cape stumpnose (iBande) *Chrysoblephus Gibbiceps*	Galjoen (Rhaliyoni) *Dichistius capensis*	Slender baardman (umthebe) *Umbrina robinsoni*
Flathead mullett (iThulo) *Mugil cephalus*	Black musselcracker (Saqhomolo esimnyama) *Cymatoceps nasutus*	Lesser guitarfish (iSibhaqabhaqa) *Rhinobatos annulatus*
White sea-barbel (uMkunga) *Galeichthys feliceps*	White musselcracker (Saqhomolo esimhlophe) *Sparodon durbanensis*	Sand mussel *Donax serra*

Leervis (iQeleka) *Lichia amia*	Brown mussel (Mbaza) *Perna perna*	Elf (Khwenyane) *Pomatomus saltatrix*
Common cuttlefish (iSikwidi) *Sepia vermiculata*	Cape rock oyster (Zwembe/mbatyisa) *Striostrea margaritacea*	
prawn (ubusunstu) *Callianassa kraussii*	Common octopus (Ngwani) *Octopus vulgaris*	
Giant mud crab (Nonkala) *Scylla serrata*	East coast rock lobster (Kolofishi) *Panulirus Homarus*	

In conclusion, from the brief fisheries history of Tshani-Mankosi, the development of LEK in this community involves the various social aspects of life, such as beliefs, culture, and diet, which are specific to a certain group. Also, understating the long-term relationship between the people and the bio-physical environment provides a good lens to view the construct of LEK in this fishing village. Most importantly, the locals can share about climatic or environmental events that affected their livelihood in the past and what they learnt from that experience; events that are affecting their livelihood currently; and some events that are perceived to have a potential effect on their livelihood in the future. These events may or may not be related and the time gaps between these events may not be consistent but what seems essential is that the local MLR users will most likely share about the important events to their livelihoods (FAO, 2015). The following section provides the LEK of the MLRU about climate and environmental change from a series of events experienced in this community. Finally, these experiences of fishers are presented according to topics and not in the sequence of the occurrence of the events. However, a chronological timeline of the events is provided to define a timeframe of the climatic and environmental change the local MLRU refers to.

5.2.2. The accumulated knowledge around climate and environmental change: Experiences, Observation, and Perception

The knowledge and understanding of MLRU about the coastal environment and marine ecosystem in Tshani-Mankosi are based on long term experience, observation, and perceptions. Hence this knowledge is intensely contextualized and localized to processes occurring at the community level. The reduced Rapid Vulnerability Assessment (rRVA) exercise 4 (refer to Methodology Chapter 4) allowed identification of the community-specific environmental and anthropogenic changes that pose a threat to the fishing livelihood of this community. Key drivers (anthropogenic and natural) of change and responses were suggested by the fishers as they may have observed and perceived. These are presented in Figure 5.8 with their ranks of significance provided. As a reminder, the stressors were ranked by the locals on the basis of the negative effect they have on the fishing livelihood.

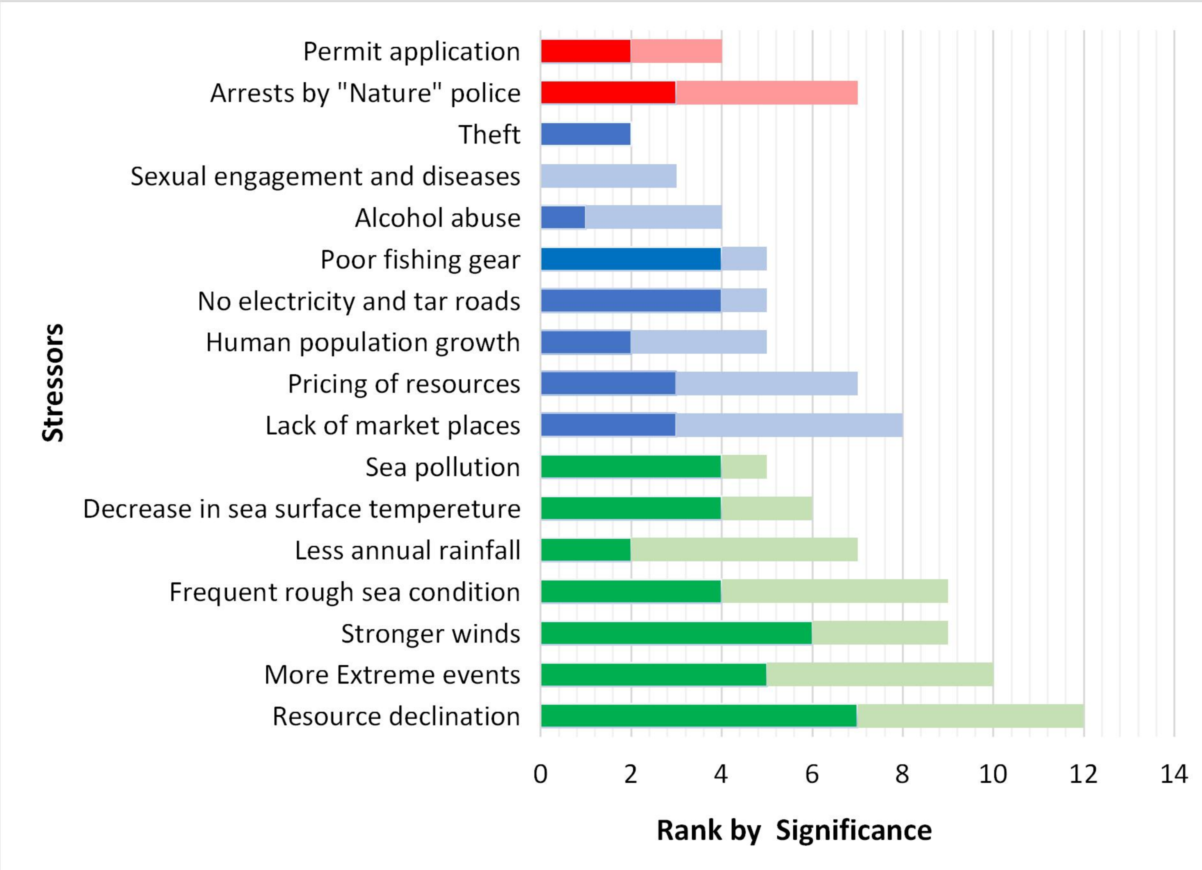

Figure 5.8: The cumulative stacked bar graph of the relative significance of different stressors voted for by the women (lighter color) and men (darker color) sea-harvesters of Tshani-Mankosi. Where green represents Environmental stressors; Blue - Socio-economic stressors; Red - Governance and institutional stressors to fishing livelihood in Tshani-Mankosi Community.

The environmental threats were ranked the highest as they are considered to have a direct, immediate, and major impacts on the coastal environment components and processes, which in turn affects the fishing livelihood of the Tshani-Mankosi community. Factors such as winds, ocean temperature, and rainfall patterns were prioritized as the key factors that impact the lives of the MLRU in this community. Moreover, the fishers repeatedly shared their concern with the unpredictability of accessible days to sea due to the irregular number of rough and calm days. Even though the socio-economic factors also received a relatively high percentage of ranks, the fishers stated that the environmental factors were of greater importance since they have less control over how the winds, ocean temperature and rainfall changes. Further exploration of environmental stressors and the associated impact revealed some evidence of change in ocean temperature, winds, and rainfall patterns based on the experiences, perceptions, and observations of MLRU at the community level. Exploring the changes in the factors affecting live in this marine dependent community is key in providing empirical evidence climate and environmental change at a local scale.

I. Ocean temperature

The sea harvesters of Tshani-Mankosi believe that the local ocean temperature must have dropped gradually over roughly the past 10 years (2007-2017) (RWMMLRU, personal communication, 2017). Even though possible reasons for this decrease in temperature were suggested, such as the sun moving closer to earth and winds not blowing regularly enough to mix the deep and surface water, the MLRU admitted to lacking a full understanding of the processes behind the observed change in ocean temperature (RWMMLRU, personal communication). The ECRL divers stated that around 2007 they started feeling that the water is colder than usual. Most of the older divers remembered being sick that year and being told by doctors that the cause of their sickness might be coming from spending time underwater without appropriate gear such as a wetsuit. They further explain their conviction of this change in ocean temperature by sharing that even in the morning when the water used to be relatively warmer, the water is now the same throughout the day. As a result, the young divers do not have a preferred time of the day for diving (DVMLRU, personal communication, 2018).

During the rRVA workshop, the mussel collecting women also shared their experiences, which led to a conclusion about the dropping of the local ocean temperature. The women shared that it is traditional practices among them that when there were no successful sales of the mussel for the day, they would keep their resources fresh by digging a hole in the splash zone of the tidal area since there is no electricity or refrigerators (RWFMLRU, personal communication, 2017). The collectors shared that in the past they would need to dig a deep grave in the sand to keep the mussels fresh otherwise they would not be in a good selling condition by the time they find a buyer. As from 2014, the mussel grave did not have to be as deep to keep the resources fresh and they suspect that this is because the water is getting cold enough that a deep grave is not necessary (RWFMLRU, personal communication, 2017). The women explained that most of the tourists they sell to cannot tell the difference between freshly picked mussels and the ones left overnight, but the local white community residents they sell to can tell the difference and that is why it is important for them to take the resource back to sea when it had not been sold and dig a pit for it. The woman expressed that a reduction in ocean temperature means less labor for them when it comes to digging the mussel graves (RWFMLRU, personal communication, 2017).

Apart from changes in sea harvesting patterns of the resource users due to environmental changes, the community members have observed changes in the harvested resources too. The traditional line fishers in the community expressed some concerns about the most loved fish species - Elf/Shad. According to the fishers, this resource is available to them during winter months (JJA) and they believe this is due to its warm water-loving nature (RWMMLRU, personal communication, 2017). It is common knowledge in the village that during winter season the seawater is relatively warmer making it more pleasurable to swim. The locals noted that more recently they hardly catch elf in their usual fishing spots (rocky shore as seen in Figure 5.7) and when they tried moving closer to estuaries, they would catch it (RWFMLRU, personal communication, 2017). The fishers indicated that this is rather happening in random winters of different years, such as 2015 and 2012. In a conversation with a local fisher expert, he admitted that they cannot explain or think of a reason why this would be (DVMLRU, personal communication, 2017). The fisher further stated that it is not only the irregular habitat of elf that is a concern, but the abundance of this resource is not predictable. In some years they find a lot of this resource and not so much in the other years. The locals struggled to remember which years the elf was abundant or not, but they could tell that currently (2017/18) the elf was less abundant compared to 2016 (RWMMLRU, personal communication, 2017).

II. Rainfall

Changes in rainfall patterns in Tshani-Mankosi community have been noticed by the locals. The impacts of these observed changes affect the fishing livelihood and the fishers shared their experiences. The fishers recalled three extreme rainfall-related events in the recent past (Figure 5.4). In 2003 the community was stricken by drought that resulted in a cholera outbreak. During this event, a few people lost their lives and doctors were sent into the village. The impacts of the drought were severe and threatening to MLRU and those who had subsistence farms at their home (SVMLRU, personal communication, 2017). The women explained that the ground spring waters started to dry up while they were preparing themselves to vote again in 2004 (RWFMLRU, personal communication, 2017). Here the date could be easily remembered because the women remembered that it was around about the time of voting in the national elections. The men agreed to this as they remembered assisting women to collect water from a near village with horse carts (DVMLRU, personal communication, 2018). During the workshop, the women expressed that the impacts of that drought were not only severe but persistent since the springs are still dry (RWFMLRU, personal communication, 2017). The community was assisted by the owners of the Mdumbi backpackers with a borehole water system (TMCT, personal communication, 2017). After learning about boreholes, the locals seem to believe that there is always water available, but it has not rained enough for the springs to start supplying water again (DVMLRU, personal communication, 2018).

In the summer of 2010, the village experienced what seems like flash floods. The local people narrated that it rained all day and every day for seven consecutive days (RWMMLRU, personal communication, 2017). Consequently, the Mthatha and Mdumbi River were flooded. The villagers described the living conditions during and after the storm as devastating (RWMMLRU, personal communication, 2017). The gravel roads were transformed into small river channels and the bridge got damaged (Figure 5.9 (B)) making it difficult for people to enter or exit the village. Moreover, livestock that was apparently trapped by the river were killed and seen floating downstream to the sea. The locals commented that the river was so full that it broke out of its meandering channel, destroying the communal farming fields that were located adjacent to the river (DVMLRU, personal communication, 2018).

Figure 5.9: Image of the normal (A) Tshani-Mankosi motor bridge and after 2010 (B) and 2017 (C) flood event. (Supplied by Sibongile Masiso)

In the event of flooding, the fishers described that the sea was polluted with all the debris from surface runoff, affecting the life at sea (RWMMLRU, personal communication, 2017). Fish were scarce for about two months after the 2010 flooding. Stranded fish such as Dusky Kob and spotted grunter were seen, and this was perceived as God's way of making a supplementary fish provision given the lack of fish during that time. During the workshop, a fisher laughingly admitted to consuming the stranded fish "*Sizityile ke nezontlanzi bezikhutshwe lulwandle futhi kange sive mntu ogulileyo ngenxa yokuzitya*" translating to "We ate the stranded fish and no fatality or sickness was reported for consuming the dead fish" (RWMMLTU, personal communication, 2017). According to the locals, the river remained turbid and took about two weeks to clean itself up after the pollution from the floods (DVMLRU, personal communication, 2018).

In 2011, the ECRL divers noted that this resource was rather submerged to rocks that they had never explored before and not found at the usual depth (RWMMLRU, personal communication, 2017). The divers commented that they have had to spend more time underwater and go a little bit further offshore to attain this resource. The divers clarified that before they started harvesting this resource, their fathers (3rd generation) had shared with them that there used to be an abundant amount of the ECRL to a point that the resource would be seen crawling on the rocky shore in numbers, especially during the winter (JJA) season (RWMMLRU, personal communication, 2017). The divers expressed their devastation when they had observed that the ECRL had migrated to even greater depths. The understanding amongst the divers was that the ECRL would eventually sink to a depth they cannot reach to in the future (DVMLRU, personal communication, 2018). In view of this, the marine living resource users of Tshani-Mankosi believe that the heavy rains of 2010 had modified the marine life here.

The floods did not only impact the fishing livelihood by directly altering marine ecosystems components as perceived by fishers but also affected the technical aspects of harvesting the resource. The line fishers mentioned that fishing became challenging as fishing rod hooks would get trapped in all the dirt deposited at sea (RWMMLRU, personal communication, 2017). The divers added that the water visibility became poor and collecting crayfish became difficult (RWMMLRU, personal communication, 2017). Moreover, during such extreme events, the sea is not accessible due to the harsh environmental conditions. Consequently, the occurrence of such events does not only pose vulnerability to the marine and coastal ecosystems but to the socio-economy of the fishers in the community.

In October 2017, a similar but relatively weaker event was witnessed, where infrastructure was again destroyed (Figure 5.9 (C)). The impacts of this event on the natural environment were more subtle (DVMLRU, personal communication, 2018). The Fishers commented that such string floods are hardly experienced in the village and they generally do not occur so close together (RWMMLRU, personal communication, 2017). This suggests that not only the intensity of floods seems to be elevated but the frequency appears to be increasing too (DVMLRU, personal communication, 2018). Finally, it is a common understanding among marine resource users of Tshani-Mankosi that rainfall patterns vary annually. However, locals reckon that the overall total amount of rainfall appears to have decreased even with the variability witnessed in the amount of rainfall from year to year and this conclusion is based on the fact that the ground spring waters have not yet been filled and are no longer supplying water (DVMLRU, personal communication, 2018).

III. Wind patterns

Among the expert fishers of Tshani-Mankosi, wind patterns are significant indicators of good or bad catch days. For example, during the workshop, a fisher stated that around winter months the whales visit the coastline often and they are normally spotted on calm sea days RWMMLRU, personal communication, 2017). The fishers agreed that the following days tend to be windy making it difficult to access the rocky shore due to high waves. However, these windy and rough sea conditions seem to bring resources, such as elf close to shore RWMMLRU, personal communication, 2017). The mussel collectors stated that in the past two years or more, even on windy days, one could still take a chance to collect at the rocky shore (RWFMLRU, personal communication, 2017). Nowadays, one cannot take that risk because the waves rise very high because of the strong wind (RWFMLRU, personal communication, 2017). Moreover, the local harvesters agreed that there seem to be lesser and lesser good catch days nowadays compared to the past because the bad sea conditions days are more frequent (DVMLRU, personal communication, 2018).

During the interactions with the locals, a shack house destroyed by winds overnight was witnessed (Figure 5.10). For the locals, this incident highlighted that weather conditions can influence more than the ocean (DVMLRU, personal communication, 2018). Such extreme impacts on their direct lives may allow the locals to improve collective memories of climatic and environmental events affecting their lives.

Figure 5.10: Image of a shack house destroyed by strong winds overnight in Tshani-Mankosi (Photo taken by Tania Moyikwa, May 2018)

5.3. Summary

In summary, the observations made by the fishers and scientific research about changes in the coastal environment and climate were centered around sea temperature, rainfall, and wind patterns. Both parties highlighted the potential impacts of these changes on the biophysical environment and/or the social dynamics of the Tshani-Mankosi community. According to the scientists, the SST of the Agulhas Current has been warming for decades, with episodes of cooling at a more local scale over the Agulhas Bank. Also, winds have been intensifying since the early 1980s with regimes of weaker and stronger winds locally south of the east coast. The frequency and intensity of rainfall has been increasing in the east coast region with significant inhomogeneity in the weather station data here. The local fishers noticed a decrease in ocean temperature from 2007-2017. Also, they had observed that the annual rainfall has decreased, however, the intensity and frequency of extreme rainfall events have increased. The increase in wind strength was observed more recently by the local community. The impacts of these changes on the socio-ecology of this region include stranding of fish, the poleward shift of fish species such as spotted grunter, sea pollution, submergence of ECRL, flooding, rough seas, and reduced access to the sea. Timelines of the information provided by the researchers and the local community are provided below.

TEMPERATURE OBSERVATION TIMELINE

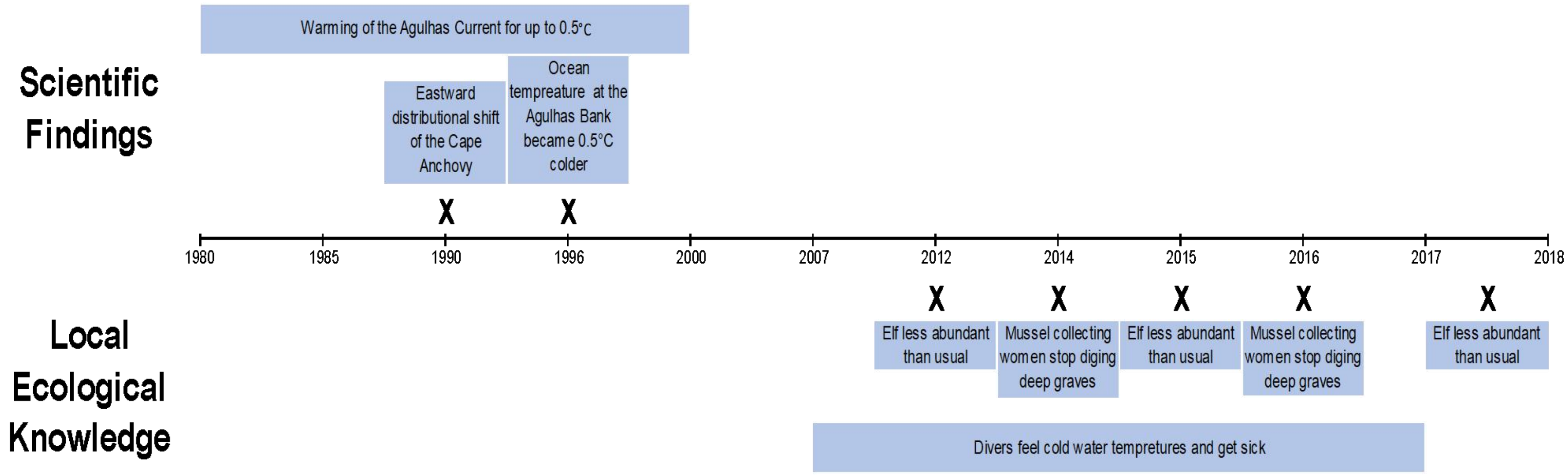

Figure 5.11: Timeline showing the timeframes of the observations related to sea temperature made by researchers and local MLRU of Tshani-Mankosi along the east coast of South Africa

RAINFALL OBSERVATION TIMELINE

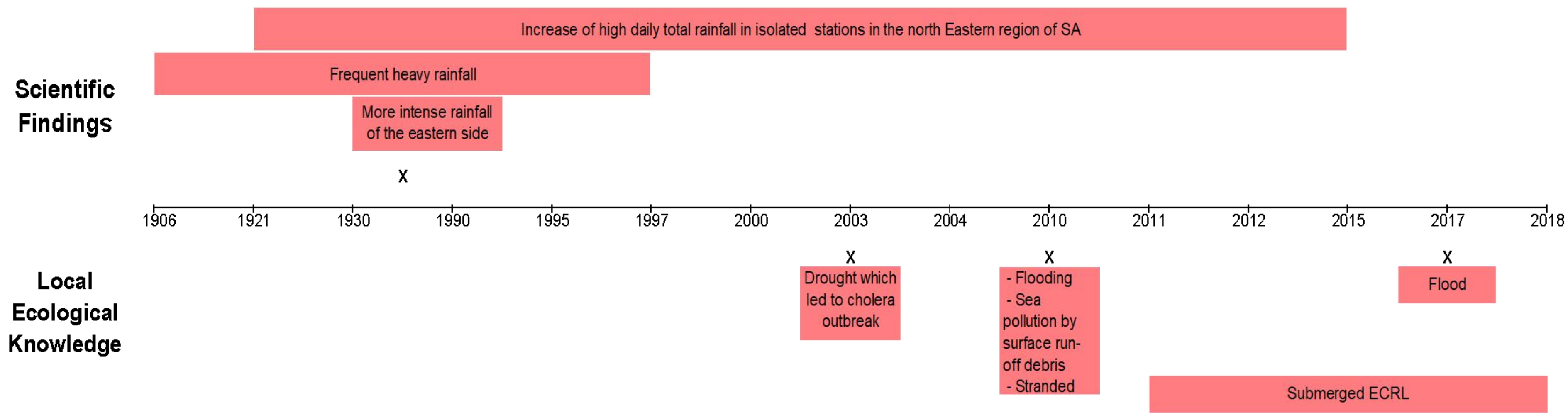

Figure 5.12: Timeline showing the timeframes of the observations related to rainfall made by researchers and local MLRU of Tshani-Mankosi along the east coast of South Africa

WIND OBSERVATION TIMELINE

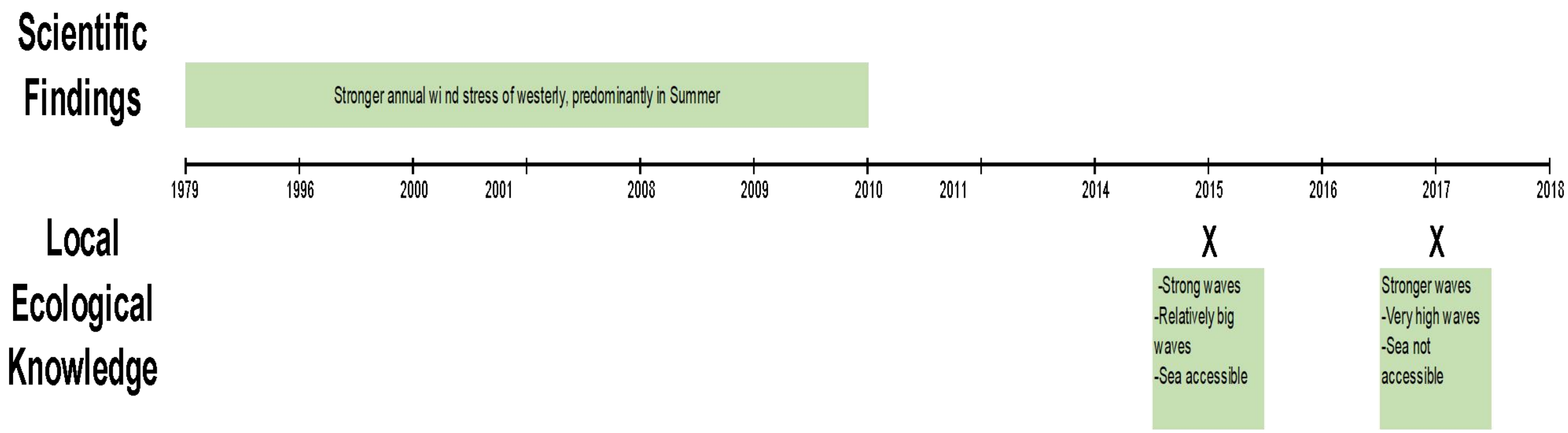

Figure 5.13: Timeline showing the timeframes of the observations related to winds made by researchers and local MLRU of Tshani-Mankosi along the east coast of South Africa

CHAPTER 6: DISCUSSION

This chapter explores the findings of this study according to the research objectives. First, the divergence and convergence of LEK and scientific efforts in the South African small-scale context are described (i.e. where the LEK and science come together and agree and where they move apart and differ). The second section of this chapter reveals the usefulness of LEK and the potential opportunities for research collaboration between scientific researchers and marine resource-dependent communities. Finally, probable challenges and limitations of research collaboration are suggested.

6.1. Convergence and divergence of LEK with scientific findings

In the South African small-scale context, there are more key factors of divergence between LEK and scientific findings than there is of convergence. Differences between LEK and scientific findings emerge from factors such as (I) how knowledge is constructed; (II) the timeframes and spatial scale over which the knowledge is accumulated or presented; and (III) the type of data outputs produced. On the other side, the main similarity factor is (IV) the parameters of interest between LEK and scientific findings.

6.1.1. Knowledge construct

Firstly, in the Tshani-Mankosi case study, it is evident that culture and spirituality play a significant role in how knowledge is acquired, used, and passed on from one generation to the other. The Xhosa culture has had a major influence on the acquisition and utility of local ecological knowledge in this community because the relationships between the natural environment and people seem to be tied down by cultural norms. For example, the people of Tshani-Mankosi showed a deeper level of connection with the environment in the way they use their language to communicate about environmental processes to one another. Within this community, thunderstorms are referred to as “Mhlekazi” which directly translates as “Sir”. The community members have shared that it is important to refer to thunderstorms in this way because it shows respect to the God-created and uncontrollable environmental conditions. (RWMLRU1, personal communication, November 2017). Also, it is commonly believed that thunderstorms are a signal of a passage of a great, mighty animal that lives in the sky. As a result, people do not only show respect to thunderstorms by calling them "Sir", they also sit on the floor, cover all shiny items and do not use water during the occurrence of a thunderstorm.

In addition, the Tshani-Mankosi community has its own naming system for MLR and environmental processes that are commonly understood in their village and most of the other Xhosa people are directly or indirectly involved in fisheries. This naming includes Xhosa names of various coastal habitats, environmental processes, and organisms (Table 5.1). It is common that marine resource-dependent communities use their indigenous language to refer to fish species (Okeyo et al., 2004). Finally, the use of local language within a small-scale fishing community can disclose cultural and spiritual beliefs and practices linked to the fishing livelihood. Hence, the link between the buildup of knowledge, and culture and spirituality.

Secondly, LEK of this marine resource-dependent community is intuitively inclined. In general, MLRU encounters many environmental phenomena that may or may not enhance their livelihood (Badjeck et al., 2010; Cinner et al., 2012). From these experiences, the MLRU is able to learn about their environment in a "trial-and-error" manner as they need to make daily decisions regarding, for example, which fishing spots they should occupy and, the times of day for fishing based on the environmental conditions experienced. Sometimes such decisions are made with minimal conscious reasoning but based on hope to make a catch. For example, when the local fishers of Tshani-Mankosi noticed that they could not catch elf in the usual fishing spots (see section 5.2.2 under ocean temperature) they decided to try a different fishing spot. Understanding the factors that informed this decision was difficult since the fishers could not explain why they changed fishing spots. In view of this research, this was interpreted as an intuitive decision. Interestingly, the fishers caught elf in the alternative fishing spot and concluded that this resource may have changed habitat due to ocean temperature changes that the fishers had experienced. This highlights that LEK in the context of small-scale fishing communities has an intuitive aspect, which can aid the buildup of knowledge within the community.

On the other side, scientific findings are associated with more theorized and systematic methods of learning. Typical scientific research requires a set of clearly defined and repeatable steps of the procedure used to attain results. This creates a consistent way of learning within the scientific community. This can be seen in the studies of Malan *et al* (2019) and Roy (2007) who both studied changes in temperature and winds over the Agulhas Bank using similar methods. It is common within environmental and climate change research to examine trends and anomalies of specified variables. The specification of variables for a study shows that scientific research related to environmental and climate change builds knowledge up by breaking this complex phenomenon into simple and fundamental parts that are interacting. Therefore, scientific research is generally more reductionist in constructing knowledge.

A lesson about Local Ecological knowledge can be shared from the case study of Tshani-Mankosi fishers and their observation about the sea surface temperature. Their knowledge covers both the ecological and social response to drivers of change. Unlike the more systematic scientific studies which usually focus on the ecological responses. For example, their observation of a reduction in ocean temperature is based on their social responsibility to this change, such as sickness, change of preferred fishing time in a day, and digging of "graves" to keep resources fresh. While the ecological responses to the change include the moving of elf from the open shoreline water to the mouth of the estuaries in this community. The locals in this community have shown to be very holistic in how they make sense of certain changes in their environment.

6.1.2. Temporal and spatial scale

LEK is generally accumulated over a long period of time in a specific locality; regarding the region of interest here scientific findings are at a broader spatial scale, except some sparse short-term studies. Although scientific research can include the use of sophisticated scientific tools and instruments that collect data on specific variables, local resource users observe the interconnected variables related to their fishing livelihood. This puts them at an advantage of understanding relationships between climatic variables and the marine ecosystems as those relationships play out in real life. The often single/discipline focus in scientific studies requires a systematic experiment to understand how trends in that certain variable or discipline influence others. For example, Tshani-Mankosi fishers observed that colder sea surface temperature along the coast gives the dusky kob a cue to migrate. The fishers could also link colder water with the strong northeasterly winds. Simultaneously, the colder water is helpful in keeping the brown mussels fresh and alive even after they have been taken away from the sea for some time. Also, the strengthened winds were reported to be making the soil drier compared to the past which in turn requires that more irrigation water is needed for their home gardens. The decrease in annual rainfall and disappearance of spring wells complicates this. These observations highlight the complexity associated with environmental changes and their impact and the usefulness of scientific findings which may be enhanced by the holistic LEK. Finally, due to the centralization of MLRU in one locality over a long time, the locals are able to uncover the complexity associated with climate or environmental change and to identify some feedbacks within a system after it has been disturbed.

6.1.3. Data output

The local resource users base their knowledge on their relationship with the natural environment. Their experiences, perceptions, and observations of environmental processes become important in the development of knowledge about the environmental process. As a result, the information they have about the environment is not usually documented but accessed through narratives. Such qualitative data can be challenged due to the account of human memory.

Climate and environmental science studies usually make use of quantitative data in a form of *in situ* data, satellite data, or modeled data. *In situ* data along the east coast of South Africa, particularly along the wild coast is limited. This may be due to the limited research cruises in this region and challenges arising from the remoteness and the irregular terrain of this coastal region, making it difficult for scientific researchers to install and maintain instrumentation to collect long term data. Furthermore, financial restrictions limit the amount of data collected. At present, the main source of data in this region is satellite data, which is limited close to the coast due to land-sea boundary conditions and strong cloud cover. Also, modeled data is constricted by a lack of data to validate the output and the limited coastal resolution due to computing power and capacity (i.e. there is sufficient computing power to run models at the resolution needed to simulate the nearshore). Consequently, most of the coastline data coming from satellite or computer models has been associated with inaccuracy even though the broader region of the Agulhas Current seems more reliable. Therefore, all sources of data along the east coast, including qualitative data, should be considered valuable for climate and environmental studies since there are challenges with data in this region

6.1.4. Parameters of interest

Despite the difference in knowledge development between the local marine resource users and scientific researchers, the two can be linked since the environmental variables of interest are often the same. In climate-related studies, scientific researchers are interested in understanding trends in temperature, rainfall, and winds. These variables are usually the basis for understanding the influence of crucial climatic processes such as ENSO. Meanwhile, local resource users pay attention to these variables since they aid in understanding climatic and environmental changes that affect their fishing livelihood. Also, the observations made by the locals and scientists regarding these variables can be relatable. For example, the observations made by the fishers in their locality were a decrease in ocean temperature, an increase in wind strength, and an increase in the frequency and intensity of floods which are consistent with the opinions of scientists as well as the available literature.

6.2. Research collaboration: Scientists and small-scale fishers

Research collaboration often requires that there is an equal partnership between those who have a common research interest. Given the convergence and divergence of knowledge between scientific researchers and local MLRU discussed above, this section explores the feasibility of research collaboration between the two by discussing (I) Opportunities and rewards of research collaboration between fishing communities and scientists from the Tshani-Mankosi case study, and (II) the potential challenges and limitations of collaborative research.

6.2.1. Opportunities and rewards of research collaboration: Practical examples from Tshani-Mankosi case study

Firstly, the Tshani-Mankosi MLRU has demonstrated the ability to observe rapid and extreme environmental events such as flash floods together with the associated socio-ecological impacts in the coastal and marine environments. Such observations are crucial in understanding the impacts of climate change on marine ecosystems and how to better manage marine resources under climate change (Potts, Götz and James, 2015; Martins and Gasalla, 2018). Even though such topics are covered in scientific research, it is usually limited to trends in the frequency and intensity of floods, the impacts of a specific flood in the environment, or the response of a specific species to environmental change induced by floods. As a result, there is a gap in the literature about the long-term monitoring of floods with their impacts within an area. Little is known about the long-term effects of multiple events of floods in the socio-ecological systems along with the east coast over time. This may be due to the lack of suitable and high-quality data on the east coast and the financial and logistical implication of conducting repeatable research in every event of floods as it would need frequent *in situ* observation of how the marine and coastal ecosystem behaves before and after an event of flooding. Yet, there are local communities, such as Tshani-Mankosi, along this coast are making these observations for their livelihood. However, this information remains undocumented but kept in the memories of the local people who get affected by these climate extreme events. A collaboration between the scientist and local resource users at the research level would allow documentation of these observations, improving data collection and management along the east coast as the locals would play a significant role in monitoring the events of flood and the associated impacts.

Secondly, the ability of MRLU to observe not only ecological responses to climate and environmental change but also to social responses provides an opportunity for more holistic climate research to be conducted in collaborative engagement. It is evident in the Tshani-Mankosi case study that the impacts of climate change affect the MLRU by altering the marine ecosystems and the services they provide as well as directly affecting the lives of the fishers. For example, increased frequency of heavy rainfall in this locality impacts the freshwater inflow into the coastal areas and the ecosystems thereafter but it also affects the number of days that the fishers can access the sea. Such holistic information is key in coming up with adaptation and mitigation strategies to the impacts of climate change, which are usually linked to building climate resilience. As a result, it is often important to know who or/and what is vulnerable to impacts of climate change to effectively develop resilience where needed and this can be informed through the holistic observation of local resources. This then provides the opportunity to come up with more contextualized and relevant climate mitigation and adaptation strategies at a community level from the research collaboration.

Thirdly, LEK has a useful role in identifying and shaping scientific research questions, areas where observation should be prioritized. In the Tshani-Mankosi case study, the local MLRU suggest that the ECRL has moved to rocks found at greater depth and further offshore since 2011. Also, it is known that flood events in this community have been occurring and changing the water quality along this shoreline for a short period of time. However, the reason for the movement of the ECRL is not clear, possibly it's due to the impacts of flood or other environmental factors such as the inshore ocean circulations along the east coast. Although poleward distributional shifts of rock lobsters linked to environmental change along the west coast of South Africa have been documented (Blamey *et al.*, 2012, 2015), little is known about latitudinal shifts in rock lobster and the possible link to frequent flood events. In this way, it is clear that research collaboration between scientists and resource users would provide a crucial platform for the shaping of research questions that are closely relevant to the social and ecological issues faced by communities that are vulnerable to the impacts of climate change. Finally, research questions that are shared between scientists and resource users should be investigated in a collaborative to allow a two-way discussion between the parts, bridging the gap between science and practice but also eliminated the need for knowledge brokers.

Considering the lack of sufficient and high-quality data along the east coast of South Africa, the knowledge of local resource users could assist in filling and/or ground-truthing the available data. Through collaborative research, historical and contemporary baseline information can be shared by the resource users, which may confirm or fill in the gaps in the more scientific findings. For example, rainfall data in the eastern cape is collected on weather stations which are coarsely spatially installed, even though this region is known for inhomogeneity when it comes to rainfall (Mason *et al.*, 1999; Kruger, 2006; Kruger and Nxumalo, 2017). Moreover, the weather stations along the east coast were deemed unusable in a study conducted by Kruger and Nxumalo (2017) due to prolonged recordings of zero rainfall even though significant amounts of rainfall were recorded in the nearby stations. It is supposed that these stations are located in regions of complex topography or have unique regional rainfall producing mechanisms, making it difficult to do quality control of rainfall data (Kruger and Nxumalo, 2017). On the other side, the local communities along this coast make the observation of rainfall patterns. The resource users of Tshani-Mankosi have provided information about rainfall patterns over time and extreme weather events related to rainfall. Therefore, research collaborations would be a crucial platform for information sharing and enhancing citizen science.

In addition to this, research collaboration is useful in providing a teaching and learning space between resource users and scientific research which may aid to reduce the chances of misunderstanding or conflicting ideas. In this study, it was noted that even though the fishers make environmental observations and experience the impacts of a changing environment, they lack academic background to be able to explain their observations. At the same time, the scientific researchers who have done work in this region lack context to effectively translate their science into something meaningful to local resource users. For example, most of the local marine resource users in Tshani-Mankosi have not completed their primary school education. As a result, these fishers are unfamiliar with basic oceanographic processes such as upwelling, even though they can describe conditions witnessed during an upwelling event, they cannot explain the mechanisms behind what they observe. This shows that, with more interaction between scientists and local resources users, areas, where environmental education can be provided to the community, would be revealed. At the same, the scientific researchers would learn what is relevant to the society so that they may be able to focus and communicate the science to be relevant to the non-scientific group.

6.2.2. Challenges and Limitations

Even though there are many benefits and practical examples from the Tshani-Mankosi case study to have a research collaboration between scientists and locals from a marine resource-dependent community, there are also challenges and limitations to this. One of the challenges is the issue of language. Tshani-Mankosi community members are IsiXhosa speakers with a very low level of education. Only a few people can communicate in English in this community and those are usually not involved in fishing activities as a primary source of food and income. Although research collaboration sessions in this community could use a translator, the translation component for collaborative research may increase chances of misunderstandings between the collaborators since some meaning can be lost in translation.

Another challenge to a community-researcher engagement may be changed in community structure. It is not rare to find a change in the community membership and leadership structure that may have a significant implication on the availability and/or accessibility to research partners in the community. For example, in the Tshani-Mankosi case study, visiting researchers are expected to introduce themselves and their research to the local traditional leader to get permission to interact with the community members. Should the leader change, the researcher would have to start all over again and introduce themselves and permission to engage community members is not guaranteed from one leader to the other. Moreover, the changing community membership implies that there may be inconstancy in the research partners. This may be demotivating to scientific researchers.

Also, some communities may have a poor historical relationship with researchers, making it difficult to engage with the researcher. This may be due to lack of experience with interacting with visiting researchers in their community or bad experience with the researchers whereby the researchers do not report back to the community and give the impression that they are taking information from the community for personal benefits. Also, not all scientists have the ability to relate with the public and this can cause damage if not managed well. Additionally, a researcher may develop a strong sense of empathy when exposed to the harsh realities of climate change and make provision of resources such as fishing gear and maybe internet facility to make the lives of his/her research partners and research process easier, creating a begging culture within the community. In addition to these factors, research collaboration may be challenged by an occurrence of local activities which may be of more socio-economic and cultural importance to the community members during crucial research time. Nevertheless, the positives gained from interactions between scientists and the local communities would have significant benefits to both parties.

Finally, the adopted vulnerability assessment has provided an efficient and quick methodology to gather socio-ecological information about Tshani-Mankosi. It has allowed an outlining of the LEK of this community by exploring the community's vulnerability based on the climate/environmental changes observed by the locals in the daily activities of their livelihood. Even though the identification of environmental stressors activity, which was essential to document LEK, could be achieved in one day by the participants, this activity would be difficult if carried out on its own and not in a process like a workshop. Moreover, this research acknowledges LEK cannot be fully learned without being embedded in the community for years or more. A significant amount of LEK has been shared by employing this methodology and perhaps spending more time and participating in the daily activities of marine resource users would allow more opportunities for documentation of LEK.

CHAPTER 7: CONCLUSION AND RECOMMENDATION

This research has looked at climate and environmental change along the east coast of South Africa from the scientific researcher's perspective as well as that of the local marine resource-dependent communities along this coast. The two overarching aims of this research were to assess areas of convergence and divergence between the knowledge of the local MLRU and researchers; as well as to identify crucial opportunities for research collaboration about climate and environmental change. In achieving these aims, this research sought to

I. Explore the LEK of marine living resource users in Tshani-Mankosi community;

II. Provide a review of scientific literature and current knowledge (through direct interviews) about environmental change and climate variability or climate change along the East Coast of South Africa

III. Critically compare and contrast LEK and scientific findings where relevant

IV. Evaluate linkages and opportunities for collaboration between researchers and resource users.

The significance of this study lies with the potential of reducing conflicts between decision-makers, researchers and marine resource users under climate change by providing different perspectives of climate and environmental change whilst understanding the associated convergence and divergence between the two data sources. It is particularly significant in the South African small-scale fisheries context as it provides an opportunity for the fisherfolk who have been historically excluded from decision-making processes, to be able to engage with the decision-makers through possible collaborative research with the scientific community. In this way, not only are historical injustices remedied, but the strong local socio-economic and cultural components of fishing communities are also considered in climate and environmental change-related research. Thereby providing a more holistic information base for the development of climate change resilience.

This research used social science methods to investigate climate and environmental change information of scientific researchers and local marine resource users. A participatory research approach was adopted in this research to gather and evaluate empirical evidence of change in the environment from research participants. A series of informational interviews with scientific researchers were conducted followed by a desktop analysis of literature, which was mostly suggested during the interviews. An adapted version of the vulnerability assessment method developed for the small-scale fishing communities along the west coast of South Africa was used. This method, called reduced Rapid Vulnerability Assessment (rRVA), is in the form of a two days' workshop and includes exercises such as 1) Socio-ecological mapping of the community; 2) identification of socio-economic, environmental and governance stressors to fishing livelihood; 3) Further exploration of environmental stressors in relation to changing environmental conditions; 4) Impacts and causes of the environmental changes; 5) development of key environmental stressors and changes timeline; and lastly 6) Key informant interviews. The information gathered about evidence of climate and environmental change was analyzed and organized according to common themes such as wind, rainfall patterns, and ocean temperature. In revisiting the aims, objectives, and findings of this research, the following section of the chapter provides three principal conclusions. The second section suggests recommendations for the progression of this research.

7.1 Conclusion

7.1.1. Climate and environmental change knowledge exist in the marine resource-dependent communities

The results of this study have shown that the knowledge possessed by the MLRU about changes in the environment fits the widely accepted definitions and characteristics of local ecological knowledge. The fishers were not formally trained about marine living resources and the biophysical processes that occur in the marine and coastal environment. Instead, they accumulated the knowledge through a constant relationship between the natural environment and themselves. Fundamentally, their experiences, observations, and perceptions of the environment are the cornerstone of their knowledge with very little formal education. The information they shared showed that it is regularly transformed with a concentration of the archival and recent socio-ecological understanding through their real-life experiences in their fisheries livelihood. Furthermore, the historical continuity in resource dependence in this community has positioned the locals to gain extensive experience with their environment over a long time. Also, these experiences are transmitted from one generation to the other through cultural practices such as storytelling.

7.1.2. Similarities and differences between LEK and scientific findings are present at two levels – knowledge type and knowledge content

This research has demonstrated that LEK and scientific findings can differ or/and be similar according to knowledge type and knowledge content. With regards to the knowledge type (nature of knowledge), differences between the conventional scientific efforts and small-scale fishers' knowledge included the intuitive, holistic, qualitative, community-based, and real-life experience-based LEK against the more rational, reductionist, regional, and statistical analysis based scientific methods. Only one similarity in the nature of knowledge between these two groups could be identified – parameters of interest. Climate and environmental change researchers investigate similar parameters to those considered by locals. Even though more differences (which can contribute towards the potential of having a conflict of ideas between the scientist and the locals) than similarities exist in the nature of knowledge between the two parts, this research has shown that there are more similarities in the content of knowledge than there are differences. Fisher's observation about rainfall and wind patterns were similar to trends document in the scientific literature. The winds were deemed increasing by both parts. Scientific researchers and local resource users seem to be in consensus with the increasing frequency of floods.

7.1.3. Research collaboration between MLRU and scientists are possible, and the benefits of such interaction are more gratifying than the challenges

This study has identified opportunities and benefits for research collaboration between climate or fisheries researchers and the marine living resources as well as the limitations and possible challenges to this. The opportunities and rewards for collaborative research between marine resource-dependent communities include improvement of data collection and management processes; contextualization of climate adaptation strategies at a community level; the shaping of new scientific research questions; a provision for teaching-learning platform for co-production of knowledge; and climate research covering all spatial and temporal scales. The challenges to collaborative research involve issues arising from language differences and illiteracy, as well as shifts in community membership and leadership structure.

7.2. Recommendations and future work

The inevitable impacts of climate and environmental change are complex, urgent and severe. Single-Discipline climate research is important to understand specific phenomena regarding climate and environmental change. However, to be able to confront the challenges posed by climate change, research collaborations that are problem-based and learning-oriented are key. Developing climate change adaptation plans can be an extremely difficult task to do without engaging communities and understanding the knowledge about climate change so as to tell who or what may be vulnerable to impacts of climate change and why they are vulnerable. Hence, the importance of including local knowledge when it comes to issues about environmental changes. In addition, it would be hard to provide a description of the environmental threat that people need to adapt to without measures of what is changing in the climate and the environment and how much it is changing. Scientific research provides this kind of information. Therefore, scientific findings and the local ecological knowledge should be considered as are equally important in climate and environmental change-related research. Thus, the need for more documentation of LEK in parallel with scientific finding to bridge the gap between research and practice.

In summary, even though general opportunities and challenges of research collaboration between scientific researchers and fishing communities exist, each research project intending to have a collaborative engagement with a community will provoke different levels of willingness for involvement depending on whether or not the research objectives and goals are shared between the two parts. Hence it is important that the objectives of the researcher are similar to that of the community members intending to collaborate with on a project. In addition, the degrees of community engagement for research may vary from hiring local research assistants to co-designing and development of research questions, methodology, and interpretation of data. For communities with overwhelming amounts of challenges and limitations for research collaboration, it may be worthwhile to begin by hiring a research assistant instead of attempting to engage the entire community. The local research assistant would play a crucial role in providing the monitoring of environmental changes by taking measurements or make an observation of climatic and environmental parameters such as sea conditions, winds and ocean temperature. The hired member may need to be trained to make necessary observations.

Lastly, there is much progress that can be made in addressing environmental change through mutual collaboration between scientific and local communities. The gap between research and practice could be filled, the discipline cross-cutting issues in climate change research could be viewed in a more holistic, boundaryless transdisciplinary approach, and citizen science would be enhanced for the benefit of communities, researchers and policymakers.

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APPENDICES

APPENDIX A: DETAILED PROGRAM OF THE RRVA WORKSHOP IN TSHANI-MANKOSI COMMUNITY

Duration	Activity	Tools/methods	Note to facilitator
20 minutes max	**Introduction** ● Present objectives of rRVA and explain the process. ● Encourage participants to ask questions for clarity and to describe their role in fishing. ● Also, discuss expectations from participants and from the field work team.	**Plenary session** ● Circulation of attendance register. ● Flipchart board to explain the rRVA objectives and process.	Make notes of the agreed house rules
60 minutes max	**Exercise 1: Village mapping** ● Develop a village map based on the livelihood's assets, important institutions, etc. ● What livelihoods exist in the community ● Learn about the income generation activities related to the livelihoods	**Small groups** ● Divide participants into small groups of 3-5 people. ● Provide participants with flipchart paper and drawing pen ● Present maps in plenary session for discussion and validation	Note the overview of the villages socio-ecological system and its main characteristics
80 minutes max	**Exercise 2: Identification and ranking of threats and stressor to livelihood** ● Individuals are asked to identify all (environmental, social, economic, cultural political, and institutional) stressors/threats linked to the livelihood at all relevant scales.	**Plenary** ● Each individual should be allowed to come up with at least 3 points. ● Write stressors on the cards and allow participants to decide if the particular stress or threat should go under which category on the listed ones: environmental; socio-economical; or management and governance. ● Each stressor is discussed in a plenary ● Succeeding the identification of stressors, each participant four stickers to paste next to their priority issues	● Hand out pen and cards to each individual ● On the flip paper chars, draw a table with headings: environmental; socio-economical; or management and governance. ● writing may not be as easy as drawing. Facilitators may need to volunteer as a scribe to avoid insecurities if there are any. ● If there are duplicate or similar threats, you can remove them but keep count

80 min max	**Exercise 3: key stressors and the associated changes** ● Unpack the highest-ranked stressors and ask participants to identify changes or any events related to the specific stressors. ● You may choose other stressors that are broader, this will allow you to probe more information about the stressor. For example, you can choose market problems instead of a bad price as a stressor to explore	**Small groups** ● Divide into 3 groups and allocate 2/6 highest-ranked stressors to each group ● Allow the groups to explore these stressors further, providing changes and events experienced related to the allocated stressor ● Feedback to plenary for discussion	● Encourage participants to think pre and -post-1990s ● Note if there is any relationship between the highest-ranked stressors and other stressors
20 min max	**Exercise 5: Timeline of environmental stressors and changes** ● Present the key events and changes observed in a timeline	**Plenary** ● Arrange the observation made in chronological order	● Draw timeline
	Exercise 4: Impacts and causes associated with environmental and climate change or variability ● Explore environmental changes or events further. Discuss the direct and indirect impacts of these events on livelihood. ● Discover the possible cause of these changes or events from participants and gather more in-depth information on the perceptions, experiences, and observations of the participants about the environment.	**Plenary** ● Explain direct and indirect impacts ● Make use of the aforementioned environmental stressors, changes, and events to brainstorm the impacts and causes	Note how a particular change can generate single or multiple impacts that affect individuals, households or community

	Wrap up workshop ● Provide a summary of the workshop ● Discuss follow up activities ● Discuss the method of giving feedback about the study' findings	**Plenary**	You can ask participants to volunteer themselves for key informant interviews or ask them to recommend people to be interviewed. You may also decide on people to interview based on the participation of individuals during the workshop
	Exercise 6: Key informant interviews ● Questions used to drive the conversation in appendix	Enhance understanding gleaned during the workshop by holding one on one interviews. Target the older community members	

APPENDIX B: LETTER OF ETHICS APPROVAL FROM THE FACULTY OF SCIENCE RESEARCH ETHICS COMMITTEE

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

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Tel: +27 21 650 2866/7
E-mail: Rachel.Wynberg@uct.ac.za
12 March 2018

Ms. Tania Moyikwa

Department of Environmental and Geographical Science

RE: The Resonance between Scientific findings and local Knowledge about climate change in a fishing community along the east coast of southern Africa.

Dear Ms. Tania Moyikwa

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.

• Implement the measures described in your application to ensure that the process of your research is ethically sound; and

• 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.

Your approval code is: FSREC 18 - 2018

I wish you success in your research.

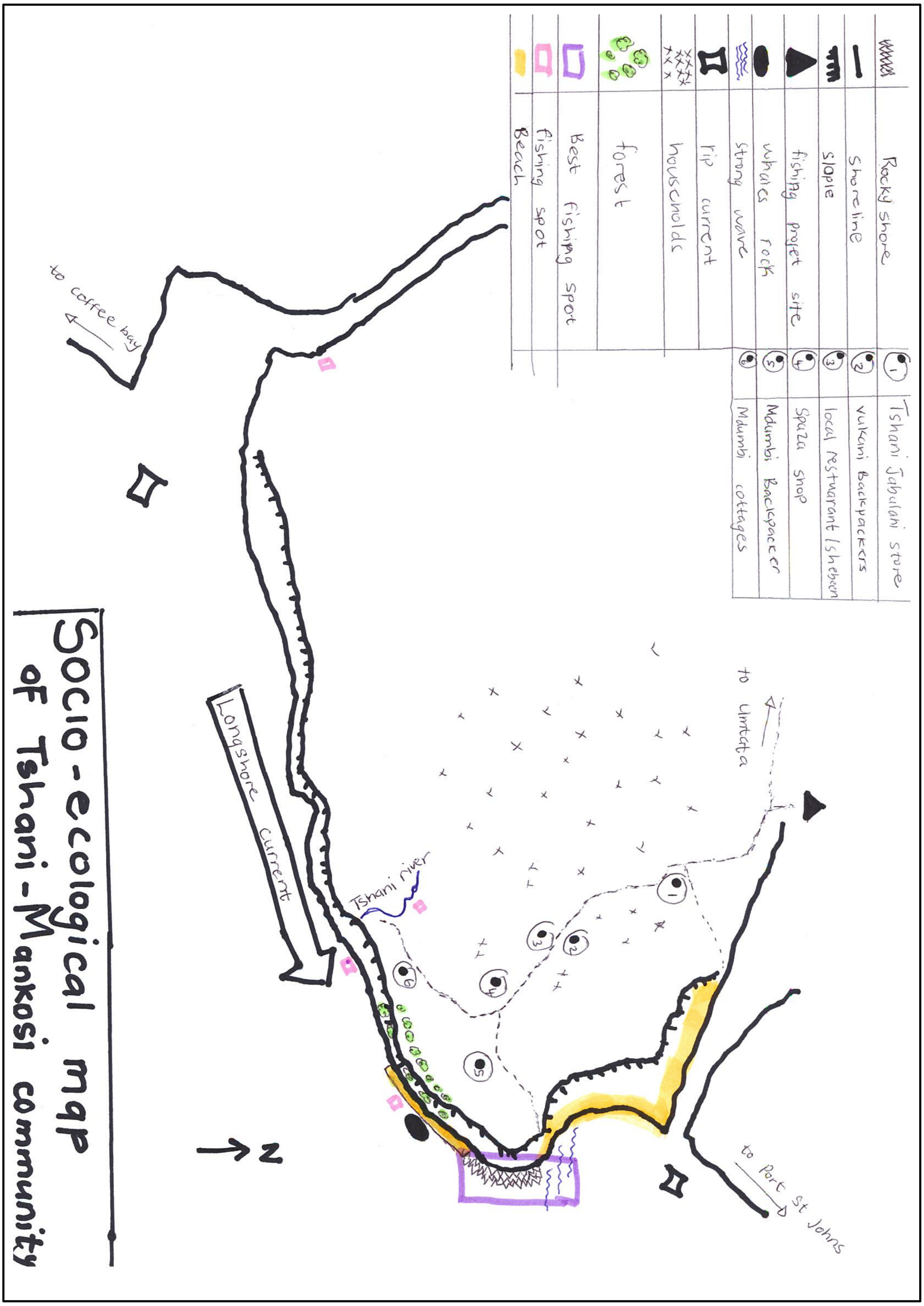
Yours sincerely

A/Prof Rachel Wynberg Chair: Faculty of Science Research Ethics Committee

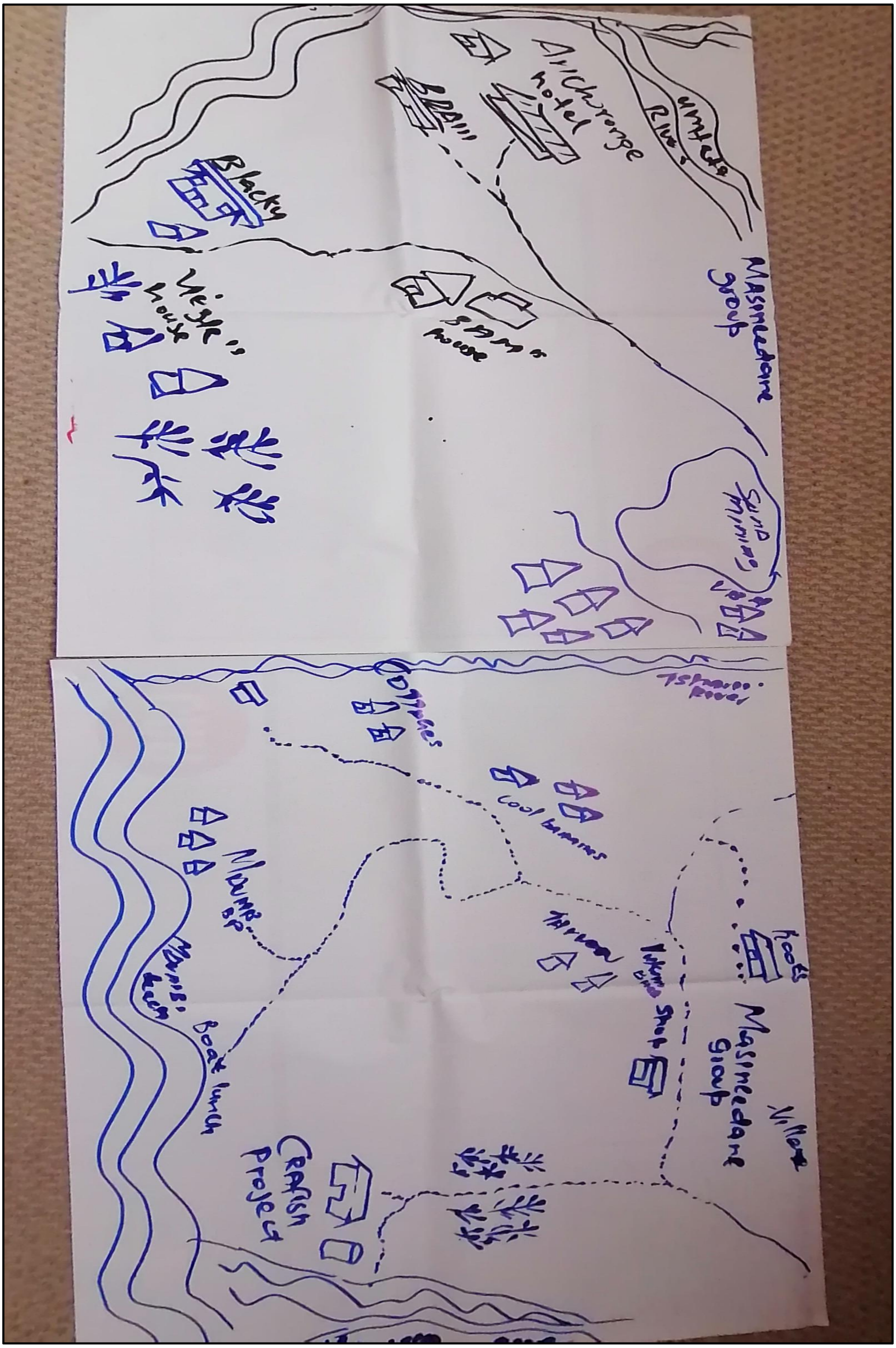
Cc: Dr. Serge Raemaekers (Supervisor)

APPENDIX C: IMAGES OF SOCIO ECOLOGICAL MAPS PRODUCED DURING RRVA WORKSHOP IN TSHANI-MANKOSI AND ONE THAT WAS CREATED BASED ON THE RESEARCHERS OBSERVATION

1.Socio-ecological map (Produced by Tania Moyikwa)



2. Three socio-ecological maps produced by research participants



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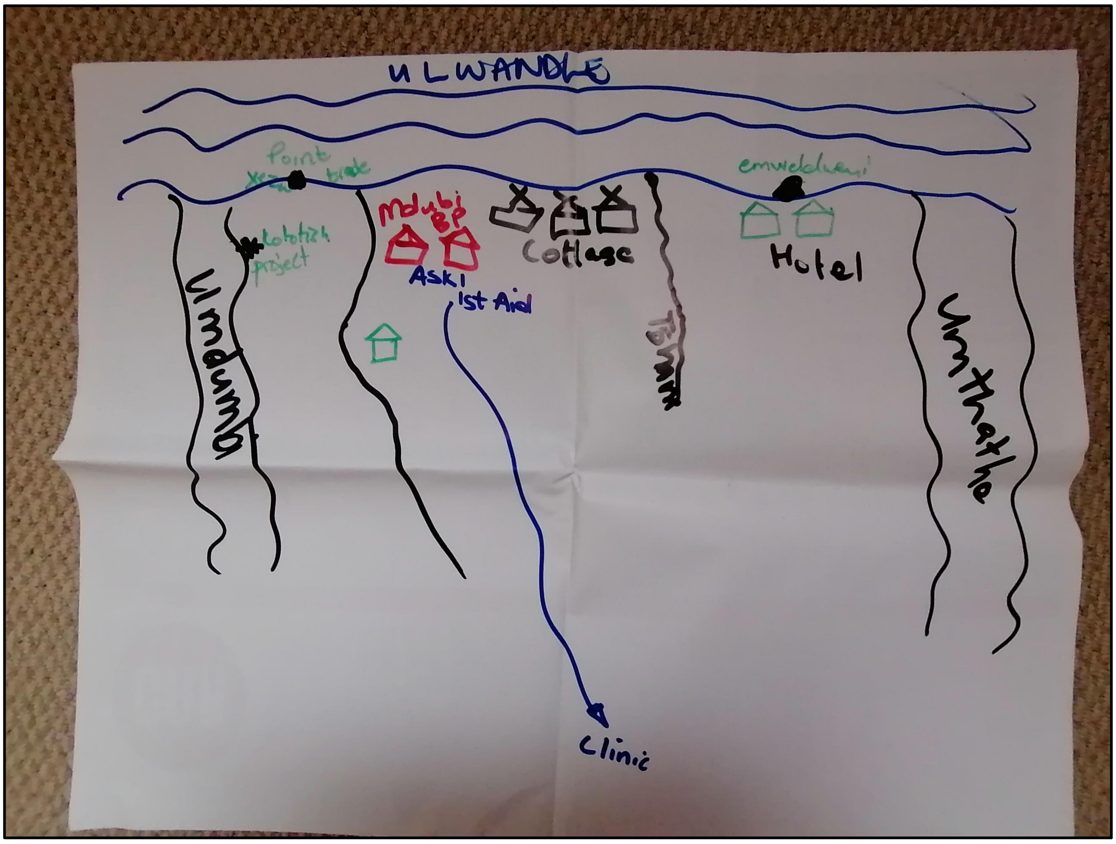
ULWANDLE
Point
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Cottage
Hotel
Umdumbi
project
Askı
1st Aid
Umthatha
Clinic

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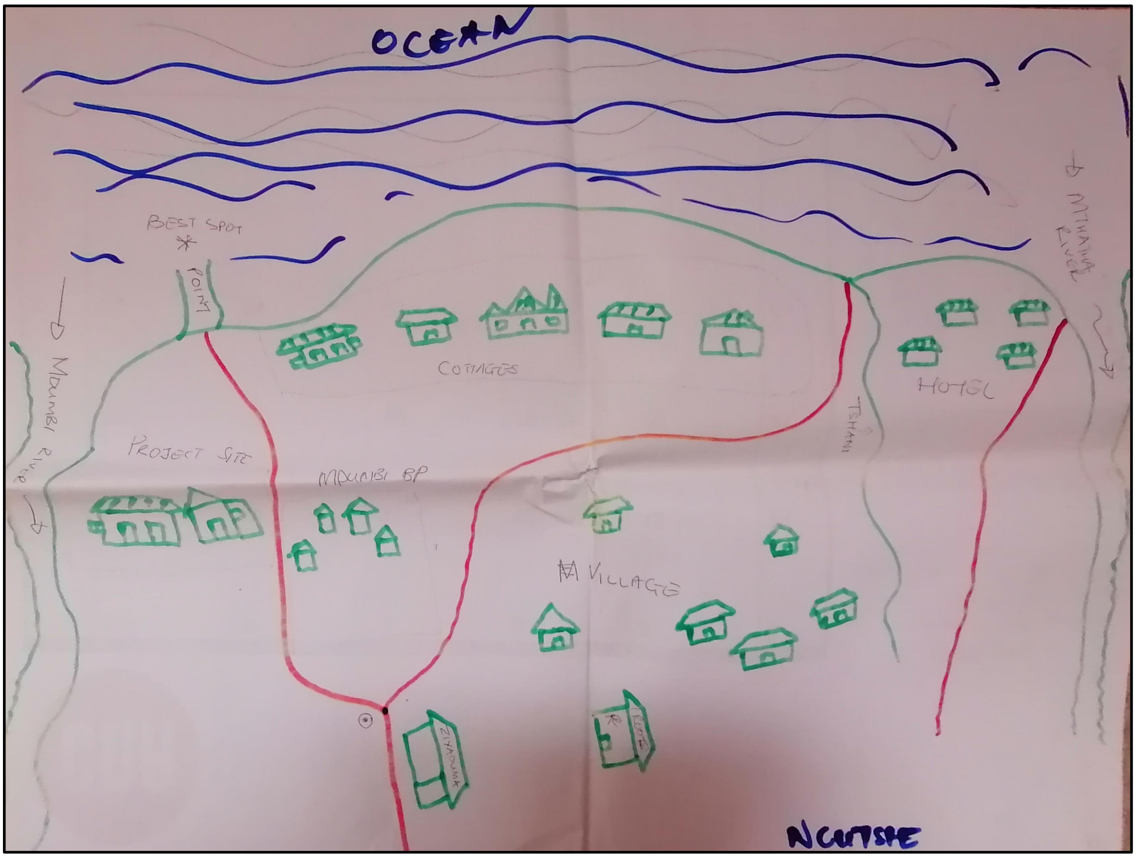
OCEAN
BEST SPOT
POINT
COTTAGES
HOTEL
MDUMBI RIVER
MTHATHA RIVER
PROJECT SITE
MDUMBI BP
TSHANI
VILLAGE
NGCWANGUBA

C