DEVELOPMENT OF A SCENARIO-BASED APPROACH FOR RESPONDING TO CHANGE IN FISHERY SYSTEMS:

A CASE STUDY IN THE SMALL-SCALE FISHERIES OF SOUTH AFRICA'S SOUTHERN CAPE

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Thesis presented for the degree of

DOCTOR OF PHILOSOPHY

in the Department of Environmental & Geographical Sciences

UNIVERSITY OF CAPE TOWN

July 2019

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Declaration

I know the meaning of plagiarism and declare that all the work in this thesis, save for that which is appropriately acknowledged, is my own. This thesis has not been submitted in whole or in part for a degree at any other university.

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Date: 5 July 2019

Acknowledgement of Funding

Financial support was provided by the National Research Foundation through a NRF-DST Innovation Doctoral Scholarship; the Department of Science and Technology's South African Research Chairs Initiative (SARChI) through the South African Research Chair in Marine Ecology and Fisheries, and the University of Cape Town through the K.J. Johnston Bequest and Twamley Scholarship.

The financial assistance of the National Research Foundation and the University of Cape Town towards this research is hereby gratefully acknowledged. Opinions expressed, and conclusions arrived at, are those of the author and are not necessarily to be attributed to the National Research Foundation or the University of Cape Town.

Acknowledgements

"The single greatest cause of happiness is gratitude".

Auliq-Ice

There are numerous people to whom I would like to offer a personal word of gratitude. My appreciation and thanks to -

My supervisors, Astrid Jarre and Charles Mather – thank you for your support and advice – your guidance, motivation and encouragement has been invaluable.

The NRF and UCT for funding support received throughout and a particular word of thanks to the personnel at UCT's Postgraduate Funding Office for all the assistance with the administrative aspects of the funding support.

Prof Marcus Haward from the University of Tasmania for support with the scenario planning, Dr Russell Richards from the University of Queensland Business School for his kind assistance with the Bayesian Modelling, Dr James Howard for the collection of the GULLS household survey data, Lee-Anne Gammage for interview transcriptions and notetaking at the workshops and Cara Pratten for assistance with notes at the workshops.

The personnel in the Biological Sciences Department - particularly the departmental admin personnel who are always so willing to offer advice and for making admin run smoothly.

The participants from the southern Cape deserve a special thanks for sacrificing valuable time to participate in the research – especially the participants from Melkhoutfontein. A special mention to Ronnie and Charmaine Gelant who also provided logistic support in Melkhoutfontein.

Family, friends and colleagues too numerous to mention - your support and encouragement have been invaluable, and for that, I am deeply grateful. Finally - a special thanks to my immediate family – Mom, Dad, Lee-Anne, Matthew and Jasmine – I am eternally grateful for all your patience, love and unwavering support.

Abstract

Development of a scenario-based approach for responding to change in fishery systems: a case study in the small-scale fisheries of South Africa's southern Cape

Small-scale fishers and the communities they support face a range of challenges brought on by change in their marine social-ecological systems (SES). The resulting complexity and uncertainty hamper their ability to achieve sustainability while holding implications for decision-making at various scales: fishers need to respond proactively to change at smaller scales of operation while managers need to apply the principles of ecosystem-based management approaches such as an ecosystem approach to fisheries management (EAF) at larger scales.

Using the small-scale fishing communities of South Africa's southern Cape as a case study, this thesis explores how structured decision-making tools (specifically causal mapping, Bayesian belief networks and scenario planning) can be applied in an interactive and iterative scenario-based approach with disenfranchised fishers in support of decision-making at multiple scales. Specifically, this thesis aims to (1) determine and describe major stressors in the fishery system of the southern Cape using the perspectives from the crew component of its linefishery; (2) establish what interactions and feedback loops (drivers of change) exist and interact at various scales; (3) use Bayesian belief network modelling in an iterative participatory process to establish the prominent drivers of change within the fishery system (from the crew perspective); (4) develop, together with fishers, four stories of what the future may hold for one of the towns using an iterative participatory scenario planning exercise, based on some of the principles of transformative scenario planning approaches; (5) evaluate the contextual suitability of the application of the various tools used throughout the research process and recommend next steps in a larger scenario planning process; and (6) create an opportunity for fishers to engage in a process that could enhance their understanding of possible change response strategies through learning, thereby increasing adaptive capacity in the support of the implementation of an EAF in South Africa.

As a start, drivers of change were established and documented, complementing earlier research. This was done to ensure that all user groups' views were represented in an initial causal map showing the drivers of change in the fishery system. In the causal mapping process, stakeholders from towns across the research area mapped out drivers of change in an iterative process. The causal maps not only helped to frame the system but also revealed important hidden drivers of change as well as feedback loops. The Bayesian belief network and scenario story development took place in the town of Melkhoutfontein. Bayesian belief networks provided insights into system uncertainty while serving as a problem reframing tool. The outputs of both the causal maps and Bayesian networks were then used to construct four scenario stories depicting possible futures in 30 years, based on inputs obtained from research participants in a visioning workshop. These scenarios not only provided examples of plausible

futures under certain conditions but also promoted new ways of thinking about the drivers of change and their likely effects, highlighting the interconnectedness in the system.

Implementing the overarching approach has provided marginalised fishers with an opportunity to freely air their views while engaging with new tools. The process does not only benefit fishers and their communities (at the small scale) but also provide valuables insights into how fishers view and experience the marine SES of the southern Cape. Moreover, the approach has identified ways in which challenges presented by scale in SES can be better addressed to ensure more effective decision-making in the pursuit of sustainability. This understanding and insight are integral for moving closer to the implementation of the EAF in South Africa, where the integration of the social dimensions of marine social-ecological systems into coherent evaluation and planning continues to be problematic.

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Chapter One

Introduction

1.1. Systems thinking and the need for scenario-based approaches

For millions of people, particularly in developing countries, fisheries remain an essential food and livelihood source (Garcia et al., 2003). Yet coastal communities, specifically those who rely on fisheries, are increasingly exposed to a wide variety of social, economic, political and biophysical stressors (Parry et al., 2007; Brierley & Kingsford, 2009; Hoegh-Guldberg & Bruno, 2010). Anthropogenic climate change and the over-exploitation of marine species in marine ecosystems place additional pressure on fisheries (Tegner & Dayton, 2000; Jackson et al., 2001; Scheffer et al., 2005; Halpern et al., 2008; Hoegh-Guldberg & Bruno, 2010; Poloczanska et al., 2013). Such changes result in coastal communities, fishing sectors and managers struggling with the ramifications, and potential opportunities of change which have significant impacts on fishers' ability to sustain fishery-derived livelihoods.

Added to these challenges, fishery dynamics span multiple scales which include temporal, spatial and governance dimensions and involve multiple actors (e.g. Berkes, 2003; Garcia & Cochrane, 2005; Jentoft & Chuenpagdee, 2013; Link et al., 2017; Jarre et al., 2018). Given this complexity, and the challenges brought about by environmental change, it makes sense to approach fisheries as part of a complex marine social-ecological system (SES) (e.g. Ostrom, 2009). In governing these SES, the Ecosystem Approach to Fisheries Management (EAF) recognises the complexity in marine SES and is widely adopted for fisheries management. EAF aims for the holistic, sustainable management of capture fisheries to promote healthy marine ecosystems together with sustainable fishery-derived livelihoods (FAO, 2003; Garcia et al., 2003).

Management frameworks such as the EAF actively promote systems-thinking, bottom-up management approaches and stakeholder participation. By implication, the implementation of the EAF as a management strategy should involve decision-making in different contexts by diverse stakeholders at various decision-making scales. Decision-making in the context of an SES is complicated with traditional, linear processes proving to be inadequate in addressing fisheries under complexity and uncertainty (e.g. Berkes, 2003). The implication of implementing such system approaches result in a need to firstly, develop system understanding at various scales and secondly, develop and implement methods that include multiple stakeholders while trading off multiple, conflicting objectives (e.g. Jarre et al., 2018).

South Africa officially adopted EAF at the World Summit on Sustainable Development in 2002 (WSSD, 2002). In contrast to management approaches advocated by an EAF, fisheries management decisions in South Africa have typically been implemented in a top-down fashion with little to no mechanisms for comprehensive stakeholder input or capacity building at the finer scales of operation. However, the Small-Scale Fisheries Policy (No 474 of

2012) (SSFP), currently being implemented in South Africa, is strongly underpinned by the principles of EAF. This requires capacity building with marginalised small-scale fishers who have little to no exposure to more structured-decision making or formal management processes, but also the establishment of practical methods and mechanisms that can aid the facilitation of multi-stakeholder processes. Importantly, the approach presented in this thesis contributes to how such inclusive co-management processes can be facilitated through a methodology that seeks to bring together diverse stakeholders, who have diverse and often conflicting goals, in a structured decision-making making context.

Given this complexity, the question that arises is: are there inclusive methods that can be applied at the smallest scales of operation of a fishery, which can at the same time also inform large-scale decision-making to promote management approaches such as an EAF? In addressing this central question, it becomes clear that traditional approaches used in fisheries management and research must be reframed and new methods and approaches explored. Such approaches strive to cross disciplinary lines, perceptions, forms of knowledge and scales (Degnbol & McCay, 2007; Garcia & Charles, 2007, 2008; Ommer & Team, 2007). To this end several authors advocate for the use of scenario-planning approaches in marine SES to address challenges with the effects of long-term system change, uncertainty and complexity (e.g. Jarre et al., 2013; Maury et al., 2017). Such approaches, using system-thinking, present the opportunity to address challenges simultaneously at different scales of interaction (e.g. Berkes, 2006; Cash et al., 2006) by addressing the need of the individual and/or household and informing policy processes such as the EAF at the same time. Figure 1.1a depicts the traditional, more linear and hierarchical, fisheries management approach used in South Africa, while Figure 1.1b shows the system-based approach to management which forms the framework within which this thesis is situated. Importantly, Figure 1.1b shows how the various relevant policy frameworks can be viewed as nested within a system context.

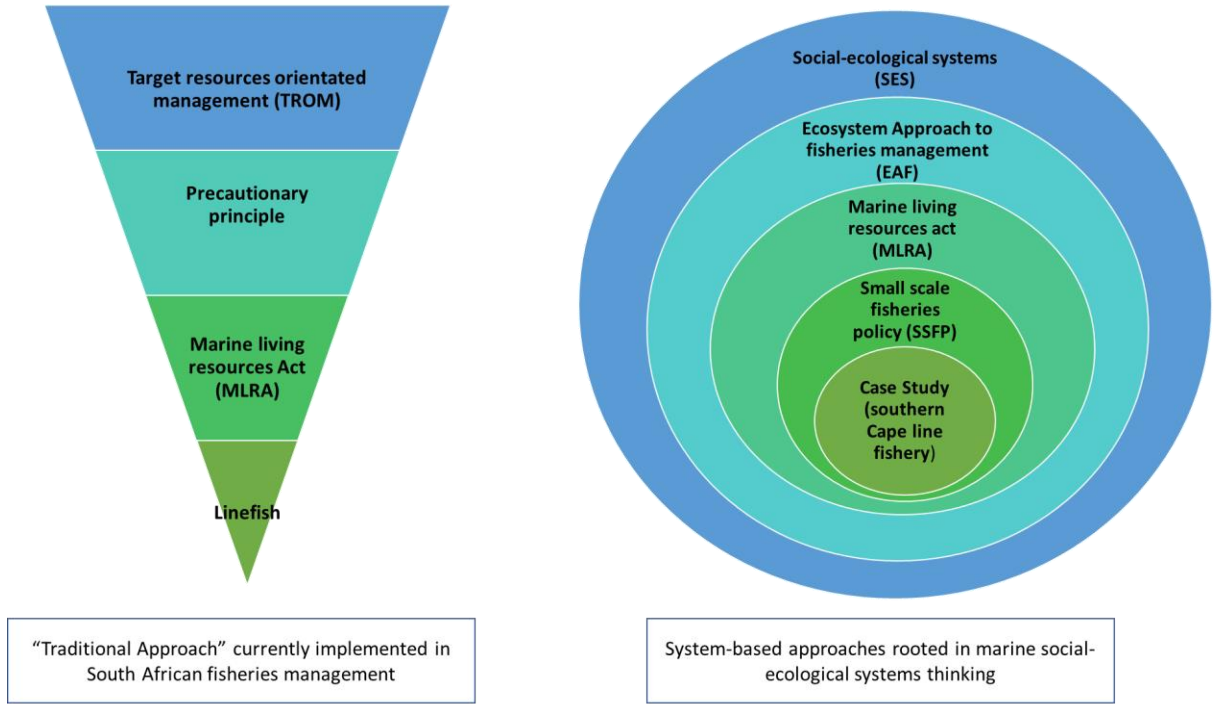

Figure 1.1. Traditional fisheries management approached vs system-based approaches. (a) shows how traditional management approaches are currently implemented in South African fisheries, (b) shows the system-based approach as applied in this thesis

This research aims to address complexity and uncertainty together with policy objectives and goals in fisheries at various scales, sound decision-making – both tactically and strategically - is needed. To this end, the research presented in this thesis uses systems-thinking to implement a prototype scenario planning approach developed with small-scale fishers who operate in South Africa's southern Cape linefishery. After establishing the drivers of change [1] from the fishers' perspectives using qualitative (Gammage, 2015; Gammage et al., 2017a) and quantitative survey methods, structured decision-making tools (SDMTs) contribute to a more holistic system description, thereby adding to the knowledge base on drivers on change. Through the SDMT development, scenarios are being generated in an interactive and iterative process. The overall approach provides a framework which can be expanded to include more diverse stakeholders from various decision-making scales. While the approach aims to strengthen EAF implementation in South Africa, it allows for the reframing of common and pervasive challenges in fisheries at the small scale for the research participants.

[1] The terms 'stressor' and 'driver of change' are used synonymously throughout this thesis. The term 'stressor' was specifically used in the interactions with the fishers as the meaning was universally understood. 'Drivers of change ' has been included in the more technical sections of the thesis. For the purposes of this thesis the terms stressors and drivers of change are "broadly defined to include a wide range of factors, including micro-and macro level social and environmental changes….of which impacts can manifest at individual household and community level as gradual or sudden shocks…" (Bunce et al. 2010: 409).

1.2. Global policy frameworks for sustainable fisheries management in small-scale fisheries

Adopting SES perspectives is not only integral to ecosystem-based management approaches, but it also offers the opportunity to integrate natural and human-social system components for moving towards more sustainable futures. At the global scale, the need for sustainable futures and oceans are highlighted by the adoption of management approaches such as the EAF and multi-national policy frameworks such as Agenda 2030 (UN, 2015a). The 2030 Agenda for Sustainable Development recognises the need for systems thinking in addressing modern societal problems. The framework pursues the goal of achieving a just and sustainable world where the fulfilment of human potential contributes to shared prosperity. Recognising the need to advance towards goals on several dimensions, Agenda 2030 aims for the end to poverty, hunger and malnutrition while striving for universal access to health care and the eradication of exclusion and inequality (UN, 2015a; CEB, 2017).

For fisheries governance, policy, investment, capacity development, stakeholder participation and collaboration are all relevant to Agenda 2030. This includes the Sustainable Development Goals (SDGs), together with other related national and international policy processes (FAO, 2018). The importance of fisheries is demonstrated by 'SDG 14 – Life below water' – which has a strong connection to fisheries. The SDGs affirm the commitment of placing equality and non-discrimination at the centre of Agenda 2030. By implication, achieving the main goals of Agenda 2030 for all fisherfolk and communities is a requirement (FAO, 2018). It has been recognised for several years that sustainable development presents a challenge for all countries and necessitates collaboration across sectors, disciplines, international cooperation and mutual accountability (FAO, 2016a).

The Food and Agriculture Organisation of the United Nations (FAO) provides the 'umbrella' policy goals that can facilitate integrative and innovative approaches for global fisheries management. The Code of Conduct for Responsible Fisheries (CCRF) (FAO, 1995), a framework for the implementation of the principles of sustainable development in fisheries, is seen to be increasing in relevance as fish consumption around the world increases (FAO, 2018). The focus of fisheries governance and development has broadened from earlier approaches to include the conservation of resources and the environment while increasingly recognising social agency, well-being, and livelihoods of people working in fishing sectors. Developed as a compliment to the CCRF, the small-scale fishery (SSF) guidelines (FAO, 2015) provide a policy framework for the attainment of sustainability of SSF. Although not legally binding, instruments such as the SSF guidelines serve to provide the required context and framework for achieving the SDGs. With a greater emphasis on the role that fisheries play as sources of livelihoods, as places where cultural values are expressed and as a buffer for shocks for poor communities; further development of the understanding of SSFs is required to support the commitments to SSF development and, ultimately, progress towards implementing Agenda 2030 and the SDGs (FAO, 2015, 2018). Importantly, the recognition and emphasis placed on the social (human) dimension in marine social-ecological systems are reflected in an ecosystem approach to fisheries management (EAF).

1.3. The ecosystem approach to fisheries management

The ecosystem approach to fisheries management (EAF) is promoted as the preferred management approach to capture fisheries. The EAF - developed with the explicit recognition of a need to advance frameworks for planning, development, and management of sustainable fisheries - is a broader framework which aims for the inclusive and sustainable management of fisheries. The EAF also accounts for the impacts that other sectors have on fisheries and the impacts that fisheries have on ecosystems (FAO, 2003). Built on the principles of Sustainable Development, the EAF "strives to balance diverse societal objectives, by taking into account of the knowledge and uncertainties of biotic, abiotic and human components of ecosystems and other interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries" (Garcia et al., 2003: 6) and specifically emphasises stakeholder engagement in management (FAO, 2003; Garcia et al., 2003; Wilson, 2006).

Although only formally recognised as a fisheries management goal by the Reykjavik Conference on Responsible Fisheries Management in the Marine Ecosystem in 2001, many international agreements over the past three decades have incorporated aspects of an EAF. In the wake of the Reykjavik conference, 45 countries pledged to incorporate EAF principles into fisheries management. The commitment to the EAF was restated with the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg. Here, signatory countries committed to "develop and facilitate the use of diverse approaches and tools, including ecosystem approach, the elimination of destructive fishing practices, the establishment of marine protected areas consistent with international law and based on scientific information, including representative networks by 2012" (WSSD, 2002:18). In 2003, the FAO published 'Guidelines for the implementation of the EAF' to provide signatory nations with the necessary guidance in support of EAF implementation (FAO, 2003). The FAO has recommended steps for the implementation and development of an EAF management plan (FAO, 2003; Garcia & Cochrane, 2005) and signatory countries are required to incorporate these principles into policy goals in support of implementation. If the EAF does not translate effectively from policy to management spaces, the likelihood of achieving sustainable fisheries will reduce.

Yet the successful implementation of EAF at the global scale has been challenging. Moving towards more inclusive approaches such as the EAF requires multiple stakeholders, disciplines and objectives that see fisheries as SES (Cochrane & Garcia, 2009; Berkes, 2012; Ommer et al., 2012). Management structures that match scales, complexity, and interdependencies of SESs are thus required (Ommer et al., 2012). Although fisheries managers have grappled with the complexities of an EAF while trying to find effective ways to identify and prioritise management objectives often in conflict with each other (Paterson & Petersen, 2010; Jennings et al., 2014).

However, current approaches for implementing an EAF tend to be used in a way that expands traditional management paradigms rather than changing them. For Berkes (2012), this evolutionary approach to implementing EAF is inadequate in dealing effectively with the multiplicity of issues and complexities associated with fisheries, thereby suggesting a more revolutionary approach is required.

In South Africa, the Marine Living Resources Act No 18 of 1998 (MLRA) espouses the concept of an EAF, although significant gaps and weaknesses exist in the Act. Although progress has been made in describing the ecological context of the SES, it has proven to be more difficult and complex to integrate social components of the linked SES (Shannon et al., 2010; Sowman et al., 2011). At the same time, there are differences in the knowledge base across fishing sectors in South Africa. Specifically, while some progress has been made towards the implementation of an EAF in the country's larger, industrialised fisheries, more sound and comprehensive policy and legal frameworks are required for long-term fisheries governance in South Africa specifically small scale fisheries (Cochrane et al., 2015).

Implementing an EAF successfully requires changes in how systems are perceived and governed by all stakeholders. In addition to tactical, narrow-focussed management approaches currently favoured in South African fisheries management, more strategic and broad-scale approaches are required (Shannon et al., 2010). Such approaches demand new ways of thinking, interdisciplinarity and collaboration. For practical implementation (Figure 1.1), stakeholder buy-in and participation is required (Shannon et al., 2010). Ultimately, not only does information (knowledge) need to be synthesised into logical frameworks that are transparent, defensible and repeatable, there is also a need to balance multiple knowledge sources while evaluating risks and uncertainties (Jarre et al., 2008).

Although the MLRA already partly captured the principles of this approach, South Africa nonetheless embarked on an incremental and proactive approach where the EAF is considered as complementary to traditional target resources-oriented management (TROM) approaches. TROM approaches aim to integrate ecosystem considerations into decision-making as opposed to overhauling the management system (Shannon et al., 2010; McGregor, 2015). The management of human activities using systems-based approaches in southern African oceans has been ongoing, with programmes such as the Benguela Ecology Programme (BEP), the Benguela Current Large Marine Ecosystem Programme (BCLME) and other southern Benguela ecosystems initiatives actively contributing to our knowledge of the ecology of this SES. Recently, building up the knowledge base of the human-dimensions of the SES has started receiving attention (e.g. Paterson et al., 2010; Sowman et al., 2013) but fisheries managers continue to struggle with the challenge of how to effectively, balance multiple objectives under an EAF (Cochrane et al., 2009; Augustyn et al., 2014).

South Africa has made some progress towards achieving the implementation of an EAF in its ocean environments. Noteworthy is the agreement on sets of comprehensive management objectives for a number of fisheries (Shannon et al., 2006; Nel et al., 2007; Petersen et al., 2010) through ecological risk assessments (ERAs), the further development of the ERA methodology (to measure progress towards achieving the objectives, most notable in terms of indicators and a knowledge-based tool (Paterson & Petersen, 2010), spatial approaches (Sink et al., 2011) and a methodology to forecast the likely effect of different management strategies in systems contexts (Shannon et al., 2010; Smith et al., 2011; Watermeyer et al., 2016; Weller et al., 2016; Cooper & Jarre, 2017a,b; Ortega-Cisneros et al., 2018).

Although progress has been made in the human dimensions of an EAF (Paterson et al., 2010; Duggan, 2012, 2018), challenges with incorporating the human dimensions into governance approaches and management decisions remain. Most notable is the progress with the implementation of the SSFP. South African research into the human dimension of the marine SES often places the focus on fishing communities, focussing (amongst others) on research into the human and political-economic dimensions of sustainable fishing, specifically in small-scale fisheries (SSF) (e.g. Isaacs, 2012, 2013). Recent research includes assessments on the socio-ecological vulnerability and development of adaptation strategies to climate change in the Benguela Current Large Marine Ecosystem (BCLME) (e.g. Sowman & Cardoso, 2010; Sowman & Raemaekers, 2018). Social-ecological indicators for SSF and drivers and poverty in fishing communities (e.g. Hara, 2014) and governance approaches in relation to high-value species such as abalone and lobster (e.g. Raemaekers, 2009) have also been examined. Sunde & Isaacs (2008) report on marine protected areas and their impact on communities while Anderson (2011); Rogerson (2011) and Duggan (2012) focus on relational ontologies within the handline and inshore fisheries. Norton (2014) conducted extensive research into marine resource law enforcement in the Western Cape. Most of this research has taken place on South Africa's west and south coasts, adjacent to the very productive southern Benguela upwelling ecosystem.

Nevertheless, the human dimensions of the southern Cape line- and inshore fisheries remain mostly under-researched. Researching the context of the southern Cape is vital as the ecosystem in the area has a distinct species structure to that found in the more productive western and southwestern Cape (Blamey et al., 2015). The distinct species structure result in a linefishery with distinctive characteristics and contexts which is currently undergoing substantial change (e.g. Duggan, 2018) and likely requires new governance and management approaches.

1.4. Developing contexts: an added layer of complexity

Complexity and uncertainty in marine SES hamper effective management of human activities and pose a risk to resource users operating at various scales. Risks for small-scale fishers are often the greatest as these are the fishers with the lowest (specifically) financial capital. The subjection of these communities of fishers to an increasingly wide variety of social, economic, political and biophysical stressors and changes (eg. O'Brien & Leichenko, 2000; Marshall et al., 2010; Perry et al., 2010; Zou & Wei, 2010; Cinner et al., 2012; Bennett et al., 2016a), leave fishers and management authorities to contend with risks linked to the stressors/changes. Furthermore, much research to date has placed the focus on single scales, with single stressors, but fishers are subjected to multiple stressors at multiple scales (O'Brien & Leichenko, 2000; Ommer & Team, 2007; Leichenko & O'Brien, 2008; Bunce et al., 2010; Gammage, 2015; Gammage et al., 2017a) with the capacity to respond to change brought about by stressors affected by actions at multiple scales (Adger & Vincent, 2005; Cinner et al., 2009.

Challenges faced by developing countries add a layer of complexity to the management of SES. Decision-making at policy and implementation scales need to address a developmental context, in that social and economic conditions should be prioritised and advanced. Without a careful balancing act, the sustainable long-term management of fisheries in heavily exploited marine ecosystems is neglected. Added to global agreements, such as Agenda 2030 (UN, 2015a) and the Paris agreement (UN, 2015b), regional and national plans such as Africa's agenda 2063 (AU, 2016) and South Africa's National Development Plan (NDP) (NPC, 2011) adds pressure on policy-makers to craft and implement balancing policies. At the same time, challenges faced by the establishment of a democratic developmental state (Edigheji, 2010), together with managing risks presented by global phenomena such as climate change, must be addressed. All this considered, decision-making at various scales marine SES can be extremely difficult for resource users and managers alike, underlining the need to re-evaluate the tools and approaches used to make decisions within the various decision-making scales.

1.5. South African (small-scale) fisheries

Gazetted as an instrument to address inequalities arising from South Africa's past, the MLRA provides the framing for the regulation of fisheries by regulating the use of marine resources through a rights allocation system. The objectives and principles of the Act relate closely to those of an EAF. This includes the need to view ecosystem conservation holistically; the sustainable conservation of marine resources; preserving marine biodiversity; the application of the precautionary principles; and the need to balance sustainability with developmental goals including economic growth, human resource developments, capacity building and job creation (RSA, 1998; DEAT, 2004, 2005). SSF was not provided for in the initial post-Apartheid policy framework (MLRA), and the continued failure to acknowledge and cater for traditional small-scale fishers resulted in mass and legal action being launched by civil society groups (Sunde, 2004; Isaacs, 2006). Despite the numerous contributions made by this sector, the role played by small-scale fishers in contributing to food security, poverty alleviation and rural development were severely neglected (Sowman et al., 2014). Subsequently, the gazetting of the small-scale fisheries policy (Act No 474 of 2012) (SSFP) has taken place, and the MLRA amended accordingly (RSA, 2014).

In South Africa, fisheries provide food security and a livelihood contribution to an estimated 30,000 people (Sowman, 2011; Sowman et al., 2014). The Marine Resources Amendment (Act No 587) of 2014 has clarified the definition of small-scale fishers and define such fishers as "a member of a small-scale fishing community engaged in fishing to meet food and basic livelihood needs, or directly involved in processing or marketing of fish, who— (a) traditionally operate in near-shore fishing grounds; (b) predominantly employ traditional low technology or passive fishing gear; (c) undertake single day fishing trips; and (d) is engaged in consumption, barter or sale of fish or otherwise involved in commercial activity, all within the small-scale fisheries sector (RSA, 2014:2). Rights allocation in the linefish sector with which the research is concerned is carried out by the Department of Forestry and Fisheries (DAFF) by a total applied effort, which limits the number of fishing boats (DEAT, 2005; Sowman et al., 2014).

Under current implementation across South Africa, the SSFP provides a framework for the management of small-scale fisheries while specifically addressing sustainable development, empowerment, and inequality. The SSFP is a people-centred approach to management and recognises the critical role played by marine resources in poverty alleviation (Sowman et al., 2014). Importantly, the SSFP – as a newer policy better in line with modern best practices - more explicitly deals with the EAF (Cochrane et al., 2015). Specifically, it outlines that marine resources harvested and utilised within the context of the SSFP will be done in accordance with the principles of an EAF, that the integrity of EAF and the implementation of the SSFP cannot compromise sustainability (and the need to balance human rights whilst ensuring the sustainability of resources (DAFF, 2012). The policy also calls for the implementation of more direct co-management approaches where fishers will have an opportunity to more directly interact with government in the development, implementation and evaluation of policy and management plans (DAFF, 2012). For fishers, this requires the establishment of a local co-management structure, that will manage local fisheries together with government while maintaining links with the national management of other fishing sectors. Local co-management structures will be nested within a multi-tiered institutional system comprising a Consultative Advisory Forum at national level, a dedicated small-scale fisheries management working group at DAFF and co-management committees and community-based legal entities at the local level (DAFF, 2012; Sowman et al., 2014).

Importantly, the approach presented in this thesis contributes to how this co-management process can be facilitated through a methodology that seeks to bring together diverse stakeholders, with diverse and often conflicting goals, in a structured decision-making making context. Due to the nature of the fishing activities undertaken, the impacts of changes in the marine SES and the 'wicked'[2] nature of fisheries management

[2] In light of marine SES complexity, fisheries governance (and ecosystem-based fisheries management) is considered to be a 'wicked problem' (Berkes, 2012). Wicked problems display the tendency to have no right or wrong answer, no technical solution, little to no clarity on when exactly they were solved or if they are even solvable (Rittel & Webber, 1973; Jentoft & Chuenpagdee, 2009).

challenges, the small-scale fishing sector (as well as the small-scale commercial line fishing sector) is particularly vulnerable to change. The same is also true for fisheries that operate in the south coast subsystem of the southern Benguela, where the research area for this study is situated.

1.6 Managing fisheries under change and uncertainty in the southern Benguela: the need for scenario approaches

The Benguela Current Large Marine Ecosystem (BCLME), an eastern boundary current system dominated by coastal upwelling, is a highly productive region that sustains important fisheries for Angola, Namibia and South Africa (e.g. BCC, 2013). The BCLME, consisting of four sub-(eco)systems, has been shown to exhibit variability at several temporal scales and is undergoing warming at its edges (Rouault et al., 2010; Dufois & Rouault, 2012; Blamey et al., 2015; Jarre et al., 2015). Various natural and anthropogenic drivers are responsible for the observed spatial and temporal changes in the southern Benguela (Blamey et al., 2015) with the various scales at which change is taking place making it difficult to tease out exact drivers and interactions (Moloney et al., 2013). The observation of long-term trends in ocean temperature is complicated by decadal-scale variability in the coastal and shelf waters of the Southern Benguela (Jarre et al., 2015). While a general warming trend of both inshore and offshore ocean temperature is expected on the Agulhas bank, different datasets have shown conflicting trends regarding cooling and warming of sea surface temperature (see Blamey et al., 2012, 2015; Lamont et al., 2017). It is important to note that there is much less agreement between the signals of different datasets for the southern coast of importance to the (hand)line fisheries in focus of this study than for the west coast. These discrepancies are the focus of ongoing research (Jarre et al., 2015; Ward, 2018).

Research on the South African west coast shows that decadal-scale changes are indicative of regime shifts[3] in the southern Benguela inshore region (Blamey et al., 2012). While stressors do display decadal-scale variability, the effects of climate change seem inevitable and add to the complexity of the marine SES which fisheries form part of. This does not only pose challenges for fishery resources but the people and communities who depend on them both in the west-coast subsystem (Jarre et al., 2013) and in the south coast (Gammage et al., 2017a,b). For the South African linefishery, with the over-exploitation of almost all warm/temperate, bottom-dwelling and subtidal linefish documented, the risk of commercial extinction for some species is a reality. This over-exploitation has an effect and negative impact on productivity (with associated social and economic impacts), trophic flow, and biodiversity of the ecosystem (Griffiths, 2000). For the inshore Agulhas Bank, Currie (2017) demonstrated a drastic change in species composition (further discussed in Chapter Five).

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[3] Regime shifts refer to "sudden strong deviation from one fairly stable system state to another, where various components of the system are affected, and the time-frame for the change to occur is relatively short" (Jarre et al., 2006).

There is, however, much uncertainty linked to these expected changes. This uncertainty, exacerbated by uncertain rates of change in natural systems, make it difficult to manage behaviour within the context of the marine SES. Uncertainties in SES are generally difficult to quantify as some key drivers are unpredictable and the change in many cases is nonlinear and complex; human response actions to forecasts tend to be reflexive, and the system may change faster than the forecasting models can be recalibrated particularly in turbulent periods of transition (Walker et al., 2002). Traditional forecasting approaches will likely not overcome the limitations posed by variance uncertainty in models, thereby hampering decisions towards mitigation and adaptation (Quay, 2010). These challenges do not only present a problem for managers and policymakers, but also for fishers whose livelihoods are influenced by the changing contexts of the system together with management decisions which have in the past had unexpected negative consequences. In the southern Benguela, an ecosystem regime shift coincided with the roll-out of individual rights in the early 2000s. In their analysis, Jarre et al. (2013) emphasise the amplification of hardships to communities at the west coast resulting from the unpredictable spatial change in important fisheries resources.

Recent research into responses to change in the SES in the southern Cape linefishery by Gammage (2015) and Gammage et al. (2017b) identify varying levels of adaptive capacity in these low- to middle-income communities. The strategies implemented by fishers, classified as coping, reacting or adapting, are dependent on both social and financial capital. Importantly, the research found that although some groups of fishers were making, long-term adaptive changes, these short- to long term adaptations took place within the context of the fishery. Within the context of increasing uncertainty within the SES, the authors advocate for fishers to implement scenario-based approaches to aid long-term decision-making for these fishers.

To circumvent the limitations of forecasts, scenario planning approaches to future change are a favoured approach to build adaptive capacity for resources users (DEA, 2013; IPCC, 2014; IPBES, 2016). Scenario-based approaches (discussed in detail in Chapter Two), provide us with an opportunity not only to reframe some of the challenges (problems) encountered in marine SES but also offer an alternative to forecasting dynamically to consider future impacts and consequence of change. Additionally, through the implementation of such approaches, it is also possible to address some of the critical components required for an EAF, and more specifically short-comings in the successful implementation thereof (successful implementation of an EAF would also be beneficial to achieving sustainability in SSF). Importantly, through the development and implementation of scenario-based approaches, we are also able to address different system needs at various scale simultaneously which may be a crucial step forward in appropriately addressing the challenges associated to up and downscaling in SES. Scenario planning has been suggested as an important tool and way forward in the management of marine SES in the context of the southern Benguela (Jarre et al., 2013). This approach is in line with approaches taken in global assessments such as the IPCC assessments of climate changes and the IPBES ecosystem assessments (e.g. IPCC, 2014; IPBES, 2016).

While scenarios based on forecasts for South African fisheries have been conducted (e.g. long-term adaptation scenarios for South Africa (DEA, 2013), participatory scenario planning approaches together with fishers have not been introduced or initiated as a decision-making or change-management tool, nor has it been employed to inform governance or the implementation of an EAF at the national scale.

1.7. The southern Cape research area

The Agulhas Bank subsystem of the southern Benguela overlaps with one of the climate change hotspots identified by Hobday & Pecl (2014). It is situated off the southern Cape coast in South Africa and includes the roughly triangular Agulhas bank, extending approximately 117 km off Cape Agulhas within the South African exclusive economic zone (EEZ). The coastal waters represent the fishing grounds off the southern Cape for the small-scale linefishery , which is the focus of the research presented in this thesis (Figure 1.2). The South African (hand)linefishery is a boat-based, multi-user, multi-area and multi-species fishery that conducts mostly day trips ranging from six to eight hours. The southern Cape linefishery operates in the inshore area of the Agulhas Bank. The primary target species of the fishery is silver kob (*Argyrosomus inodorus*) (Griffiths, 2000; Blamey et al., 2015), other species targeted in the absence of kob include silvers/carpenter (*Argyrozona argyrozona*), redfish (like red roman, *Chrysoblephus laticeps*) and various species of shark. In recent years, increasing resource scarcity, variability in physical systems and policy uncertainty has plagued this fishery (Gammage, 2015; Gammage et al., 2017a). The crew component – small-scale fishers who act as crew in the small-scale commercial linefishery – were not well represented in previous research and is the focus of this study. They mostly reside in the towns of Mossel Bay, Bitouville, Melkhoutfontein, Vermaaklikheid and Slangrivier (Figure 1.1). These sites stretch over 200 km of coastline in the southern Cape and consist of fishing communities in rural, semi-rural and peri-urban areas with direct and indirect access to the ocean (Gammage et al., 2017a).

The Southern Cape Interdisciplinary Fisheries Research (SCIFR) project, a long-term interdisciplinary research project established in the southern Cape, uses SES thinking and aims to generate a new understanding of social-ecological interactions which will contribute towards building SES that are better equipped to effectively respond to change (Jarre et al., 2018). Importantly, this project's research takes place at smaller, localised scales, specifically within the context of the South African linefishery. Research undertaken within the context of SCIFR include research into relational ontologies in the kob fishery (Duggan, 2012); descriptions of stressors that drive change and fishers' responses to them (Gammage et al., 2017a,b); climate variability in local farming and fishing systems (Ward, 2018); and ethnographic research built around the themes of education, citizen science and direct marketing of fish (Duggan, 2018). Outside the scope of SCIFR, Greenston (2013) and Greenston & Attwood (2013) examine issues of by-catch management in the inshore trawl fishery that operates in the same area as the southern Cape line fishery.

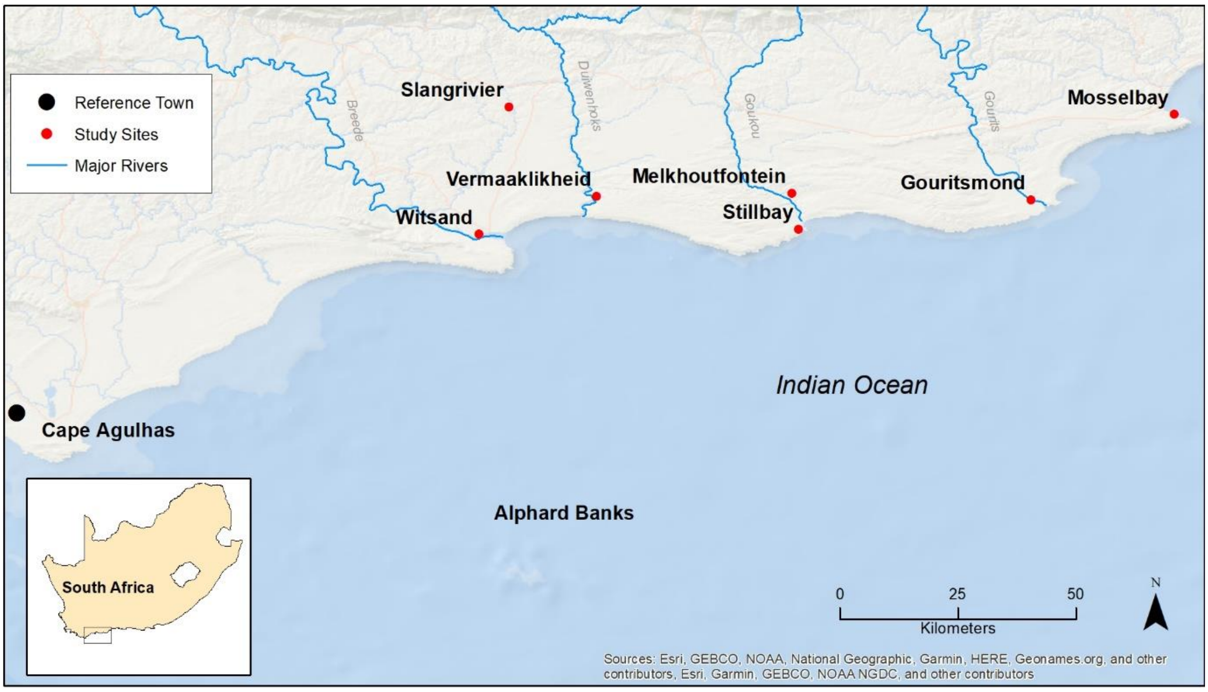

Figure 1.2. Map of the research area. Mossel Bay - large urban centre situated on the coast; Bitouville - situated next to Gouritsmond at the Gourits River mouth ; Melkhoutfontein - situated approximately 8 km from Still Bay on the coast, Vermaaklikheid - 7 km from the coast as the crow flies, but fishers often travel 47 km by road to launch in Still Bay; Slangrivier - situated 26 km inland as the crow flies, fishers travel 38km by road to Witsand where boats are launched at the Breede River mouth.

1.8. Situating this thesis

Based on the challenges highlighted by complexity, uncertainty, 'wicked problems', development- and policy objectives at international and national scales, a need arises to develop and implement multi-use methods that can simultaneously address multi-faceted complex problems such as capacity building at the small scale and informing EAF implementation and sustainable development at the larger scale. These challenges underscore the already identified need to re-evaluate how marine SESs are perceived, studied, managed and governed. From a methodological perspective, this does not necessarily constitute a need to 'reinvent the wheel' but to consider how existing methods can be used and applied in novel ways. The use of structured decision-making tools (SDMTs) in an interactive and iterative participatory scenario-based approach in the context of the South African linefishery is an example of how existing methods can be used in novel ways to address some of the challenges raised by changing marine SESs at various scales of operation.

The research presented in this thesis explores a process by which a participant-led structured decision-making process could be implemented in the future. This is important as it adds to our knowledge of the human dimensions of the South African linefishery and makes an important contribution to the body of knowledge by (1) enhancing our understanding of the South African linefishery , specifically the southern Cape which is under-researched in this regard, and (2) providing important insights and lesson into how structured decision-making tools can be developed and implemented in an interactive and iterative scenario planning approach in the context of the South African linefishery , specifically the southern Cape, where no such futures planning exercises or research has taken place.

Knowledge gaps in the human dimension of the marine SES have been highlighted at the local scale by the Southern Cape Interdisciplinary Fisheries research project (SCIFR) (Jarre et al., 2018). The SCIFR project forms the background to previous work which describes stressors that drive change and fishers' responses to them (Gammage et al., 2017 a, b). At the larger (national) scale, a cross-country comparison carried out by the Belmont Forum-funded project "Global Understanding and Learning for Local Solutions (GULLS)" has presented a unique opportunity for comparisons among different coastal communities in the different hotspot countries (Hobday et al., 2016). Data collected in the southern Cape for a comparative social vulnerability assessment (Aswani et al., 2018) as a first step, allows for the analysis of participant responses at a finer resolution. This analysis supplements earlier work (Gammage et al. 2017a, b), and is an essential component of current and future research into responses to future change and system transformation under the SCIFR project.

Results from previous research by Gammage (2015) show different change response strategies currently implemented by fishers while highlighting an often-haphazard way of decision-making and the poor understanding of the rationale used in decision-making. These communities also seem to be coping and reacting rather than adapting. To ensure sustainable livelihoods, these communities need to respond to these changes in a more informed, structured manner that allows them to diversify their livelihoods activities while making informed decisions (Gammage, 2015; Gammage et al., 2017b). Although conducted as a small, local study the research has impacts and insights into how the human dimension of the marine SES can be better integrated into the EAF in South Africa by offering a methodological blueprint for future, multi-stakeholder processes at bigger scales of operation whilst promoting social learning and capacity-building for participants operating at the local scale. While the research does not directly contribute to a policy process, the results can eventually inform policy and management decisions by laying a foundation of research for scenario building at the community scale.

Belton & Stewart (2002) and Haapasaari et al. (2012a) emphasise the significance of adequate problem identification and framing at the start of any policy process. This means that the most critical elements and interrelationships within a system will be taken into consideration whilst facilitating the understanding of problems in their entirety, helping identify the right questions whilst denoting the first steps in developing holistic knowledge, research and ultimately, management strategies (Young et al., 1999; Walker & Harremoës, 2003; Sluijs & Craye, 2005; Clark & Stankey, 2007; Verweij & Densen, 2010). Structured decision making is an approach by which system descriptions can be improved upon together with existing tools for problem framing and re-framing in itself the first step in any scenario planning process (Belton & Stewart, 2002; Kahane, 2012a). Not only is the use of the tools and process beneficial to the individual/household/community as participants, but also to researchers and managers alike. This knowledge is essential for the development and implementation of a scenario-based approach to future adaptation in support of sustainable community wellbeing and development in, e.g. SSF.

1.9. Aims of this thesis

This thesis research directly contributes to building the understanding of local scale interactions and their impacts within the context of the southern Cape linefishery. Drawing on a thematic framework of stressors that lead to change in the research area (Gammage, 2015) and recent work in connection with the Global Learning for Local Solutions (GULLS) project, this iterative participatory approach goes beyond qualitative system descriptions by making use of SDMTs with a group of marginalised fishers who have never before participated in such as process. The overarching scenario-based approach, implemented as a prototyping exercise,[4] broadly seeks to explore methods by which system descriptions are enhanced, problems reframed, and future orientated thinking engaged within an iterative and participatory process in disadvantaged communities. Specifically, the research aimed to:

1. Determine and describe some of the drivers of change in the fishery system of the southern Cape using the perspectives from the crew component of the linefishery in the area.

2. Establish what interactions and feedback loops (drivers of change) exist and interact at various scales within the context of the linefishery in the southern Cape.

3. Develop a prototype Bayesian belief network (BBN) model in an iterative participatory process to establish the prominent drivers of change within the fishery system (from the crew perspective). The use of BBNs in this context is not only a problem restructuring and decision-making tool, but also provides valuable insights into the values held by participants.

4. Develop, together with fishers, four stories of what the future may hold for Melkhoutfontein using an iterative participatory scenario planning exercise based on some of the principles of transformative scenario planning approaches.

[4] A prototype model (or in the case of this research, modelling process), is an original model/process which can serve as a bases for other models or processes. The implementation of a prototype model (or in the case of this research, process which makes use of modelling techniques), holds many advantages when carried out in an interdisciplinary context – it provides the means to deal with potential in the process, serves to establish a 'common' language and sense of purpose between participants, produces preliminary results and provides all participants a sense of the ability/potential of the process (model) thereby allowing for the reconsideration or refinement of the process (model) (Starfield & Jarre., 2011).

5. Evaluate the contextual suitability of the application of the various tools used throughout the research process and recommend next steps in a larger scenario planning process.

6. In support of the implementation of an EAF in South Africa, create an opportunity for disenfranchised fishers to engage in a process that could improve adaptive capacity by enhancing their understanding of changes in the marine SES and possible responses to these changes.

Figure 1.3 shows this overall framing for the research and indicates how the research contributes at multiple scales of interaction.

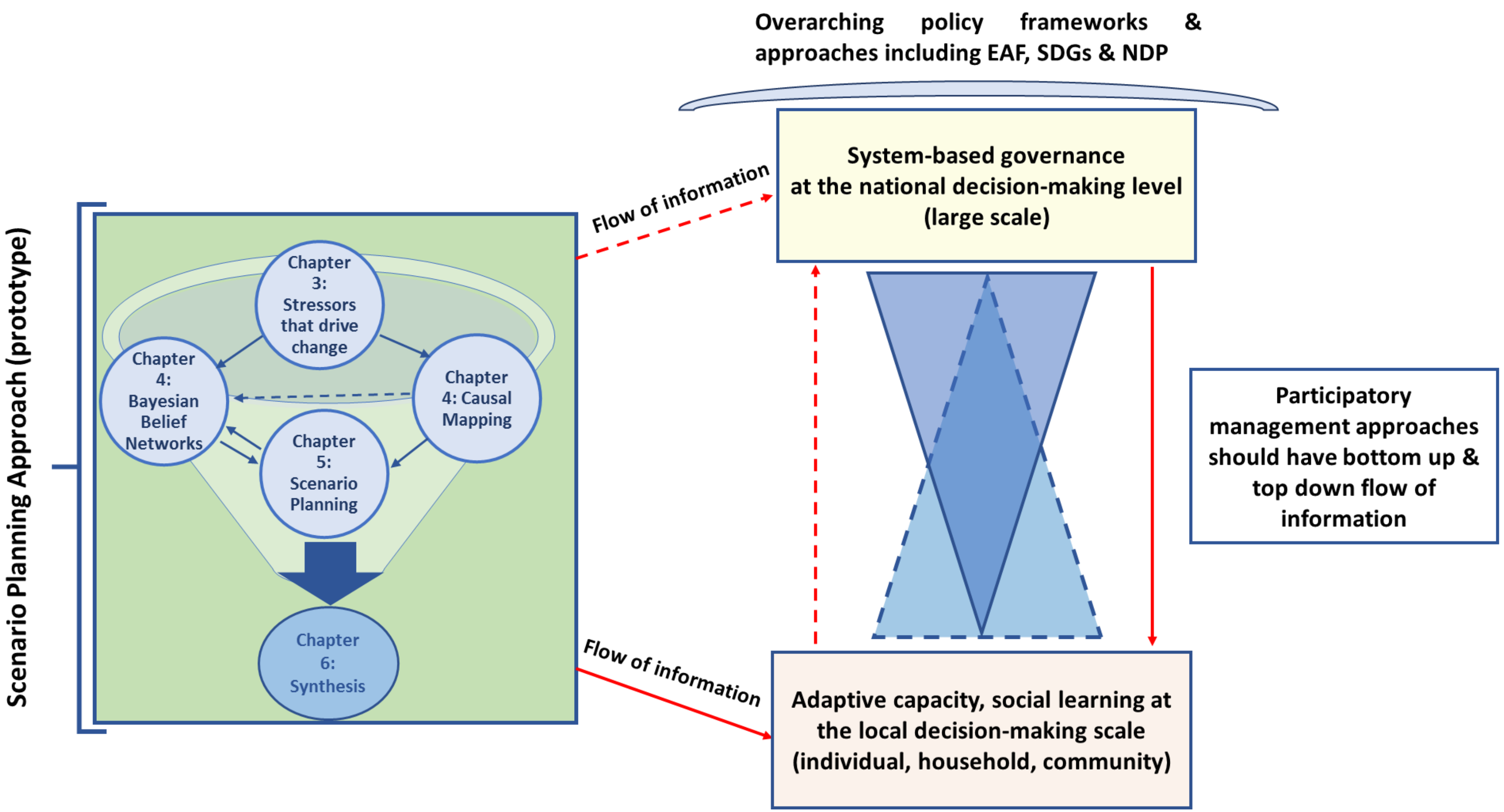

Figure 1.3. Overall framing within which this research takes place. From left to right - this prototype scenario-based approach to management employs various decision-making tools to generate both quantitative and qualitative knowledge. For this project (shown by the solid red lines which are 'flow of information'), the knowledge generated through the implementation of the tools contributes to capacity building (enhancing adaptive capacity) and more informed decision-making by the individual/household or community at the smaller scales of operation. While top-down interactions (scaling down) is functional in the current management paradigm (shown by the inverted triangle), practical mechanisms to facilitate bottom-up interactions are ill-defined or non-existent. Through the implementation of the approach, a method is identified in the present research that facilitates the multi-directional flow of information (shown by broken lines) in the pursuit of the implementation of an EAF together with other over-arching policy goals such as Agenda 2030.

1.10. Thesis structure and research questions

The over-arching question which this research seeks to answer is:

Are structured decision-making tools suitable for use in an interactive and iterative way with participants in the South African line fisheries? Can the methodology, which aims to build capacity and enhance adaptive capacity at the small scale, have the potential at the same time to inform the implementation of an EAF in South Africa meaningfully?

The following presents the chapter-specific research questions together with a brief outline of each the chapter:

Chapter Two: Literature review and methods

The literature reviewed firstly examines fisheries as SESs and explore some of the key schools of thought linked to SESs thinking including vulnerability, adaptation, resilience, and transformation. Next, is a brief overview of the use of structured decision-making tools in the management of complex and uncertain SES, is presented. A comprehensive overview of the three decision-making tools used in this approach – causal mapping, Bayesian modelling and scenario planning – follows. The chapter concludes with an overview of the overarching (general) methods used in the development of the approach in the context of the thesis.

Chapter Three: Thematic analysis of stressors as described by the commercial linefishery crew (small-scale fishers)

This chapter presents a thematic analysis of stressors that lead to change based on fishers' perceptions as primary data, supplemented by research literature as secondary data. The thematic analysis has been done to form a more holistic view of the driving forces of change within the context of the crew component of the fishery. This analysis complements previous research (Gammage, 2015; Gammage et al., 2017a) as it aims specifically to plug a knowledge gap in this previous research and forms the basis of both the causal diagrams and the Bayesian belief networks. The chapter speaks to Aim 1 from Section 1.9 and seeks to answer the following research questions:

Is the knowledge of drivers of change held by fishers who act as crew in the linefishery (also identified as traditional small-scale fishers) in the southern Cape is the same or complementary to that described by other user groups (mostly skippers)?

Chapter Four: Making sense of wicked problems – Are structured decision-making tools useful in problem structuring with marginalised fishers in social-ecological systems?

Chapter Four explores the use of structured decision-making tools, specifically Causal diagrams and Bayesian belief networks (BBNs) in an interactive and iterative research process and specifically addresses Aims 2 and 3 from Section 1.9. The general question asked in this chapter is *"What can be learned about the fishery system and its interactions through the use of the decision-making tools and their outputs?"* and *"What can be learned through the iterative implementation process?"*

The first section of this chapter addresses the causal mapping process and seeks to answer specific questions:

(i) What interactions, including indirect interactions and feedback loops[5]*, are revealed through the use and development of causal maps for the southern Cape linefishery?*

(ii) Is the use of the causal maps appropriate and beneficial in an iterative and interactive process with stakeholders who are unfamiliar with more structured decision-making processes?

To address the research questions, causal diagrams showing the drivers of change and interactions were constructed based on information obtained for each community using household survey results from Chapter Two and the thematic framework identified by Gammage (2015). These diagrams, constructed for the crew component and per town, have been scaled up to provide coverage of the whole research area. Research data were used to supplement the data obtained from the participants to provide a more holistic and balanced system description. The first causal diagrams were fed back to key participants to allow for refinement of the final product. Importantly, the causal diagrams form the conceptual systems model for the weighted hierarchy and BBN and a tool which workshop participants can use and refer to throughout the workshopping process.

The second part of the chapter is concerned with the BBN development process and seeks to answer the following questions:

(iii) What are additional insights gained into the drivers of change and linked uncertainty that exists in the southern Cape linefishery system through the development and use of the weighted hierarchy and BBN?

(iv) Is the use of the BBN appropriate and beneficial in an iterative and interactive process with stakeholders who are not familiar with the tool?

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[5] A feedback loop in a causal map is a 'system structure that causes output from one node to eventually influence at the same node' (http://thwink.org).

A BBN, with the central tenet of achieving a sustainable fishery derived income, was constructed for Melkhoutfontein. Participants identified a hierarchical structure with drivers which places the most influence on the central theme. The resulting BBN and sensitivity analysis provides insights into drivers which influence decision-making and allows for the exploration of the differences between the initial hierarchical structure and the model outputs and allowed for the further exploration of the uncertainties linked to the different drivers of change as well as the interactions amongst these drivers. The results of the sensitivity analysis also helped to identify significant additional key driving forces (KDFs) for the scenario stories constructed in Chapter Five.

The research and results presented in this chapter not only further explore the indirect drivers of changes together with feedback loops not apparent from the thematic analysis while providing graphical models of the complex system, but also provides essential experience and insight into the use of structured decision-making tools with stakeholders. The analysis presented in the chapter focusses not only on new insights of system interactions but, as importantly, on the process and insights gained from the process thereby addressing aims 5 and 6 within the context of the causal mapping and BBN.

Chapter Five: *S*cenario-planning

This chapter not only reports on the development of scenario stories as a product but also reflects on the process through which the stories were developed. The scenario-planning process described in this chapter was carried out at the small scale as a prototyping exercise and specifically addresses Aim 4 from Section 1.9. The analysis presented in the chapter focusses not only on the results but, as importantly, on the process and insights gained from the process thereby also contributing to addressing aims 5 and 6 within the context of the scenario prototyping exercise. This is done by addressing the following questions:

(i) What are possible pathways (future stories) for the future development of Melkhoutfontein within the context of key driving forces as identified through an interactive, participatory scenario planning process?

(ii) Does this process promote capacity building for disenfranchised (and often powerless) fishers, to not only create adaptive capacity at the smallest scale of operation, but al using methods that could potentially be implemented at larger scales of operation in support of the implementation of an EAF?

This scenario-planning prototyping exercise utilised the principles of a transformative scenario planning process to formulate and design long-term scenarios for the fishing community of Melkhoutfontein. This was achieved using a series of workshops where fishers from Melkhoutfontein were engaged. Four scenario stories were constructed following the workshopping process. These stories were constructed around the interactions of two key driving forces identified by fishers. Information regarding fish availability and potential warming/cooling in the Agulhas Bank was added to the fisher stories to derive the final stories. These additional drivers were chosen based on the outputs of the BBN sensitivity analysis. Information on the future macroeconomic trajectory and potential socio-economic futures (derived from large-scale scenarios such as the Indlumithi SA Scenarios 2030) was added to complete the stories. These stories were fed back to participants through a pamphlet distributed at the end of the research process.

Chapter Six: Synthesis and conclusion

Chapter Six provides a synthesis of key findings that stem from Chapters Three to Five by specifically addressing aims 5 and 6. As a start, I reflect on what insights the use of the tools and the development of the approach has provided regarding our knowledge of the southern Cape Linefishery - specifically, new insights gained from the use of the causal maps and Bayesian belief networks (BBNs). Next, follows a reflection on the scenario-based approach and the processes followed throughout. The chapter concludes with a reflection on the implications of the approach on the implementation of an EAF in South African fisheries, governance in general and issues of scale.

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Chapter Two

Literature review and overarching approach, design and methods

This literature review seeks to provide an overview of concepts and topics linked to the development of a scenario planning approach as a means of responding to change in fishery systems. First, as the thesis is grounded in systems-thinking approaches in the context of fisheries as social-ecological systems (SESs), an overview of the development of the SES framework and related schools of thought on responding to change in an SES is provided. The motivation for the use of scenario planning as an approach follows. As the research specifically uses structured decision-making tools (SDMTs) to develop system understanding and as a means of problem framing and restructuring, the definition and role of SDMTs and modelling with stakeholders is described. Next follows an extensive overview of the SDMTs used in this research – Causal Maps (diagrams), Bayesian belief networks (BBNs) and Scenario Planning, including participatory scenario planning. The chapter concludes with a section outlining the over-arching approach and methods adopted for this thesis.

2.1. The social-ecological systems perspective and associated schools of thought

The research presented in this thesis draws on a social-ecological framing. In this section, fisheries as SES are firstly defined and explored. Next, as issues of scale are central to decision-making contexts in SES, the concept of scale (and complexity) in relation to SES is explored. Although this research is not explicitly framed within the context of resilience and transformation, they are important schools of thought which underpin much of the previous research upon which this thesis builds as well as an overview of some schools of thought related to the study of SES. The section thus concludes with an overview of resilience and transformation and their application within SES and fisheries.

Fisheries as social-ecological systems

Fisheries are widely recognised as part of marine SES (e.g. Ostrom, 2009). Early fisheries SES research strived to involve wider variety sources of knowledge in the management of human behaviour in ecosystems (Berkes & Folke, 1998; Berkes & Jolly, 2002; Berkes, 2003; Olsson et al., 2004). The authors maintained that there was a need to develop a framework to facilitate knowledge integration. Berkes & Folke (1998) in their initial analytical framework – aiming to investigate social structures and interactions shaping management practices - moved towards working with multiple perspectives while integrating the human and ecological in an overarching framework.

Ostrom in 2007, defined a framework within which to analyse SES which identified essential components and interactions within the SES to inform the development, structure and attributes of the system (Ostrom, 2007). Importantly, the concepts outlined in the framework envisioned enabling researchers with diverse backgrounds to engage with one another across SES scales (McGinnis & Ostrom, 2014). Without such integrated perspectives on complex problems, researchers not only remain bound by disciplinary limits but also to developing understandings limited aspects of the SES resulting in misinterpretations of observed phenomena and changes (Ommer & Team, 2007; Ommer et al., 2012).

In a more recent framing of the SES approach, Schoon & van der Leeuw (2015) distinguish three integral aspects of an SES. These are the integration of social and ecological perspectives into a coupled system; the assumption that SES are dynamic with a high degree of uncertainty; and an inter/transdisciplinary perspective to account for complexity and dynamics. Inherent to this is the assumption that interactions in SESs are an iterative relationship (Ommer & Team, 2007; Park et al., 2012; Binder et al., 2013), with interactions within the system encompassing multiple internal scales (Perry & Ommer, 2003; Ommer & Team, 2007). Essentially, all planetary resources utilised by humans form part of complex SESs which are comprised of multiple subsystems and internal variables from the biophysical and social (including cultural) systems (Norberg & Cumming, 2008; Ostrom, 2009). Such SESs have the ability and capacity to self-organise and adapt based on past experiences. (Folke, 2016) These systems are characterised by emergent non-linear behaviour while generating substantial uncertainties (Norberg & Cumming, 2008). Described in the context of fisheries, such complex SESs comprise subsystems such as the resource system (e.g. linefishery); resource units (fish), users (fishers) and the governance system (organisation and rules that govern fishing). Importantly, all these elements are separable, but through their interactions produce outcomes at the level of the SES. These outcomes feedback to affect the subsystems and their component as well as other SESs of varying sizes and scales (Ostrom, 2009). More recently, Biggs et al. (2015a: 8) have described SES as "cohesive systems in themselves that occur at the interface between social and ecological systems, characterised by strong interactions and feedbacks between social and ecological systems that determine the overall dynamics".

Social-ecological systems and scale

Complexity and the ensuing uncertainty within SESs make management especially difficult for long-term, sustainable outcomes (Garcia & Charles, 2007, 2008). Global environmental problems do not occur in isolation but tend to be interconnected in sometimes unexpected ways. It is thus useful to conceptualise the global environmental system as a complex adaptive system with several attributes that are not observed in simple systems. While simple systems can be described using a single perspective and standard analytical models, the same does not apply to complex adaptive systems (Biggs et al., 2015a). In complex systems, scale influences nonlinearities and tipping points, inherent uncertainty or unpredictability, self-organisation, connectivity, path-dependence and emergent properties such as resilience. All of which cannot be predicted just by examining parts of the system (Biggs et al., 2015a).

SESs comprise groups of (often diverse) interlinked resource users, together with multiple resources, which occur at multiple scales and are influenced by spatial and temporal changes in the complex system (Janssen et al., 2007). In the context of this thesis, scale refers to the extent, duration, resolution, grain and hierarchical level of the SES that include the physical dimensions of time and space (Scholes et al., 2013). For research concerned with the success or failure of the system, the biggest challenge arising is understanding the interconnections between spatial and temporal scales (e.g. Ostrom, 2009). In SESs, many research findings are scale-sensitive as responses depend on the spatial and temporal scale at which the research took place (Scholes et al., 2013).

Examining system-change over time at any one scale requires developing an understanding of inter-system connectivity at multiple scales (Scholes et al., 2013). Perry et al. (2011) illustrated the influence scale has on responses in marine SES through drawing on case studies from four different marine SES by combining the impacts of environmental and global socio-economic stressors. Those responses which took place over short time scales, and allows the system to remain unchanged, were deemed as 'coping'. Stressors occurring on longer time scales that require permanent responses to change were termed 'adaptive' responses as the marine SES moved into a new state or condition. An example is where fishing communities cope with short-term fish stock shortages by changing behaviour to accommodate a reduction in catches, whereas if shortages were experiences on the long-term and stocks collapse, the adaptation required would involve more permanent behavioural changes together with interventions from management authorities (Perry et al., 2011).

Resilience and transformation in social-ecological systems

In response to the challenges presented by scale and complexity, several sub-disciplines have evolved within the SES paradigm to explore complex system dynamics. Resilience thinking has emerged as a dynamic and changing assemblage of interrelated concepts which include adaptation, vulnerability, and adaptive capacity (Smit & Wandel, 2006). This thesis, grounded within a broader SES thinking paradigm, at times borrows from specific resilience concepts such as vulnerability, adaptive capacity and transformation where relevant.

The concepts of vulnerability, resilience and adaptive capacity are relevant to both the biophysical and social domains (Gallopín, 2006). Previous studies relating to these terms have tended to place the focus on either the ecological or social aspects of the system, with a more recent move towards more holistic conceptualisation and models of SESs (Young et al., 2006). Threats or hazards posed by disturbances or stressors at multiple scales have provided the context for research where the behaviour and evolution of SES have been described in terms of vulnerability, resilience or adaptive capacity (Young et al., 2006). In the study of the human dimensions of environmental change, specifically, when considering the anthropogenic influence on such change, vulnerability, resilience and adaptive capacity have become increasingly prominent (Folke, 2006; Janssen & Ostrom, 2006; Folke et al., 2011; Biggs et al., 2012).

Emerging from the field of ecology (Janssen & Ostrom, 2006), resilience has developed as a concept used to analyse population ecology in plants, animals and the management of human activities in ecosystems (Janssen & Ostrom, 2006) and has been promoted as an integral characteristic of a robust SES (Walker et al., 2004; Folke, 2006; Folke et al., 2010; Berkes & Ross, 2013). The concept of resilience, which emerged as a perspective to understand population interactions in ecology, has been strongly influenced the work on ecosystem stability by C. S. Holling (1961, 1973), which includes their ability to withstand disturbance and resist change (Walker et al., 2004; Folke, 2006). Grounded in system perspectives, contemporary resilience thinking emphasises the reliance of resource-dependent people on the environment and the subsequent interactions that unfold. This serves to highlight the linkages between the social and ecological in SESs thinking (Béné et al., 2012). Resilience thinking thus provides a perspective to analyse a system as being a complex adaptive system where interacting factors shape and impact the system's ever-changing nature (Walker & Salt, 2006).

The ecological concept of resilience was adapted by Adger (2000) who provided a definition of 'social resilience' or "the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change" (Adger 2000: 347). Resilience thinking was brought into the realm of general SES thinking and adopted by some social theorists by a variety of authors (e.g. Walker et al., 2002, 2004; Olsson et al., 2004; Folke, 2006; Folke et al., 2010; Berkes & Ross, 2013). Presently, the concept of social resilience highlights the dependence of social groups on the environmental health of their surroundings. This demonstrates the correlation of the resilience of the natural subsystem with the resilience, adaptive capacity, and vulnerability of dependent human resource users. Small disruptions in the natural system could have large consequences in the social and vice versa in contexts where humans remain reliant on resources such as fish (Ommer & Team, 2007).

Contemporary resilience thinking for SESs comprises three wide-ranging, interacting pathways. The first pathway is described in terms of absorptive capacity, persistence or resistance. This depicts a scenario of coping where mechanisms within the system buffer against shock or change without the need to change the status quo (Béné et al., 2012). This absorptive capacity manifests as a stable system which absorbs disturbances and maintains function with little to no change (Walker & Salt, 2006). The second pathway is flexibility or incremental change. This gradual, subtle change of the system or elements therein allows for the system to cope with the impacts of drivers of change (Collie et al., 2004; Béné et al., 2012) and is informed by "the adaptability of a system to change" (Bennett et al., 2014b: 2). From fieldwork observations, Cork (2010) suggests that where complex adaptive systems experience disturbance, subtle changes can manifest in different elements of the system and can result in the post-disturbance system displaying new characteristics. The third pathway is transformation. Transformation describes a fundamental change in the system (Collie et al., 2004; Folke et al., 2010; Pelling & Manuel-Navarrete, 2011; Béné et al., 2012; Pelling et al., 2015a; Armitage et al., 2017) into an altogether new and different form.

Adaptability and vulnerability are important terms used to describe the resilience of an SES (Walker et al., 2004; Gallopín, 2006; Folke et al., 2010). Adaptability, or adaptive capacity (Gallopín, 2006), is the ability of the system to learn to adjust to disruptions both in and outside to remain intact (Folke et al., 2010; Armitage et al., 2017). When trying to build resilience there exists, a "dynamic adaptive interplay between sustaining and developing with change" (Folke 2006: 259). This ability to change or reorganise contrasts with earlier (ecological) definitions of resilience which did not make allowance for reorganisation. Adaptation is therefore defined as "a proactive response strategy that seeks to reduce the vulnerability of a community to a change" (Bennett et al., 2016b: 3). Adaptation to environmental variability has been a focus of anthropological studies since the early 1990s with the concept subsequently becoming more common in the study of the cost of anthropogenic climate change (Janssen & Ostrom, 2006; Vincent, 2007). For approaches in SESs, "adaptation is generally perceived to include an adjustment in SESs in response to actual, perceived, or expected environmental changes and their impacts" (Janssen & Ostrom, 2006: 237). Adaptation is not exclusive to environmental changes and can include responses to political, economic and social changes in SESs.

The degree and manner to which the SES can adapt are characterised by its adaptive capacity and vulnerability to change (Smit & Wandel, 2006). Vulnerability has been defined as "the susceptibility of an entity, such as an individual, group, sector, community or country, to an endogenous change, stressor or threat and the ability of the entity to recover from that threat" (Bennett et al., 2016b: 2). System vulnerability varies as the characteristics of the system (over time) and the nature of the disturbance changes (Brooks et al., 2005). Through the process of adaptation, new vulnerabilities may be introduced (Janssen et al., 2007). This shows the contextual nature of vulnerability – which can positively or negatively by influenced by change or intervention. Importantly, where vulnerabilities overwhelm the system, new system states may emerge (Cinner, 2011). Adaptive capacity, resilience and vulnerability are linked so that an improvement in adaptive capacity can result in an improvement in resilience and a reduction in vulnerability (Brooks et al., 2005).

Transformation occurs when the pressure exceeds the ability of the system to maintain its original state, resulting in fundamental system characteristics that are altered into an entirely new one (Walker et al. 2004). Galafassi et al (2018: 1) define transformations as "fundamental changes in and across various domains spanning from individuals' mindsets, attitudes, and beliefs to social norms and practices, to institutions and political systems". A social-ecological approach emphasises how fundamental transformations can lead to changes in natural capital through the reconfiguration of social-ecological relations (Olsson et al., 2014). The importance of deliberate transformation is highlighted by Walker et al (2004). Purposeful fundamental changes are brought about by human actions with these changes usually taking three forms: collaboration, participation and shared learning; governance components (e.g. policy and co-management); and entrepreneurial action to improve livelihoods (Armitage et al. 2017).

Transformation can be viewed as a pre-emptive or forcible radical and fundamental response which occurs when a system's capacity to absorb stressors/changes are exceeded so that resilience or adaptive capacity are lost or broken down. Flexibility and innovation become limited when social groups become constrained by coping mechanisms that limit their capacity to transform (Béné et al., 2012). Thus, where system change poses a threat to livelihoods, absorptive or adaptive capacity is not a sufficient change response. These responses limit communities' ability to engage appropriately with challenges in the SES (Béné et al., 2012). To engage in deliberate transformation, people need to proactively engage more deeply with other SES components to bring about change as opposed to a passive or slow experience. Importantly, all the concepts discussed above are characterised by drivers of change and their variability and as conditions at the various scales of the SES change, the adaptive capacity, vulnerability, resilience, and transformability will also change.

To achieve sustainability within SES in increasing uncertainty, new capacities to bring about system transformation are required (Frame & Brown, 2008; Sardar, 2010; Miller, 2011; ISSC, 2012; Proust et al., 2012). This includes "approaches to help facilitate transitions, open up thinking, reimagine futures, work with intractable problems, encourage dialogue across diverse groups of people, and provide a sense of empowerment and hope in an era where the extent of the challenges seems overwhelming and debilitating" (Sharpe et al., 2016: 1). To mobilise transformations for sustainability, actors across all scales and domains need to galvanise new system trajectories. In such networks, actors can develop shared narratives about system identity, form alliances that could challenge existing power configurations and connect resources for strategic interventions (Westley et al., 2013). Simultaneously, processes where knowledge is developed collaboratively between practitioners and scientists, are suggested as a strategy for the integration of various perspectives, values and knowledge systems on nature-society relations (Neis & Felt, 2000; Lutz & Neis, 2008; Tengö et al., 2014). Such processes have been studied in several ways, including transdisciplinarity, knowledge co-production, and codesign (e.g. Flyvbjerg & Sampson, 2009; Mauser et al., 2013; Moser, 2016).

To develop an understanding of social-ecological dynamics, the resilience lens has been widely applied (Folke et al., 2016) in developed to developing contexts (e.g. Berkes et al., 2003; Walker et al., 2006; Folke et al., 2010) An example is the description of general principles for building resilience within SESs to enhance the capacity of such systems to continue providing ecosystem-services while being subjected to unexpected shocks and incremental change (Biggs et al., 2015a). Folke et al. (2011) examine traps and regime shifts within the context of the Maine lobster fishery in the United States and agricultural activities within the Goulburn-Broken catchment in the Murray Darling Basin, Australia to emphasise the importance of understanding what resilience entails. A few examples of where the resilience perspective has been successfully applied is the outcomes of high impact climate events on rural livelihoods in Central America (Mcsweeney & Coomes, 2011) influences of environmental and economic change on land-use choices among farmers in Latin America (Eakin & Wehbe, 2009); interactions between society and nature along the United States-Mexico border (Morehouse et al., 2008); and poverty traps of rural drylands in sub-Saharan Africa (Gordon & Enfors, 2008). For the southern Cape, Gammage (2015) and Gammage et al. (2017a,b) carried out research which examined drivers of changes and fishers' responses to change using a resilience-based approach to vulnerability as a theoretical and conceptual framework. This thesis builds on the work of Gammage et al. (2017a,b) albeit with an Ecosystem Approach to fisheries management (EAF) implementation being on the foreground.

2.2. Structured decision-making tools for the implementation of an ecosystems approach to fisheries management

It is widely recognised that the social-ecological and governance dimensions of an EAF are tightly coupled (Berkes & Folke, 1998; Ommer & Perry, 2011). To effectively implement an EAF, decision-makers need to balance multiple objectives, considering priorities and trade-offs between conflicting objectives in a multiple stakeholder context (FAO, 1999; Garcia et al., 2000; Degnbol & Jarre, 2004; Garcia & Cochrane, 2005) thereby bringing the need to integrate different criteria in support of decision-making, to the fore. Problem framing and structuring processes are important steps in many decision support processes which include (but are not limited to) integrated assessment (IA), multi-criteria decision analysis (MCDA) and structured decision making (SDM) (Belton & Stewart, 2002; Gregory et al., 2012). Problem structuring refers to the process of making sense of an issue by striving to identify among others, key concerns, goals, stakeholders, actions and uncertainties (Belton & Stewart, 2002). More formally defined, it is the process through which factors and issues that require further discussion and analysis in developing an understanding of the situation, is developed (Rosenhead, 1989; Belton & Stewart, 2002).

Structured decision making (SDM) provides a context for the structuring of problems that are related to multiple objectives and stakeholders. According to Gregory et al. (2012:6), SDM can be defined as the "collaborative and facilitated application of multiple objective decision-making and group deliberation methods to environmental management and public policy problems". Generally, SDM combine analytical methods with insights into human judgement to assist and inform decision-makers as opposed to prescribing preferred solutions (Gregory et al., 2012). Specifically, and in its practical implementation, SDM can be viewed as an organised, inclusive and transparent approach, based on values and preferences, which is not only used to understand complex problems but also to generate and evaluate creative alternatives (Gregory et al., 2012; Robinson & Fuller, 2017). Gregory et al. (2012) highlight that SDM is grounded in the premise that good decisions are based on an in-depth understanding of values and consequences. Importantly, the approach is able to contribute to consistency, transparency and defensibility in decision-making processes and is particularly important when considering the technical and value-based controversies that can be present in public policy decision-making contexts (e.g. Belton & Stewart, 2002; Wilson & McDaniels, 2007; Gregory et al., 2012; Robinson & Fuller, 2017).

Methodologically, SDMTs provide the framework through which decision-support processes are facilitated and implemented. These tools, developed in the context of decision sciences over the course of 50 years, are designed to assist both individuals and groups in addressing complex decisions together with difficult group dynamics (e.g. Belton & Stewart, 2002; Guimarães Pereira et al., 2005; Gregory et al., 2012). An extensive and recent overview of SDM by Belton & Stewart (2002) & Gregory et al. (2012) highlight the need for SDM - together with the SDMTs developed in support of SDM - in the context of environmental decision-making. This includes methods that help with idea summation and optimisation methods that help to structure these ideas such as casual (cognitive mapping) and value trees (Belton & Stewart, 2002).

Modelling with stakeholders has developed as a field of study where alternative management strategies can be linked to multiple objectives in a systems context (van den Belt, 2004; Gray et al., 2017). Participatory modelling (PM) involves multiple stakeholders (often scientists and members of the public) working together to develop conceptual and dynamic models in addressing environmental problems (see Whatmore, 2009; Gaddis et al., 2010; Sandker et al., 2010; Voinov & Bousquet, 2010; Gregory et al., 2012; Gray et al., 2017). However, to be able to apply these methods, one first needs to ensure that stakeholders are willing to consider the possible solutions to complex problems, which often requires them to be willing to 'sit in the same room'. In South African fisheries, the levels of conflict are often so high that many stakeholders are unwilling to engage in such processes. To this end, group interactions with a more homogenous group of stakeholders have been applied with some success (Paterson et al., 2010; McGregor, 2015; McGregor et al., 2016). The importance of stakeholder participation and engagement in the implementation of an EAF in South Africa, highlighted in Chapter One, cannot be over-emphasised. While the participation of representatives of large, established fishing companies is relatively well-developed in South Africa (Staples, 2010), stakeholder participation in fisheries management overall remains fragmented (e.g. Hara et al., 2014).

2.2.1. Application of structured decision-making tools in South African Fisheries

SDMTs have been used in various context in South African fisheries. Some pertinent applications are highlighted to demonstrate the scope completed work and highlight the contribution made by this thesis.

The first application of SDMTs is problem structuring methodology, the most prominent example being the Ecological Risk Assessments (ERAs) carried out in the BCLME (Nel et al., 2007). To trace EAF implementation, Ecological Risk Assessment (ERA) provided a means to begin to identify problems and objectives related to EAF not effectively addressed in management plans. (Fletcher, 2005; Nel et al., 2007). Under examination in the BCLME ERA were existing challenges and needs related to EAF and the development of management options required to manage resources sustainably at the level of the ecosystem (Nel et al., 2007). This type of risk analyses involves examining the source of the risk, the ramifications thereof and the likelihood that the risk may reoccur (Nel et al., 2007). Although not fisheries specific, other problem structuring methods that work well with diverse stakeholders are visual methods such as 'post-it' notes, which is a flexible visualisation tool that can be used in untangling problems in a group setting (Belton & Stewart, 2002), and causal mapping. Causal mapping is extensively discussed in Section 2.3.1.

Various comprehensive system state analyses have been concluded within the BCLME. Paterson et al. (2007, 2010) utilised collaborative methods to develop the prototype expert system that used a fuzzy-logic model of expert knowledge. The aim of the research was in aid of a multiple-criteria analysis in the context of EAF implementation efficacy in the South African sardine (*Sardinops sagax*) fishery. McGregor (2015) developed a hierarchy of weighted means to assess the efficacy of EAF implementation for ecological well-being dimension in the South African sardine fishery, adopting an iterative, participatory approach for its implementation. Importantly, McGregor (2015) and McGregor et al. (2016) emphasise the importance of social learning, and the necessity (specifically in South Africa) to place as much an emphasis on social learning as on tool development, i.e. whether that process through which tools are developed with multiple stakeholders is just as important as the end-product. Lastly, Lockerbie et al. (2016) and Lockerbie (2017), developed a methodology to evaluate ecosystem state and trends across a wide variety of ecosystems that included the southern Benguela

In their research into the human dimension of the EAF in the northern Benguela within the context of the Namibian hake fisheries, Paterson et al. (2013) and Paterson & Kainge (2014) in exploring the historical exploitation of Namibia's fish resources and its effects on fishery management, show how closer collaboration between scientists and fishers have the potential to improve the accuracy of survey estimates and stock assessments with the ultimate aim to inform fisheries management decisions. In a similar way as Paterson et al. (2010), Paterson et al. (2015) present objective hierarchies and a preliminary evaluation of the state of EAF implementation in the human dimension of the Namibian Hake fishery. For South African rock lobster fisheries, optimisation methods have been applied within the Right's allocation process in the Western Cape (Joubert et al., 2008; Stewart et al., 2009). Specifically, the authors highlight the value of using the Multi-Criteria Decision Analysis (MCDA) in creating a problem structure that can be communicated between groups, the value of causal mapping as a way to extract decision objectives and the applicability and suitability of using the methodology to address problems that involve highly divergent groups where some stakeholders are functionally illiterate (Stewart et al., 2009).

Various ecosystem modelling approaches have also been developed in support of the evaluation of alternative management strategies within an ecosystem context. Models developed within the context of the BCLME include *EcoPath/EcoSim,* a trophic mass-balanced model which has been used to explore the effects of altered fishing on three small pelagic fisheries and hake in (e.g. Shannon et al., 2000); *OSMOSE* , a spatial, multispecies, individual-based model simulating which has allowed for an exploration of the effects of overfishing on the structure and function of southern Benguela foodwebs (Travers et al., 2010); and the *Atlantis* model which present scenarios of fishing under climate variability and change (Ortega-Cisneros et al., 2017). Furthermore, the use of spatialised approaches within marine SESs is gaining traction with a wide range of spatialised approached being used in the research into South African fisheries. Such spatialised approaches include Sink et al. (2011) who report on implementing spatial approaches in identifying focus areas for offshore biodiversity protection. Kirkman et al. (2016) emphasise the need for marine spatial planning in support of the implementation of ecosystem-based management. Furthermore, Algoa Bay serves as a case study for the first South African marine area plan (see Dorrington et al., 2018). One of the drawbacks of the existing ecosystem models of the Benguela is that they emphasise offshore fisheries and thus the resolution of the models is not optimised for coastal fisheries such as the linefishery.

System models have also been used to evaluate the likely strategies for the management of the African penguin (*Spheniscus demersus*) in view of multiple drivers of change, including pollution, fishing and climate change. Weller et al. (2016) developed a stochastic, stage-specific system dynamics model with spatial components to investigate the interaction of multiple pressures on penguin population development of Dyer and Robben Islands, two prominent penguin colonies. The results show how site-specific scenarios can be used to explore conservation options in data-scarce situations. The approach followed by Weller et al. (2016) followed the concept of modelling with stakeholders following van den Belt (2004).

However, what has not yet been achieved within the South African context is the combination of objectives in the EAF dimension (Ecological-Human dimensions) with specific multiple futures as imagined by stakeholders. The contribution made by the present thesis is specifically in exploring the linkages between the social and ecological dimensions by taking a people-centred view in the context of an inshore (line) fishery. This is achieved through the implementation of a scenario-based approach which makes use of SDMTs in an interactive and iterative process.

2.3. Structured decision-making tools used in this research

Approaches derived from systems perspectives such as system diagrams (cognitive/causal mapping) and scenario planning have been taken up within SESs research in support of knowledge co-creation (Peterson et al., 2003a; Oteros-Rozas et al., 2013; Jetter & Kok, 2014). These techniques can contribute to the construction of mutual understanding among participants. By fostering learning about plausible futures, they may inform policy and enhance environmental management (Carpenter et al., 2006; Oteros-Rozas et al., 2013; Rogers et al., 2013). Adequate problem framing involves all relevant stakeholders and focuses the intention to the socially constructed nature of management challenges and problems (Belton & Stewart, 2002; Haapasaari et al., 2012b). This manner of problem framing (using structured tools such as causal maps and Bayesian network modelling) moves beyond the values and interests of stakeholders and strives to incorporate stakeholders' perceptions and line of reasoning (Clark & Stankey, 2007; Jones et al., 2011). By making it explicit how various individuals and/or groups piece together a specific problem (such as resource scarcity) it becomes possible to facilitate reciprocal and social learning, but also enhance better and more effective communication as well as the development of more effective management mechanisms (which include policy, strategies and tactics) (Clark & Stankey, 2007; Jones et al., 2011). In the research presented in this thesis, the prototype scenario-based approach makes use of causal mapping, BBNs and participatory scenarios in an SDM context. The following subsections present an overview of these tools.

2.3.1. Causal mapping (diagrams)

A causal diagram is a "qualitative model of how a given system operates" (Özesmi & Özesmi, 2004: 44). Cognitive maps are "directed graphs or digraphs, and thus they have their historical origin in graph theory" (Özesmi & Özesmi, 2004:44). The use of causal diagrams in problem structuring has been discussed by various authors (Belton, 1997; e Costa et al., 1999; Belton & Stewart, 2002; Montibeller & Belton, 2006; Stewart et al., 2009). Diagraphs were first used to depict causal relationships amongst variables defined by stakeholders instead of researchers by Axelrod (1976). The most common reasons for using causal mapping that is relevant to this research, is to facilitate the development of system descriptions, as a means to system structuring, to help decision-makers to understand, delineate and organise the problem, to elicit and structure the stakeholders' knowledge of the problem situation and to stimulate new causal thinking (Marttunen et al., 2017). Causal mapping is useful in decision-making and to examine people's perceptions of complex social systems by many researchers (Table 2.1)

Causal diagrams/maps provide a more formal, yet visual way to carry out problem structuring and are especially useful as they allow for the identification of critical areas of concern, the organisation of ideas to clarify goals and actions as well as highlighting of knowledge gaps. Causal mapping is also a process that is particularly useful if the initial problem statement is very general if the issues at hand are particularly 'messy', and when aiming to model complex relationship between different variables (Belton & Stewart, 2002; Özesmi & Özesmi, 2004). Examples include issues around southern African rock lobster fisheries (Basson, 2009; Stewart et al., 2009).

Table 2.1. Areas of Causal diagram application and related case studies/publications

Area of application	Publication	Case studies (examples)
Energy	Roberts, 1973	Development of the building and analyses of an energy demand digraphs using expert opinion.
Urban planning	Bauer & Wegener, 1975	Simulation, evaluation, and conflict analysis in urban planning
Policy	Axelrod, 1976; Hart, 1977	Application of methodology to policy areas (case studies);
Music	Bougon et al., 1977	Theoretical and empirical analysis of the Utrecht Jazz Orchestra (methodology for organisational analysis).
Decision-support	(Klein & Cooper, 1982; Nakamura et al., 1982; Montazemi & Conrath, 1986)	Use of cognitive maps to examine behaviour and perceptions of individual decision-makers (research war games); decision-support systems for software coding of causal cognitive maps, use of cognitive mapping for information requirement analysis in IT.

A more recent example includes Stewart et al. (2009) who describe the possible implementation of an MCDA process in the context of the fishing rights allocation process in the Western Cape province of South Africa where the approach used started with the preparation of summaries of data gathered from workshops as a summary of clusters. In this process, the maps served as the primary documentation of the workshop results which could be (and were) fed back to research participants for confirmation of correctness. These maps also provided the platform for analyses and reflection by researchers and allowed for critical features of the problem structure around rights allocation to be identified (Stewart et al., 2009).

A causal map is built on predetermined and defined variables as well as the causal relationship that exists between these variables. The variables could be physical, measurable quantities such as the amount of precipitation or more complex aggregation and abstract ideas such as political forces. The person making the map decides what the crucial variables are and then draws the causal relationships among the variables. The strength of these connections can then be expressed for example, with a number between +1 and -1, with the direction of the relationships indicated with arrowheads (Özesmi & Özesmi, 2004). Importantly for this research, the causal maps can be made in close conjunction with stakeholders who have unique knowledge of the particular SES (Özesmi, 1999, 2000; Prigent et al., 2008; Stewart et al., 2009). Stewart et al. (2009) show the ease in which the compilation of the maps allows for the easy identification of 'tails' and 'heads'. 'Tails' are described by Stewart et al. (2009) as "concepts with no incoming arcs, and which may be associated with external driving forces and/or policy actions" whilst 'heads' are described as "concepts with no outgoing arcs, and which therefore may be associated with consequences perceived by the group to be of fundamental importance".

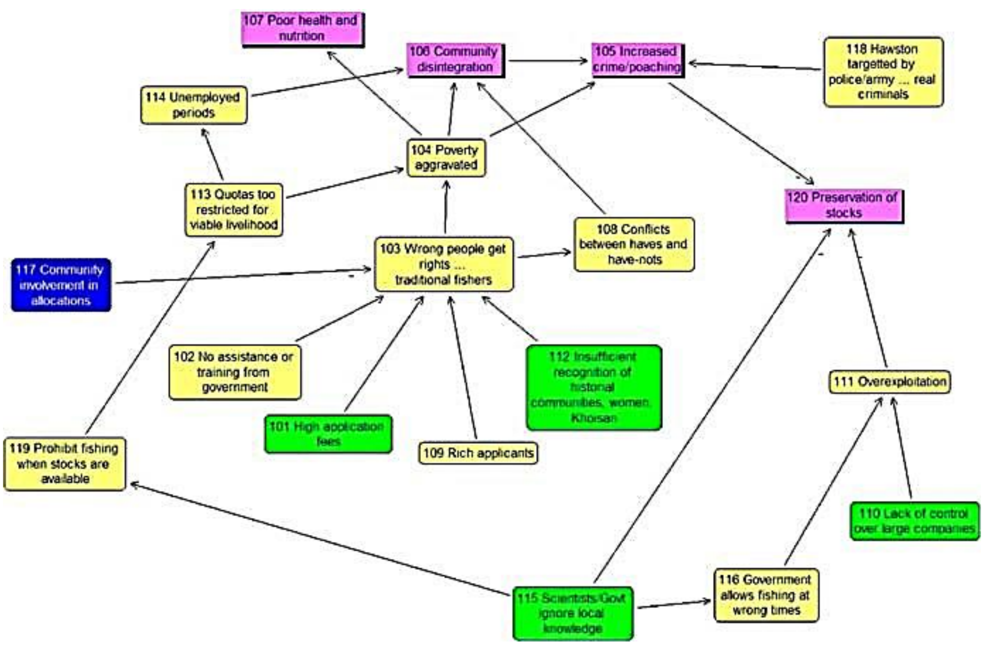

Figure 2.1. Causal map emanating from a workshop in the Hawston community during a fishing rights allocation process in the Western Cape (adopted from Stewart et al., 2009).

Figure 2.1. shows an example of a causal diagram drawn using the approached outline by Steward et al. (2009). The map shows what can be defined as a central theme (concept 103 – wrong people get rights… traditional fishers) with the remainder of the map providing an indication for the reason of the theme while at the same time outlining a new course of action which could be implemented and is followed through the arrows that constitute the map. Additional interpretation is facilitated by the classification of concepts concerning driving forces, policy proposal and goal-related issues (see Stewart et al., 2009) but also highlight the possibility of feedback loops in such a map.

Advantages and disadvantages of causal maps

Causal maps have several advantages. These include: (1) the ability to draw feedback processes (Kosko, 1987); (2) the ability to deal with several, often poorly defined, variables (Kosko, 1986); (3) the ability to model relationships between uncertain variables (by using a little or a lot descriptions) (Kosko, 1986); (4) the ability to model systems with limited scientific information but where expert and/or local knowledge is available; (5) the ease and speed with which causal maps can be constructed (Taber, 1991; Kosko, 1992a, b) whilst reaching similar results with lower sample sizes when compared to other techniques (Özesmi, 2001); (6) the ease and speed with which many knowledge sources can be combined (Kosko, 1992a); and (7) the ease and speed of qualitatively modelling the system and the effect of different policy options.

Disadvantages of causal maps include: 1) the encoding into the maps/diagrams participants knowledge, ignorance, misconceptions and biases (Kosko, 1992b); (2) the possibility of modelling "what–if's" although "why's" remain indeterminable (Kim & Lee, 1998); (3) no real-value parameter estimates of inferential statistical tests are provided (Craiger et al., 1996); (4) no regard to temporal component (time) and thus unable to model transient behaviour within an system (Schneider et al., 1998; Hobbs et al., 2002); (5) an inability to deal with co-occurrence of multiple causes shown by "and" conditions; and (6) "if & then" statements can only be coded qualitatively (Schneider et al., 1998).

Many of the disadvantages of using causal maps can be overcome through the implementation of complementary methods and tools. As an example, it is possible to partly overcome the first disadvantage by the combination of different cognitive maps constructed around the same question. The combination of maps of many stakeholders improves the resulting map (Dickerson & Kosko, 1994; Özesmi & Özesmi, 2004). The fact that the maps/diagrams do not depict "why's" can partly be circumvented by examining cognitive interpretation diagrams (where connections are drawn to reflect weight and sign of the causal relationships) as it is easier to follow the causal relationships between the variables - see Özesmi & Özesmi (2004).

For the purpose of the present research, the advantages of using the causal maps far outweigh the possible disadvantages as many of the disadvantages are not relevant in the context which the tool is being used.

Importantly, not only do the causal maps provide important insights into the drivers of change in the SES, but they also serve as the conceptualisation of the Bayesian belief network (BBN).

2.3.2. Bayesian belief network analysis

Bayesian belief networks (BBNs), also commonly referred to as Bayesian networks, are models that provide graphic and probabilistic representations of the relationships that exist amongst variables within a parameterised system. The word 'belief' is often included to reflect the subjective probabilistic nature of the approach. BBNs are tools that are suitable for decision analysis under uncertainty (Smith et al., 2018). A BBN is defined as a "statistical multivariate model for a set of variables" (Aguilera et al., 2011: 1376) which are defined regarding both qualitative and quantitative components. The term BBN refers to an acyclic[6] directed graph of probability distributions (Nicholson & Flores, 2011; Johnson & Mengersen, 2012) and was formally characterised by Judea Pearl in 1988 (Pearl, 1988). In the early 1990s, BBNs became important tools for dealing with uncertainty. This was because the formulation of efficient algorithms for probability computations became increasingly available (Andersen et al., 1990; Jensen et al., 1990; Shenoy & Shafer, 1990). The potential for model applications has been increased by the development of machine learning techniques (Cooper & Herskovits, 1992; Spirtes et al., 2000) which formally characterised their expressive power along with designing an algorithm that allowed for the efficient computing of probability for a given network structures (Aguilera et al., 2011). Friedman et al. (1997) advocated the use of BBNs as tools for pattern recognition or classification and showed that these models were able to compete with structuring methods such as classification trees. Advances have been made in the implementation of dynamic modelling, showing the change over time (Friedman et al., 1997).

In general, BBNs aid ecological risk-based decision-making by providing a tool that is able to integrate numerous lines of evidence, including process-related information which stems from both existing data and/or expert judgement (Varis & Kuikka, 1997a; Kuikka et al., 2011; Barton et al., 2012; Haapasaari et al., 2012a). There are many factors which motivate the use of BBNs. The graphical nature of the model assists in problem structuring (Rumpff et al., 2011), and through the process of focussing ideas in the development of the model and through a process of coproduction of the network structure (e.g. Newton, 2009), promotion of social learning between scientists and users (Davies et al., 2015). The use of BBNs encourage system structure transparency (e.g. Henriksen et al., 2007) and address the interaction between variables and uncertainty explicitly (Henriksen & Barlebo, 2008; Landuyt et al., 2013). Where appropriate and depending on the purpose of the BBN, options arising from different outcome scenarios can be explored quickly (Haines-Young, 2011). Such an option could include cost-benefit analyses of alternative scenarios and different management interventions to meet agreed objectives (Barton et

[6] "Acyclic directed" refers to the fact that the model assumes a sequential flow of information among variables and with no dynamic feedback loops (Barton et al., 2012).

al., 2012; Landuyt et al., 2014). Furthermore, BBNs provide a framework which can deal with both small and incomplete datasets (Hamilton et al., 2015), while still applying to large datasets. BBNs can 'learn' from new data so that they always reflect the current state of knowledge (e.g. Trifonova et al., 2015).

When considering fishery problems the approach is especially useful when examining human perspectives (Haapasaari et al., 2007; Haapasaari & Karjalainen, 2010; Levontin et al., 2011) whilst offering the opportunity for the integration of quantitative and qualitative data, different knowledge systems and perspectives into one model (Haapasaari et al., 2012b; van Putten et al., 2013). BBNs are also an excellent means of summarising information in complex systems (Zorrilla et al., 2007). In complex systems (such as fisheries), there is a high amount of variability not only in temporal and spatial scales in how drivers of change are perceived, but also and in response to these changes. Considering this messiness and the characteristics of BBNs, it would appear the use of BBNs in this fishery system would provide a tool for the knowledge integration and system analysis required which goes one step beyond the purely qualitative analysis of causal diagrams. Additionally, using system thinking approaches (such as the hierarchy) and the BBN as a method of policy planning may present managers with several fundamentally different future perspectives to consider when planning for the future (Postma & Liebl, 2005).

The BBN approach has successfully been applied to various disciplines and fields which include artificial intelligence, medicine, and epidemiology (Pearl, 1988; Haas, 1991a,b; Jensen, 1996; Jensen et al., 2007). BBNs have been used in environmental and management problems for more than 20 years, but have come to the fore in the last 10 years most especially in the fields of environmental modelling and integrated assessment (e.g. Varis et al., 1990; Barton et al., 2012; Smith et al., 2018). A literature review of BBNs by Aquilera et al. (2011) found that the dominant fields of application for BBNs have been computer sciences and mathematics. Although the approach has been gaining traction in environmental sciences, only approximately 4.2% of articles published in the review's timeframe are from the environmental sciences. The 19 articles shown in Table 2.2 provide examples and highlight the interest of the approach.

Table 2.2. Areas of BBN application and related case studies/publications

Area of application	Publication	Case studies (examples)
Surface and groundwater management	Reckhow, 1999; Borsuk et al., 2003, 2004; Bromley & Jackson, 2005; Castelletti & Soncini-Sessa, 2007; Ticehurst et al., 2007; Barton et al., 2008; Henriksen & Barlebo, 2008	Water quality prediction, river basin management, daily load development models in river estuaries, Eutrophication models, water resource management and well field management, assessment of the sustainability of coastal lakes
Ecology and wildlife population viability	Marcot et al., 2001; Borsuk et al., 2006; Marcot, 2006	Fish and wildlife population viability under land management alternatives, modelling of rare species under forest plan, characterisation of species risk regarding the forest plan
Fisheries and ecosystem-based management	Varis & Kuikka, 1997b; Kuikka & Hildén, 1999; Hammond & O'Brien, 2001; Hammond, 2004; Uusitalo, 2005	Use of multiple environmental assessment models by a Bayesian meta-model, Environmental uncertainties in Baltic cod, stock assessment model uncertainty, BN-driven stock assessment, estimation of Atlantic Salmon smolt carrying capacity of rivers.
Climate change	Varis & Kuikka, 1997a	Elicitation of expert judgement in case studies on climate change impacts on surface water.
Social dynamics of fishermen	Haapasaari et al., 2007; Haapasaari & Karjalainen, 2010; van Putten et al., 2013	Management measures and fishers' commitment to sustainable exploitation, Atlantic Salmon fisheries in Baltic sea, Formalising expert's knowledge to compose alternative management plans – socio-ecological perceptions to the future management of Baltic Salmon; Bayesian model of factors affecting the participation in an indigenous lobster fishery in the Torres Strait (Indian/Pacific Ocean).

BBN characteristics

BBNs make the dependence or cause and effect relationships between variables explicit. An example of this is a situation when an increase in fish abundance will increase the likelihood of fishing. The relationship between nodes is represented by the causal linking of nodes using conditional probability tables (CPTs). The use of CPTs is what distinguishes BBNs from similar model frameworks (Smith et al., 2018). Such causal relationships influence the likelihood of the outcome stages of the variable of interest shown in the BBN (Marcot et al., 2001; Ticehurst et al., 2007). In short, a typical BBN "makes use of an (i) a visual graphical representation specifying the dependence relations (links) between random variables (nodes), and (ii) a set of probability distributions for the states of each child node conditional on the states of its parent nodes, and these quantify the strength of each dependence relationship" (Smith et al., 2018: 453).

The associated directed acyclic graph (DAG) structure is one of the most important characteristics of BBNs. The DAG determines the dependence and independence relationships amongst variables and makes it possible to ascertain the relevance or irrelevance of variables regarding other variables that are of interest. Connections amongst variables in the DAG can be serial, converging and diverging with information flowing differently amongst the three connection types. It is possible to determine the variable relevant to the goal variable when the rules associated with serial, converging and diverging connections are applied (Aguilera et al., 2011). The quantitative component of the BBN is a conditional distribution for each variable and allows for the determination of the strength of the relationships between variables are once the structure has been defined by the qualitative component (Aguilera et al., 2011).

Various reliability and sensitivity analyses can be carried out on the BBN results. These include parameter and evidence sensitivity and value, and their results here are various reliability and sensitivity analyses (e.g., parameter and evidence sensitivity analysis, the value of information analysis) (Smith et al., 2018). Carrying out these procedures aid model selections, comparison, testing and evaluation of the strength of evidence (see Johnson et al., 2013) for an example application of these techniques). These procedures are readily available in most commercial software.

Advantages and disadvantages of BBNs

A complete summary of the advantages of and disadvantage of the use of BBNs is provided by Castelletti & Soncini-Sessa (2007), Uusitalo (2007) and Kragt (2009). Some advantages and disadvantages pertinent to the research presented in this thesis are highlighted here.

Advantages

BBNs are an excellent way to engage stakeholders, producing a product where knowledge and values can be incorporated in outputs of various formats (Barton et al., 2008). BBN results easily summarise information and is useful for placing the focus of dialogue on important issues (Zorrilla & García, 2010). The process permits holistic structuring of large entities, the integration of biological, social and economic issues and the clear-cut consideration of values concerning assumed facts. The use of BBNs in a participatory approach addresses structural uncertainty as it elaborates on alternative influencing factors and causalities (Haapasaari et al., 2012b). New data or knowledge required to understand the system better can be identified through the model development process (Smith et al., 2018).

Nodes in the BBN that are modelled using a probability distribution enable estimations of risk and uncertainty (Uusitalo, 2007). The probabilistic representation makes BBNs an appropriate tool for the modelling of environmental systems since it can address uncertainty (Rieman et al., 2001; Said Ghabayen & Kemblowski, 2004; McCann et al., 2006; Henriksen & Barlebo, 2008; Wang et al., 2009; Haapasaari & Karjalainen, 2010).

BBNs are also able to quickly and efficiently model complex systems with e a large number of variables (Getoor et al., 2004). Should an exact solution be unavailable, algorithms that utilise deterministic approximation methods or simulation modelling techniques can deliver approximate solutions (Aguilera et al., 2011). Missing values in input data can be addressed by the BBN and the resulting model predictions built from them (Woody & Brown, 2003; Nadkarni & Shenoy, 2004; Ozbay & Noyan, 2006; Uusitalo, 2007; Axelson et al., 2009; Bressan et al., 2009).

Haapasaari et al. (2012a) report that Bayesian-based influence diagrams are a useful tool for formalising the nature of policy problems as well as to demonstrate the different views and priorities held by various stakeholders. Their BBN can provide a base for a large amount of information (from various data sources) while maintaining simplicity and being easy to understand. It allows for the large entities to be structured holistically as well as the integration of biological questions with social and economic issues and the explicit consideration of values concerning assumed facts. Haapasaari et al. (2012a) furthermore hold that employing the participatory approach in the BBN process addresses structural uncertainty as alternative influencing factors and causalities are expanded, thereby providing a platform that allows for the effects of management measures on the system to be considered. This approach turns the attention to the logic that is used by different stakeholders in reasoning and shows where management problems are seen as similar or different (Haapasaari et al., 2012a). The associated conditional probability tables could also provide managers with valuable insight when assessing options for management outcomes (Tiller et al., 2013).

Disadvantages

Mastering the approach can require time-intensive training – although commercially available software such as Netica™ does offer extensive tutorials and background information required to operate the software. BBNs are not always suitable for dealing with dynamic systems with large amounts of variables as the computational burden required to solve probabilistic relationships increases exponentially as the number of variables increases (Zorrilla & García, 2010). It remains important when defining the BBN structure to consider the network complexity (Barton et al., 2008) as the knowledge required to parameterise the BBN grows exponentially as the number of parent (or root) nodes (and associated states) increases. The network building process and estimation of the model parameters require more data as the number of variables is increased if the accuracy is to be maintained (Pradhan et al., 1996; Tremblay et al., 2004; Ordóñez Galán et al., 2009).

Application of BBNs to fishery contexts

To understand the social complexities that exist in fisheries resources a good understanding is required of motivations, values, interests, concerns and constraints of resource users who are either directly or indirectly dependent on the resource. Also, it is required that one looks beyond competing views of different user groups in order to consider internal differences between various stakeholders as they are not homogenous (Brosius et al., 1998; Agrawal & Gibson, 1999; Brown, 2002; van Putten et al., 2013). Failure to take group (stakeholder) heterogeneity into account when making management decisions may result in inequalities and conflict and the ultimate undermining of fisheries management policies and regulation (Neis & Felt, 2000; van Putten et al., 2013).

Although they have significant impacts on management outcomes, fisher behaviour and participation are generally not well understood (van Putten et al., 2011). Van Putten et al. (2013) found small-scale rock lobster fishing in the Torres Strait in the Indian/Pacific Ocean to be influenced by social and cultural drivers. In their study it became essential to capture the complexity of value systems since these were drivers of economic activity and resource consumption. In a study of an SES on Lihir Island, Papua New Guinea, Dambacher et al. (2007) showed that complexity must be captured in models that describe decision-making and behaviour. Should the model only place focus on measurable variables, there is a risk of an oversimplification of the relationships and interactions between the social and ecological domains, their studies highlighted the difficulties of incorporating qualitative knowledge (e.g. Dambacher et al., 2007, 2009, 2015; Alexandridis et al., 2017).

The definition of a problem is the first step in any modelling exercise, including BBN construction. In the context of the present research, this problem identification process is an ongoing process which does not just take place within the context of the BBN development. The problem identification process is rather initiated within the causal map development process and - due to the iterative nature of the research (workshops) - is carried through to both the BBN and scenario planning processes.

Defining the problem is best achieved by including stakeholders from the beginning of the process so that the active participation and acceptance of the final product is assured. Stakeholders are also able to provide information about interests, concerns, perceptions, data to name a few. Different stakeholders value and opinions have been effectively shown using BBNs in the context of fisheries management (Hammond & O'Brien, 2001; Levontin et al., 2011; Haapasaari et al., 2012a). BBNs can capture behavioural complexity (Pearl, 1988) although it is difficult and often impossible to measure the magnitude of the interaction strengths of all the variables in the system to acquire deterministic relationships. General observations, defined by uncertainty, can provide qualitative information about variable interactions (Dambacher et al., 2007). Levontin et al. (2011) show the importance of the inclusion of sociological information such as the quantification of uncertainty about the fisher commitment to management policies while highlighting the link between commitment and implementation success in other BBN modelling approaches. Stakeholder commitment, from a modelling perspective, is associated with implementation uncertainty. Levontin et al. (2011) view implementation uncertainty as for the difference between desired and realised fishing effort. Levontin et al. (2011) use a probabilistic management model to evaluate potential management plans for the Baltic Salmon fishery (see Figure 2.2). This is done by drawing on several scientific studies (biological stock assessments with integrated economic analysis of commercial fisheries, evaluation of recreational fisheries and a sociological study that is aimed at understanding stakeholder perspectives and potential commitment to alternative management plans). BBNs were aimed to be used to synthesise and evaluate the robustness of management decisions to different priorities and sources of uncertainty. The process followed shows how research from varying disciplines and scientific disciplines could be combined to allow policy-makers to take stakeholders perspectives into account using BBNs. Lastly, the approach can quantify the impacts of a source of uncertainty as well as highlight gaps in system knowledge.

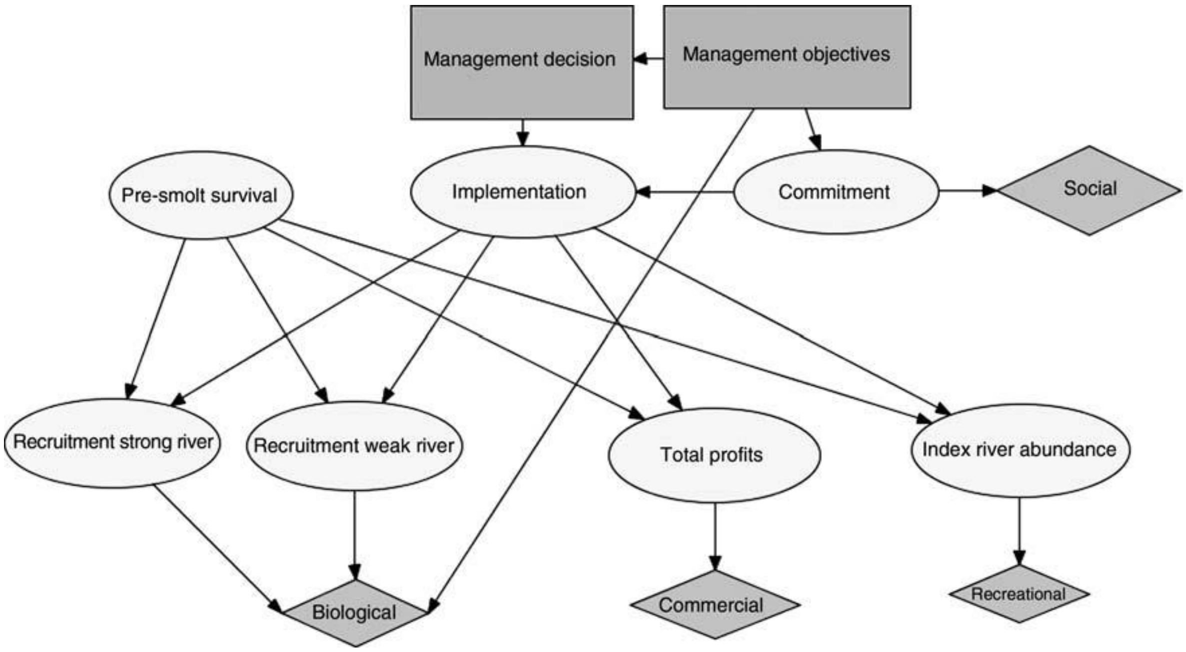

Figure 2.2. The BBN for Baltic salmon management. This BBN was constructed to synthesise findings from separate studies that aimed to evaluate management strategies for Baltic Salmon fisheries. The BBN is used as a decision-support tool to help discern the interactions between uncertainties, scenarios, and diverse stakeholder interests. Rectangles represent decision nodes, oval nodes are random variables, and the utility functions[7] are represented by the diamond-shaped nodes (adopted from Levontin et al., 2011)

2.4. Introduction to scenarios and their use in environmental studies

Our present era, characterised by uncertainty, change and innovation, places an increased emphasis on scenario planning techniques due to its usefulness in uncertain and complex systems (Amer et al., 2013). Scenario planning stimulates strategic thinking and helps to overcome thinking limitations by the creation of multiple futures (Amer et al., 2013). Initially rooted in operations research, scenario planning was first developed in World War II and subsequently elaborated upon in the 1970s in corporate strategic planning (Goodwin & Wright, 2004; Oteros-Rozas et al., 2015). The consideration of multiple possible futures holistically assists in future planning and while significantly enhancing the ability of various stakeholders to deal with uncertainty. Scenario planning helps us to prepare and innovate for the future, is an excellent way to question the future, provide a real picture of the

[7] "Utility functions in this network are the functions of the random variables in the network (output). Utility values are assigned to each state (or a contribution of states) of variable(s) upon which the utility depends" (Levontin et al 2011: 635).

environment, highlights several trends and events in the future and presents complex elements together into a clear, systematic, inclusive and plausible manner (Amer et al., 2013).

Dator's Laws of the Future (Dator, 1996) states that the future cannot be studied because it does not exist. The creation of scenarios as a method of decision support in policy making is more about ideas of the future and not the future direction. An alternative and preferred future can and should be envisioned, invented and evaluated on an ongoing basis (Tiller et al., 2013). The scenario development process can aid fishers in considering permutations of possible futures and pathways to those futures (Daw et al., 2015). It can also help present-day decision-making by providing necessary strategic direction for both fishers (on the smallest scale) and policy-makers (at the much larger national scale). Scenarios are also valuable tools to help move resources users/stakeholders away from the problem space to the solution space.

A scenario presents a logical, internally consistent and conceivable description of a potential future system state (Heugens & Van Oosterhout, 2001). The aim of scenario planning exercises is to articulate numerous alternative futures in a manner that spans key sets of important uncertainties, using both quantitative and qualitative methods and data (Peterson et al., 2003a; Swart et al., 2004; Kok & Van Delden, 2009; Carpenter & Booth, 2015). Scenario planning is a strategic, exploratory and deliberative planning process used to find innovative and robust solutions that aim to address futures that are both complex and uncertain (Bennett et al., 2016a). Scenarios are considered to be a valuable tool that helps organisations prepare for possible eventualities and makes them more flexible and innovative (Amer et al., 2013). Scenarios planning is a method that facilitates the inclusion of diverse stakeholder groups who hold different views in order to construct explicit future models by developing narrative or images aimed at re-orienting collective actions (Bennett et al., 2016a).

Scenario planning methodology has been used increasingly over the past ten years. Amer et al. (2013) hold that prior research has shown that there is an association between the adoption of scenario planning techniques and uncertainty, unpredictability and instability of the overall system. The increase in uncertainty within complex systems has highlighted the importance of the identification of future trends and landscapes to affect the changes needed to guarantee wellbeing. Scenarios can, in principle, be developed for any time frame but are more useful over the longer term (20 - 25 years) (Martelli, 2001).

On a large scale, the IPCC Working Group II AR 5 report (2014, Chapter Two) notes that the use of scenarios is a vital tool for addressing uncertainty in climate change impact predictions. The report also highlights that scenarios serve a variety of purposes which includes informing decision making under uncertainty, scoping and the exploration of poorly understood issues, and the integration of knowledge from diverse knowledge domains. While scenarios are widely used to mitigate the impacts of climate change, there are fewer studies that report on the use of scenarios as a participatory tool to enable adaptation decision-making, which is an important motivation for the research presented in this thesis. Evaluations of scenarios and modelling of biodiversity and ecosystem services that will be completed in the implementation of IPBES8 directive 3 (c)9 is not only expected to result in a comprehensive guide for various stakeholders but will also aid in the promotion and facilitation of further development and uses of scenario tools and methodologies (IPBES, 2016). The IPBES scenario and modelling assessment aim to establish the foundations for the use of scenarios and models in activities under the IPBES with the purpose of providing insights into future socioeconomic development pathways and policy options (IPBES, 2016). This foundation is being used to provide the necessary guidance needed to evaluate alternative policy options by using scenarios and models. This includes multiple drivers of future impacts; the identification of criteria by which the quality of scenarios and models may be evaluated; ensuring that regional and global policies are comparable', the inclusion of inputs from stakeholders at various scales; the implementation of capacity -building mechanisms in order to promote development and the use and interpretation of scenarios and models by a wide range of policymakers and stakeholders.

Using scenario planning for long-term planning and strategic foresight facilitates quicker adaptation to major disturbances and changes (Varum & Melo, 2010). Future uncertainty increases as we move from the present and into the future. Figure 2.3 highlights the widening "scenario cone" and broadening of the realm of future possibilities. Although only three possible "futures" are shown in the diagram, this does not exclude the possibility and probability of various multiple futures.

[8] The intergovernmental science-policy platform on Biodiversity and Ecosystem services is an (IPBES) is an intergovernmental body established to assess the state of biodiversity and of the ecosystem services it provides to society. The IPBES does not conduct new research but rather enjoins scientists and other stakeholders around the world to review and assess recent scientific and technical information that is produced in relation to the understanding of biodiversity and ecosystem services. The IPBES has for core functions – capacity building, knowledge generation catalysis and assessment and policy support. Four objectives are defined – capacity building and knowledge foundation, regional and global assessments, thematic and methodological issues and communication and evaluation. (http://www.ipbes.net)

[9] Directive 3 (c) – "policy support tools and methodologies for scenario analysis and modelling of biodiversity and ecosystem services based on a fast track assessment and guide" – (http://www.ipbes.net/work-programme/scenarios-and-modelling)

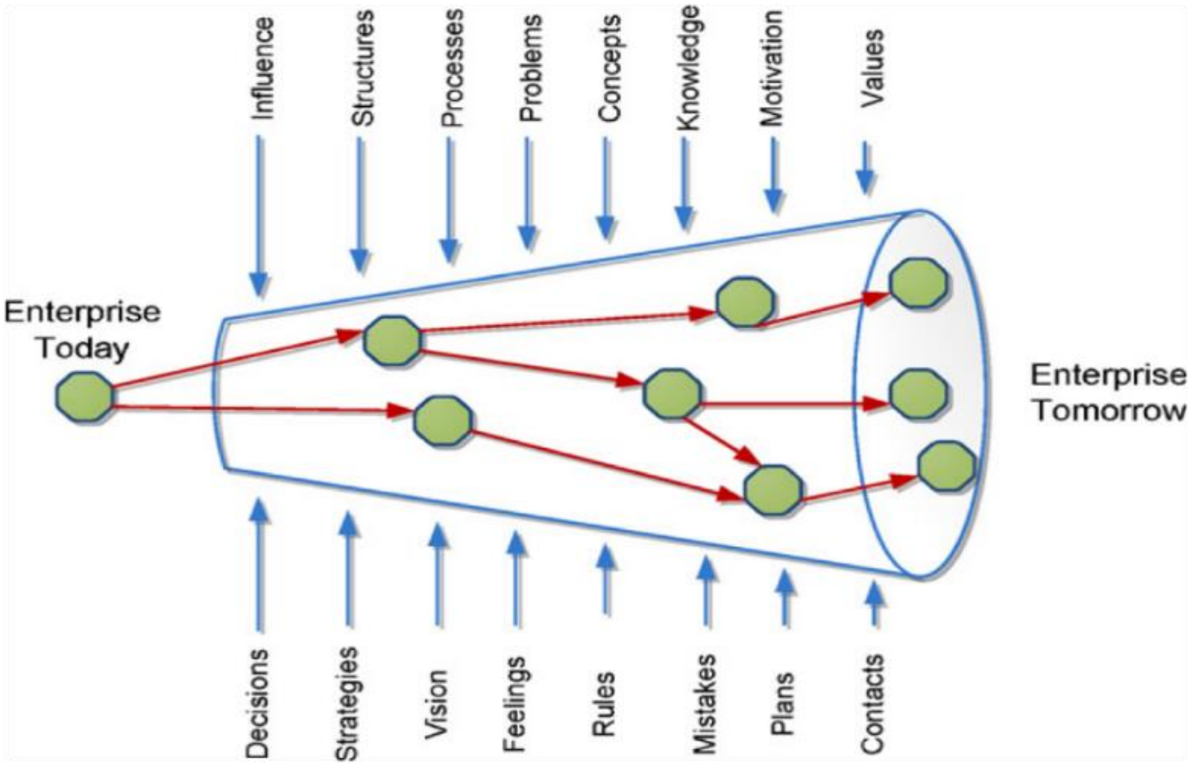

Figure 2.3. Scenario cone showing multiple possibilities where the widening cone also signifies the broadening of the realm of future possibilities. The various factors which are generally able to influence the direction of the future development are also shown (adopted from Amer et al., 2013)

Pierre Wack, whose two papers (Wack, 1985 a,b) are widely cited in the scenario planning literature (Burt, 2010; Durance, 2010), has presented scenario building criteria based on three main principles. These include the identification of predetermined elements in the environment, the ability to change the mindset in order to re-perceive reality and the development of a macroscopic view of the (business) environment (Amer et al., 2013). Pre-determined elements are past actions and events that have already occurred or are likely to occur. It is critical to unfold the consequences of these events because they act as the drivers that push outcomes (Amer et al., 2013).

Role of scenario planning in environmental studies

An increase in scenario planning in environmental research over the last 25 years may be attributed to several apparent benefits. These include the ability to foster complex long-term thinking that allows for the dynamics and sustainability of SESs to be explored (Oteros-Rozas et al., 2015). The adaptability and accessibility of scenario planning might also explain this trend.

The scenario planning process is often concerned with influencing decision making (Wollenberg et al., 2000). Influencing decision-making means that there is a potentially wide range of implications for various groups of stakeholders. Consequently, scenario planning undertaken in environmental research and in the management of natural resources has in recent years, become more participatory. Used in a participatory manner, scenario planning can involve local communities in envisaging futures for SES and to identify actions and policy required to increase resilience (Walker & Salt, 2006; Wesche & Armitage, 2014; Bennett et al., 2016a). By involving different stakeholder groups that have both influence and interest in the SES, including those potentially most affected. The approach encourages social learning, innovation and action in order to achieve the sought-after goals (Bohnet & Smith, 2007; Kok et al., 2007; Butler et al., 2014a, 2015; Bennett et al., 2016a).

Walker et al. (2002) suggest that scenario planning is also a valuable tool in the examination of the qualitative advantages and disadvantages of likely and desired future scenarios as well as the potential policies and actions that are required to adapt to or to mitigate against possible outcomes. A perceived lack of rigour may be viewed as a weakness of the tool, although this is more often than not compensated for by the tools' ability to clarify, distinguish and explore social-ecological feedbacks and potential surprises which are often not adequately represented in conventional quantitative modelling approaches (Bennett et al., 2003). The ability to address feedbacks and surprises are considered to be fundamental when managing for sustainability in complex SESs (Kok et al., 2004; Walz et al., 2007).

Table 2.3. Examples of published scenario research and associated areas of application

Area of application	Publication	Case Studies
Terrestrial resource management	Evans et al., 2006, 2008; Dowsley et al., 2013	Practical ways for communities to deal with future change, the use of future scenarios as a tool for collaboration in forest communities and the development of community capacity for natural resource management
Conservation and development	Daconto, 2007; Daconto & Sherpa, 2010	Scenarios as a participatory decision tool- case study in Kathmandu, application of scenario planning to park and tourism management in the Salormanth national park, Khumbu; Nepal
Community development	Rawluk & Godber, 2011	Widening the scope of scenario planning in communities to encourage greater participation and learning in Ukupseni, Panama
Adaptive infrastructure management	Hamilton & Thekdi, 2013	Use of scenario analysis for adaptive management of natural resource and infrastructure systems
Disaster risk management	Birkmann et al., 2013	Scenarios for vulnerability: opportunities and constraints in the context of climate change and disaster risk
Terrestrial and Marine conservation	Peterson, et al., 2003b; Palomo & Martín-López, 2011; Evans et al., 2013; Haward et al., 2013; Palacios-Agundez, 2013	Scenarios as tools for conservation; protected area management under the ecosystem services framework (case study from Southwestern Spain); Climate change impacts, adaptation options and outcomes for the Great Barrier Reef; Climate change scenarios and marine biodiversity conservation; relevance of local participatory scenario planning for ecosystem management policies, case study from Basque country, Northern Spain
Biodiversity assessments	Sala et al., 2000; Gude et al., 2007	Global biodiversity scenarios; biodiversity consequences of alternative future land use scenarios in Greater Yellowstone
Management and protected areas	Brown et al., 2001	Use of scenarios in trade-off analysis for Marine protected area management.
Ecosystem services (ES) and their relationships to human well-being	Kok et al., 2004; Carpenter et al., 2006	European and Mediterranean scenarios – upscaling local to regional contexts, an overview of Millennium Ecosystem Assessment scenarios for ecosystem services
Land-use change in general, but specifically desertification and land degradation	Jessel & Jacobs, 2005	Land use scenario development and stakeholder involvement as tools for watershed management within the Havel River Ba

2.5. Participatory scenario planning (PSP)

The rationale for involving stakeholders in scenario planning follows both normative and pragmatic arguments. Many of these relate to process-oriented results that emerge from broader participation discourses (Stringer et al., 2006; Butler et al., 2013, 2015). This is done to empower stakeholders (Reed et al., 2013); simulate innovation (Butler et al., 2013); mitigate conflicts (Kahane & Van Der Heijden, 2012); encourage social learning (Volkery & Ribeiro, 2009) and integrate different types of scientific and local knowledge, perceptions, expectations and aspirations (Bohnet, 2010; Von Wirth et al., 2014). PSP is solution-oriented and not only aids in the increase of adaptive capacity (Kahane & Van Der Heijden, 2012; Carlsen et al., 2013) but also in the identification of policy recommendations for sustainable (Bohensky et al., 2011; Palomo & Martín-López, 2011) and adaptation pathways (Butler et al., 2014b). PSP can also produce information on how stakeholders may respond to future challenges and thus contributes to the management decision making through a process to a better understanding of complexity in SESs. A PSP is also able to facilitate the mobilisation of stakeholders to respond to new threats or opportunities. Complexity thinking (seen as a key aspect of resilience) is also generally increased when engaging with PSP (Biggs et al., 2015b).

Opportunities and challenges in conducting participatory scenario planning (PSP)

Oteros-Rozas et al. (2015) in their review of 23 PSP exercises identified opportunities and challenges within the context of three themes: (1) the usefulness of PSP to participants and researchers, (2) the contribution made by PSP to the decision-making process and (3) the common methodological challenges for PSP. The following highlights some important aspects that are pertinent to the research presented in this thesis.

The usefulness of PSP to participants and researchers

The engagement with stakeholders in this type of research is constructive as it contributes toward improving equality and quality in environmental decision-making, thereby improving its legitimacy. The involvement of stakeholders in research processes through placed-based PSP projects provides a voice to multiple perspectives of social-ecological futures, leading to a potential reduction of power asymmetries and allows for more equitable decision making. Stakeholder involvement can also potentially increase the legitimacy and acceptance of policy options by the various stakeholders involved in the process. (Peterson et al., 2003a; Bohensky et al., 2011a,b). Peterson et al. (2003a) outline three case studies where scenario planning was used in the planning of business, political and ecological contexts and report on how the scenario planning process in these case studies positively influenced decision-making. This is especially true in the case of the Shell oil company where the scenario planning process resulted in the adoption of business strategies that were contrary to the consensus opinion of the day but resulted in growing Shell into a global company.

Bohensky et al. (2011), considered scenarios to be necessary for simulating futures and thinking regarding climate change and its influence on the Great Barrier reef in Australia where the use of scenarios fostered communication among many stakeholders (mostly scientists). In a case study in Milne Bay in Papua New Guinea, they used scenarios to explore ecotourism futures, conducted a short evaluation of the participants’ perceptions before and after the scenario planning and found that perceptions regarding major drivers of change did occur. This created an increased awareness of the drivers of change and associated processes that occur at broad temporal and spatial scales together with the need for long-term planning. The inclusion of knowledge and information from a diversity of sources can lead to an increase in the quality of the scenarios and policy options (Hill & Williams, 2010; Palomo & Martín-López, 2011; Ravera & Hubacek, 2011). Innovative strategies and opportunities for collaboration among multiple stakeholders can also be identified (Butler et al., 2015). In the mainstreaming of future uncertainty into decision-making for community development in the Nuse Tenggara Barat province in Indonesia, stakeholders' awareness of the local and global drivers of change and threats together with the need to plan for such changes was increased through the implementation of the PSP process (Butler et al., 2015, 2016). Collective reflections and discussions of potential policy options to deal with current and future in SESs were also made possible. Lastly, participants' understanding of SESs was enhanced, and it became possible to integrate their qualitative, context-specific local knowledge of the system while engaging with participants with issues surrounding uncertainty, surprises and contradictions (Oteros-Rozas et al., 2013; Butler et al., 2014b).

PSP content and outcomes contribution to decision making

The ability to bridge multiple knowledge systems allows PSP to bring together and produce new knowledge for environmental decision making and can lead to enhanced environmental decision making in a context of complexity. Case studies of PSP included in the review by Oteros-Rozas et al. (2015) accomplished this in two ways: (1) by the exploration of complex social-ecological trade-offs and (2) the creation of novel solutions. PSP has demonstrated that it is an area where multiple knowledge systems interact to co-create new understandings of present situations and build shared visions of possible future developments. This is demonstrated by case studies using PSP to envision the future of transhumant pastoralism (a livestock rearing system) in Spain, to develop and refine scenarios for the future of the UK Uplands and in protected areas using the ecosystem services framework in the Doñana SES in south-western Spain (Palomo et al., 2011; Oteros-Rozas et al., 2013; Reed et al., 2013). PSP is also able to provide a platform for the coproduction of synthetic social-ecological knowledge and the co-design of new environmental strategies as it enables communication and interaction amongst stakeholders (Martín-López & Montes, 2015), which can move beyond simplistic win-win assumptions (Daw et al., 2015). This is demonstrated by a case study of a fishery system in Mombasa, Kenya where important drivers and dynamics from a conceptual framework, secondary and modelled responses from the Ecopath with Ecosim model (developed using a participatory modelling approach) were combined into four scenarios and introduced to primary stakeholder well-being focus groups and secondary stakeholders in participatory workshops. The potential of the approach is that it increases the awareness of trade-offs, promotes discussion of what is acceptable, and can potentially identify and reduce obstacles to compliance (Daw et al., 2015). PSP acknowledges the diversity of ecosystem services as it explicitly considers trade-offs around them (Oteros-Rozas et al., 2015).

In principle PSP can address critical aspects of governance such as the influence of local vs global-drivers of change, centralised government vs collaborative governance, fragmented weak governance with and without innovators and community vs neoliberal orientations (Oteros-Rozas et al., 2015). The fact that a governance dimension was included in half of the case studies reviewed by Oteros-Rozas et al. (2015) supports this view. The PSP also helps place the focus on plausible futures in order to facilitate the discussion of concrete actions, strategies and policy options using various bodies of knowledge and diverse stakeholders (Daw et al., 2015). The PSP process contributes data (knowledge) on changes that are experienced at the local scale and the possible impacts of various futures. This is useful in achieving an improved and holistic understanding of current and possible future system conditions and dynamics at various local, regional and political scales (Butler et al., 2014a).

Challenges and Potential solutions

The review by Oteros-Rozas et al. (2015) has identified four main challenges in conducting PSP. The first is a tension between explorative and normative analyses. In their review, the explorative approach to PSP was the most reported approach, although many scenario names suggest that normative judgements have also been seen to be important. Normative scenarios are distinctive in the portrayal of the future as 'it should be' and they can inform policies by providing images of landscapes (system states) that would be able to meet societal goals (Nassauer & Corry, 2004). Value judgements play a role in the generation of choices, and the review suggests that it would be beneficial to more explicitly discuss and present such value-choices in scenario-generation. This becomes significant as the majority of scenarios in the review by Oteros-Rozas et al. (2015) were funded and conducted as sustainability science projects which are not valued neutral but rather pro-sustainability. These projects thus have a specific normative framework that is assumed as opposed to being specifically articulated.

Value-laden discussions are typically emotionally charged discussions and require a lot of effort and skill on the part of the facilitator. Stakeholder diversity and inherent power dynamics can be challenging and often require that a large amount of investment in facilitation be made (Butler et al., 2015). The PSP is typically constructed using previous research within the study region which results in the identification of multiple stakeholders impacted by regional dynamics resulting in a diverse stakeholder group (Oteros-Rozas et al., 2015). Some groups of stakeholders such as indigenous people and industry representatives, do tend to remain absent from the process. If the aim is co-construction of future scenarios, it is highly recommended that not only a systemic identification of stakeholders relevant to the SES take place but also the matching of diverse stakeholders and actors to take part in the PSP (Oteros-Rozas et al., 2015).

Communicating PSP results is another challenge identified from the review. It is a requirement that engagement with a diverse set of stakeholders take place and communication requires careful thought and considerable effort. The authors recommend using diverse types of outputs to enhance and improve communication. Using different outputs often include using standard scientific outputs such as technical papers and reports as well as outputs that incorporate arts such as posters or videos. Artwork can not only serve as a tool for the communication of PSP results, but it can also be used as a tool for facilitating communication among different stakeholder groups during and after the PSP process (Oteros-Rozas et al., 2015).

Classification of scenario planning methods

No single approach to scenario planning exists, and a review of the literature reveals that there are several methodologies used for the generation of scenarios with many common characteristics among them (Joseph, 2000; Chermack et al., 2001; Bradfield et al., 2005; Varum & Melo, 2010). Scenario planning has traditionally been, and often still is, a practitioner-driven approach. Chermack et al. (2001), Bradfield et al. (2005) and Keough & Shanahan (2008) have reviewed various methodological approaches and guidelines scenario building literature. Bishop et al. (2007) also studied more than a dozen techniques used in scenario planning and provided comment on the utility, strengths and weaknesses of the various methodologies.

Scenario typology and generating techniques

Börjeson et al. (2006) suggest a scenario typology with three main classes of scenario studies. This classification is based on principal questions that users may want to pose about the future (See Figure 2.4 and Table 2.4):

1. What will happen?
2. What can happen? Moreover,
3. How can a specific target be reached?

An increase in resolution is attained by allowing each category to contain two different scenario types. These are determined by using different angles of approach to the questions defining these categories. In addition to the principal question asked, two more aspects of the system must be considered when characterising scenarios:

1. The concept of system structure – consider the connections and relationships between two distinct parts of the system as well as the boundary conditions which govern system development.
2. Distinguishing between internal and external factors - internal factors are controlled by actors in the system and external factors are outside the influence of the actors.

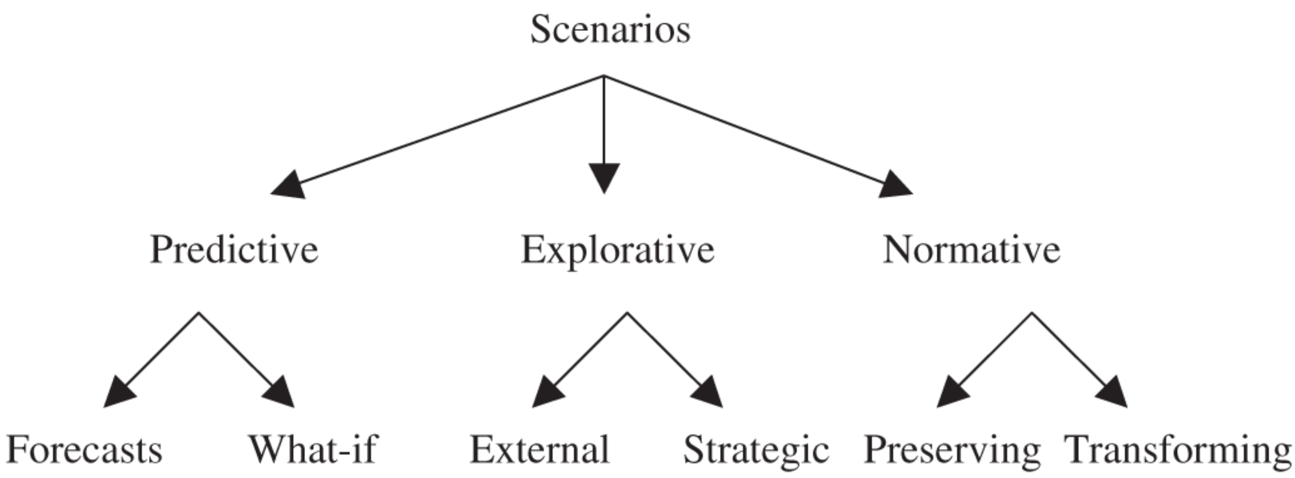

Figure 2.4. Scenario typology with three categories and six types (adopted from Börjeson et al., 2006)

Table 2.4. Combination of techniques in the phases of scenario development. Note that all techniques can be used in several phases but only their main contribution is mentioned in this table (adopted from Börjeson et al., 2006)

Scenario types	Techniques		
	Generating	Integrating	Consistency
Predictive			
Forecasts	• Surveys • Workshops • Original Delphi method	• Time series analysis • Explanatory modelling • Optimising modeling	
What-if	• Surveys • Workshops • Delphi methods	• Explanatory modelling • Optimising modeling	
Explorative			
External	• Surveys • Workshops • Delphi modified	• Explanatory modelling • Optimising modeling	• Morphological field analysis • Cross impact
Strategic	• Surveys • Workshops • Delphi methods	• Explanatory modelling • Optimising modeling	• Morphological field analysis
Normative			
Preserving	• Surveys • Workshops	• Optimising modeling	• Morphological field analysis
Transforming	• Surveys • Workshops • Backcasting Delphi		• Morphological field analysis

Predictive and normative scenarios are discussed in more detail as these are the two scenario typologies that underpinned the research presented in this thesis.

Predictive scenarios attempt to answer, "what could happen questions" and are executed as either forecasts or "what if" scenarios. The overall aim of a predictive scenario is to attempt predictions of the future. Attempts at future prediction ensure that this type of scenario is closely related to probability and likelihood as the prediction relates to the estimated likelihood of the outcome (Börjeson et al., 2006).

Predictive scenarios enable the possibility of planning and adaptation to situations that are expected to occur with reasonable certainty. It is useful to decision-makers who need to deal with foreseeable challenges and take advantage of opportunities. Predictions are also useful to make decision-makers aware of problems that are likely to arise if some conditions of development are fulfilled (Börjeson et al., 2006).

Predictions are usually made within one structure of the predicted system, i.e. assumed that laws governing system development would prevail during the relevant periods. Historical data often play an essential role when outlining scenarios. The focus is on the causalities which lead to an outcome in a step-wise manner (Börjeson et al., 2006).

The Delphi method can be used as a technique for collecting and structuring ideas, knowledge and views from both experts and stakeholders. The Delphi-method recognises that human judgement is a legitimate input to forecasts and predictions and that the collective judgement of several informed people is likely to be better than a single individual's judgement. The main idea of a classic Delphi study is to collect and harmonise the opinions of a panel of experts on the chosen issue (Höjer et al., 2008). Criticism for the method includes that the structuring for consensus results in the loss of valuable information (Höjer et al., 2008).

The other typology, more favoured for this research, is normative scenarios. Normative scenarios start with specific normative starting points and the focus of interest it places on certain future situations or objectives and how they could be realised/reached. The type of normative scenario that may be useful to apply to this research is the transformative scenario. Such scenarios make use of techniques such as backcasting or Delphi backcasting. The Delphi backcasting method is a combination of backcasting and Delphi study. The first part consists of formulating images of a future that is target-fulfilling while the second part uses a Delphi-like process where experts are asked to evaluate scenarios in respect of their feasibility and coherence to the defined target. Using 'repeated rounds' allows for the provision of an opportunity that allows for the incorporation of criticism and new suggestions into the scenarios (Höjer & Mattsson, 2000; Goodwin & Wright, 2004).

Backcasting views the starting point as a high-level and highly prioritised target that seems unreachable if development were to continue the current trajectory. Marginal adjustment of current development will not be enough to affect the necessary changes in the system. A break in the trend is necessary to reach set targets. Typically, the results of such a backcasting study are several targets, fulfilling images of future states which show solutions to the societal problem using a discussion of changes that would be needed to reach the "ideal". This type of scenario relates to long-time perspectives of 20-25 years (Börjeson et al., 2006).

Dreborg (1996) underscores the importance of images of the future as the foundation for the discussion of goals and decision-making in the policy-forming process. Börjeson et al. (2006) believe that the point of backcasting is to encourage investigations of new paths along which development could take place. Höjer & Mattson (2000) assert that drawing distinctions between internal and external factors are not useful in a backcasting study - ensuring that all factors are kept internal to the backcast can assist in displaying factors that may be crucial to achieving targets. All solutions are thus kept open and no restrictions imposed by the initial classification (Börjeson et al., 2006).

A problem with backcasting is that it can result in expensive short-term decisions with long-term targets or available options changing before the target is reached (especially when considering the 20 - 25-year timeline, typical in scenario planning discussed above). It is reasonable and appropriate to select backcasting if the long-term target is perceived to be more important than the short-term efficiency of the system and/or when the user perceives the long-term target as easy to predict (Börjeson et al., 2006).

An example of such a backcasting method is the Transformative Scenario Planning process (TSP). The transformative TSP aims to change the future collaboratively by transforming rather than adapting in the long term. The TSP process centres on the construction of scenarios of possible futures with the purpose of influencing the future. This involves planning by engaging in a disciplined process of thinking ahead together with all relevant stakeholders a then altering actions accordingly and offers a new way to work together to change the future (Kahane, 2012a,b). The TSP in its current form originated from the Mont Fleur scenario planning process in the early 1990s (Kahane, 1992). Before the political transition, leaders from all sectors and sphere of South African society examined the forces shaping the country and how these forces could be directed to create a prosperous South Africa. The three-day workshops, facilitated by members of the strategic planning group at Shell oil[10], aimed to create a shared understanding of the dangers and opportunities that faced a South Africa in transition (Peterson et al., 2003a). Four scenarios were developed: (1) the Ostrich, where negotiations to end apartheid failed; (2) Lame Duck, in which the negotiated transition is slow, complicated and indecisive; (3) Icarus, in which the transition was successful, but the new government enacted populist economic policies that led to economic crises; and (4) Flight of the Flamingos, in which the gradual improvement in the social and economic status of South African happened

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[10] Shell oil used adaptive scenario planning process in 1970s in order to evaluate long-term decisions that allowed the company to navigate the 1970s oil crisis in a profitable manner that allowed it to become an oil industry leader (Peterson et al., 2003a).

as diverse groups worked together (Kahane, 1992; Peterson et al., 2003a; Kahane & Van Der Heijden, 2012). The scenario creation process appeared to have enriched the negotiation process by creating shared awareness of the potential pitfalls of transition (such as excessive spending, overly narrow focus on details of the negotiated settlement and insufficient change), improving the quality of the transition toward democracy. Figure 2.5 is a visual representation of the logic used in the scenarios, while Figure 2.6 shows the possible future paths identified.

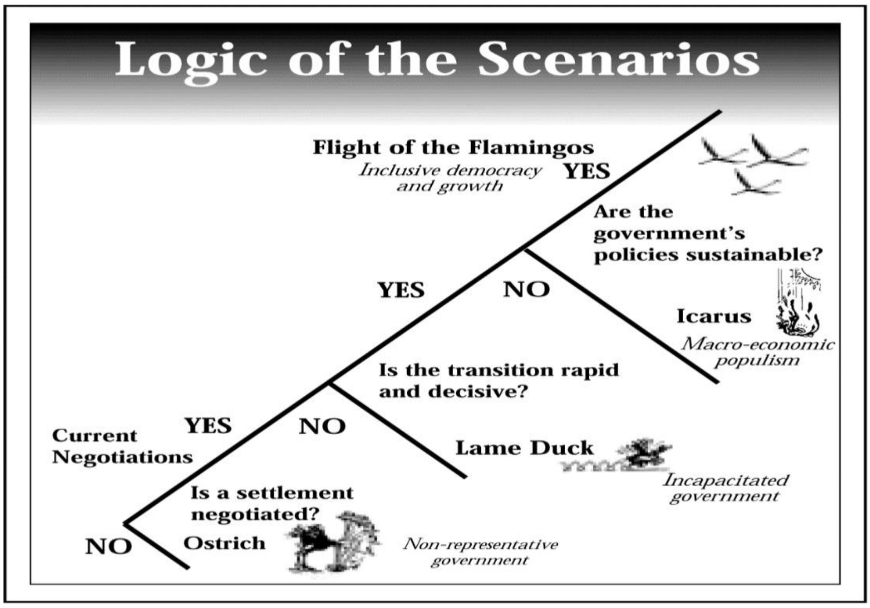

Figure 2.5. The logic of the Monte Fleur scenarios for a transformed South Africa (adopted from Kahane, 1992)

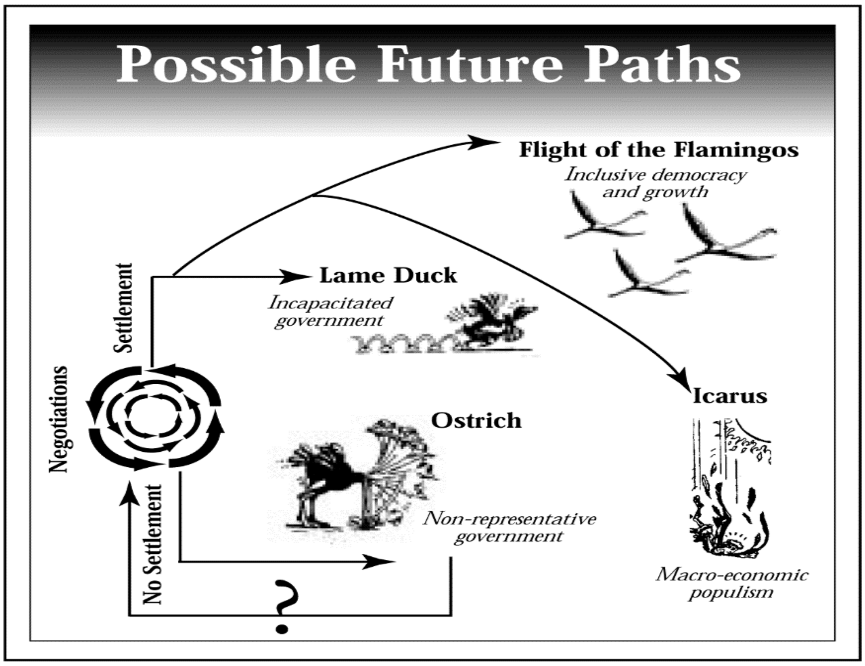

Figure 2.6. Possible future paths identified by the Monte Fleur scenarios for a transformed South Africa (adopted from Kahane, 1992)

The TSP process offers a way for people to work with complex problematic situations that they want to transform but cannot do so unilaterally or directly. The process is useful to groups/systems that find themselves in situations with three principal characteristics: (1) the current system situation is unacceptable, unstable or unsustainable; (2) the situation cannot be transformed by the people in the system on their own or by just working with friends/family; and (3) situation cannot be transformed directly and the actors are too polarised to be able to agree on anything (Kahane & Van Der Heijden, 2012). Actors in the TSP transform themselves in four ways (1) transforming their understanding of what is happening and could happen in and around the system; (2) transforming their relationships as they work together in the scenario team by enlarging empathy for and trust in other actors; (3) the intentions of actors are transformed as their transformed understandings, and relationships shift; and (4) the aforementioned transformations allow the actors to transform their actions and thus their situations. TSP consists of three components, all of which must be present to generate transformations. The first component is a whole-system team of actors that represent a microcosm of the entire system. The second component is a strong container within which actors can transform their understandings, relationships and intentions and the third, a rigorous process (Kahane & Van Der Heijden, 2012). The TSP process consists of five steps (Figure 2.7). These steps include convening a whole systems team, observing what is currently happening in the system, constructing stories about what could happen in the future, discovering what can and must be done and finally, acting to transform the system.

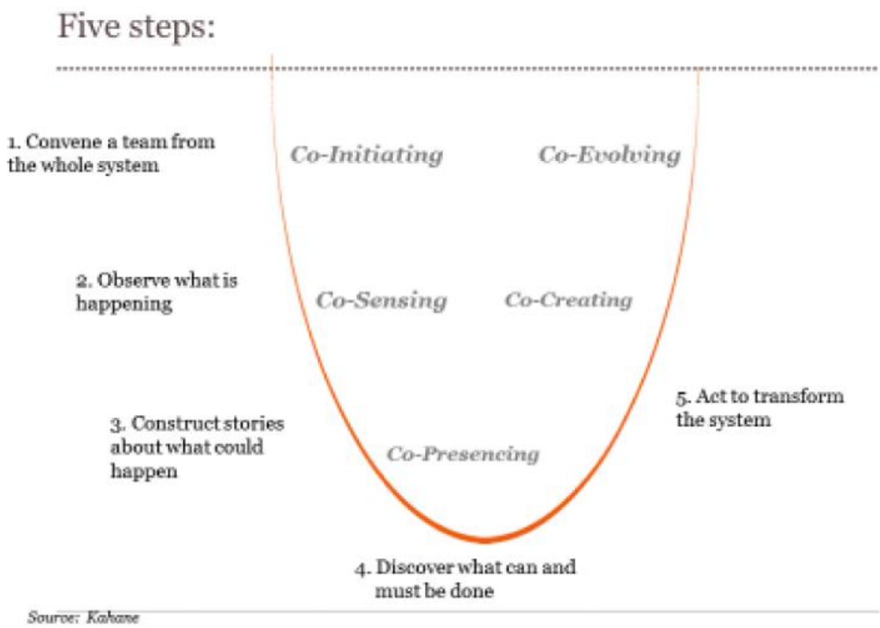

Figure 2.7. Five steps of the TSP. The process includes five stages: co-initiating (convening), co-sensing (observing and constructing), co-presencing (discovering), and co-creating and co-evolving (acting) (adopted from Kahane, 2012).

The following is a brief overview of the steps presented by Kahane & Van Der Heijden (2012):

In Step 1, the co-initiation phase of the TSP, a first step is to articulate the theme or concern being addressed, seeking out allies and mapping of the stakeholders of the system. It then becomes necessary to enrol a team of people from across the system who want to, and can, influence the future functioning of the system.

Step 2, the co-sensing stage requires that the TSP team build up a rough and shared understanding of what is happening in the system. It is essential for participants to go beyond their own established views and gain new perspectives on the system and undergo the necessary preparation to have the material to enable the construction of the stories of the future. This is done using various methods and data sources which include research teams and papers, noteworthy stakeholders, industry experts, learning journeys, own experiences, the scenario team as a microcosm of the whole.

In step 3, the co-presencing phase is the stage where the scenarios of what could happen in and around their system are constructed. This is done using a multi-step process and by using various methods (depending on the group and facilitator). This stage includes identifying and prioritising the driving forces of system change. It is vital to search for driving forces behind driving forces as these can be enablers which strengthen the driving force or inhibitors which weaken the driving force. It is essential to choose a “workable” number of scenarios to create with four being the accepted norm.

The co-creating stage involves the actual story creation when an image of the end state in 20-25 year are constructed. It is essential to consider a sequence of events, a causal logic to the story that unfolds between now and then. Metaphors, images and names for each scenario must be identified. Scenarios must be compared to differentiate better and create coherence between them. The scenarios must be documented in a way that communicates the work convincingly and engagingly and while demanding and provoking reflection, emotion, and action.

The last step, co-evolving, requires stakeholders to start working to transform actively. The activities in this step usually are not foreseen or planned and may also not necessarily be being part of the scenario project as such, as they evolve from the understanding and personal transformation of the participants. This transformation in thinking and the potential this has for change is demonstrated in this quote from Trevor Manuel (former South African Minister of Finance and Minister responsible for the National Planning Commission) who said of the Mont Fleur TSP process “...I could close my eyes now and give you those scenarios just like this. I’ve internalised them, and if you have internalised something then you probably carry it for life”.

In summary, it is necessary to highlight some differences between the adaptive scenario planning process (such as used by Shell) and the TSP. Adaptive scenario planning endeavours to anticipate and adapt to futures that seem unpredictable while the TSP process allows people within the system to influence and transform the system. The critical difference between the two approaches is that adaptive scenario planning utilises stories about possible futures to study what could happen whereas the TSP assumes that studying the future is insufficient and so it also uses stories about possible futures to influence what could happen. The adaptive scenario planning approach places the focus on promoting new systemic understanding while the TSP assumes that new understandings alone are not enough and places additional focus on producing cross-system relationships and transforming intentions. The TSP enables people to transform their problematic situation through building strong alliances of actors that understand the system, one another, and what they need to do to attain a better future (Kahane, 1992, 1998, 2012a; Kahane & Van Der Heijden, 2012).

2.6. Overarching research approach, design and methods

This thesis, situated within the context of a local marine SES, is rooted in interdisciplinarity, which is underpinned by an over-arching research approach that bridges individual chapters. This is done to create a holistic and integrated view of prototyping of a scenario-based approach using SDMTs in an iterative and interactive process at the local scale. This section provides an overview of the over-arching approach, design and methods underpinning the research. Details related to the various parts of the research (and associated methods) are provided in each of Chapters Three, Four and Five.

To address many of the present era's environmental challenges, an integrated view which address system problems is required, as opposed to the more traditional disciplinary perspectives (Nicolson et al., 2002). By bridging perspectives and disciplines, one can adequately address such system problems and complex processes across multiple temporal and spatial scales (Nicolson et al., 2002). An integrative approach is appropriate for addressing challenges and problems in complex SES. Interdisciplinarity presents a valuable approach as a way to solve problems and answer questions that cannot be addressed through a single method or approach (Newing & Contributors, 2011). Ommer & Team (2007) and Paterson & Petersen (2010) emphasise that developing new attitudes, methods and solutions require new integrative and transdisciplinary approaches.

2.6.1. Research strategy and approach

Building on my own M.Sc. research (Gammage, 2015) and recent work in connection with the Global Learning for Local Solutions (GULLS) project (Hobday et al., 2016; Aswani et al; 2018), this study used a multi-layered approach based on using SDMTs to address responses to change that cause vulnerability in fishery systems.

The research, characterised by an iterative, participative process throughout used an inductive research strategy. Contrary to deductive approaches where the researcher generates a specific hypothesis, designing data collection to test the specific theory, inductive research does not have a specific hypothesis (Newing & Contributors, 2011). Data collection was guided by a comprehensive set of problems (issues) and data used to generate theories or better understandings of these problems. The advantage of using such an inductive research strategy is that it starts off with overly broad open-ended questions and is especially useful in situations where little is known about the research area and structure. The strategy is also particularly useful where wanting to build up an in-depth understanding of complex situations (Creswell & Plano Clark, 2011; Newing & Contributors, 2011).

The over-arching approach used in this thesis is associated with a pragmatist worldview. This paradigm advocates the use of mixed methods as a pragmatic way to understand human behaviour with approaches that are more practical and pluralistic and can shed light on the behaviour of participants, the beliefs that stand behind these behaviours and the consequences that is likely to follow as a result of these behaviours (Kivunja & Kuyini, 2017). The pragmatist worldview, in short, places the focus on "the consequences of research, on the primary importance of the question asked rather than the methods, and on the use of multiple methods of data collection to inform the problems under study (Creswell & Plano Clark, 2011: 41). Pragmatism is associated with mixed method research as the philosophy is well-developed and appealing for the integration of approaches (Johnson et al., 2007). The choice of the approach followed by pragmatists has linked directly to the purpose of and the nature of the research questions posed. Research carried out in the context of this paradigm is often multi-purpose with a 'what works' tactic, which allows the researcher to address questions which cannot be classified as qualitative or quantitative, is applied to the research design and methodology (Creswell & Plano Clark, 2011). The ontology associated with the approach looks at both singular realities - where a hypothesis is tested -and multiple realities - which provide perspective. The researcher chooses the most appropriate data collection method to answer questions using a practicality epistemology (Creswell & Plano Clark, 2011). Mixed methods are the typical methodology of choice for interdisciplinary research (e.g. Ommer & Team, 2007) as they allow for an integrated approach to problems in complex systems (Creswell & Plano Clark, 2011).

2.6.2. Research design, methods and analysis

A case study design which focuses on small-scale fishers of the southern Cape is used to develop and prototype a scenario-based approach to change in fishery systems. A case study design involves the detailed data collection about a singular 'case' or set of circumstances with the aim to contribute to its understanding and the wider theoretical understanding while engendering theories about underlying issues (Newing & Contributors, 2011). Case study research is largely observational and is particularly good at building in-depth descriptions and understanding of a specific situation. Case studies aim at a detailed understanding of the selected case to add to both broader systems understanding and broader theoretical and understanding to generate theories about underlying issues (Newing & Contributors, 2011).

Previous thematic analysis of qualitative data already collected provide insight into stressors that drive change in the SES in South Africa's southern Cape linefishery (see Gammage 2015, Gammage et al. 2017a and Chapter Three of this thesis). These analyses have provided an overview of broad system interactions but provide limited insight into the effects of the interactions between different stressors at multiple temporal and spatial scales of a "messy" system. Building on this previous research and through developing the understanding of the drivers of change in the marine SES from the fishers' perspective, together with the systematic and iterative implementation of the SDMTs in a scenario-based approach, the detailed case study for this thesis aims to better understand the southern Cape marine SES and how SDMTs contribute to change response strategies in fishery systems. Figure 2.8 presents a graphical overview of the methods used within the context of the over-arching approach and conceptual framework.

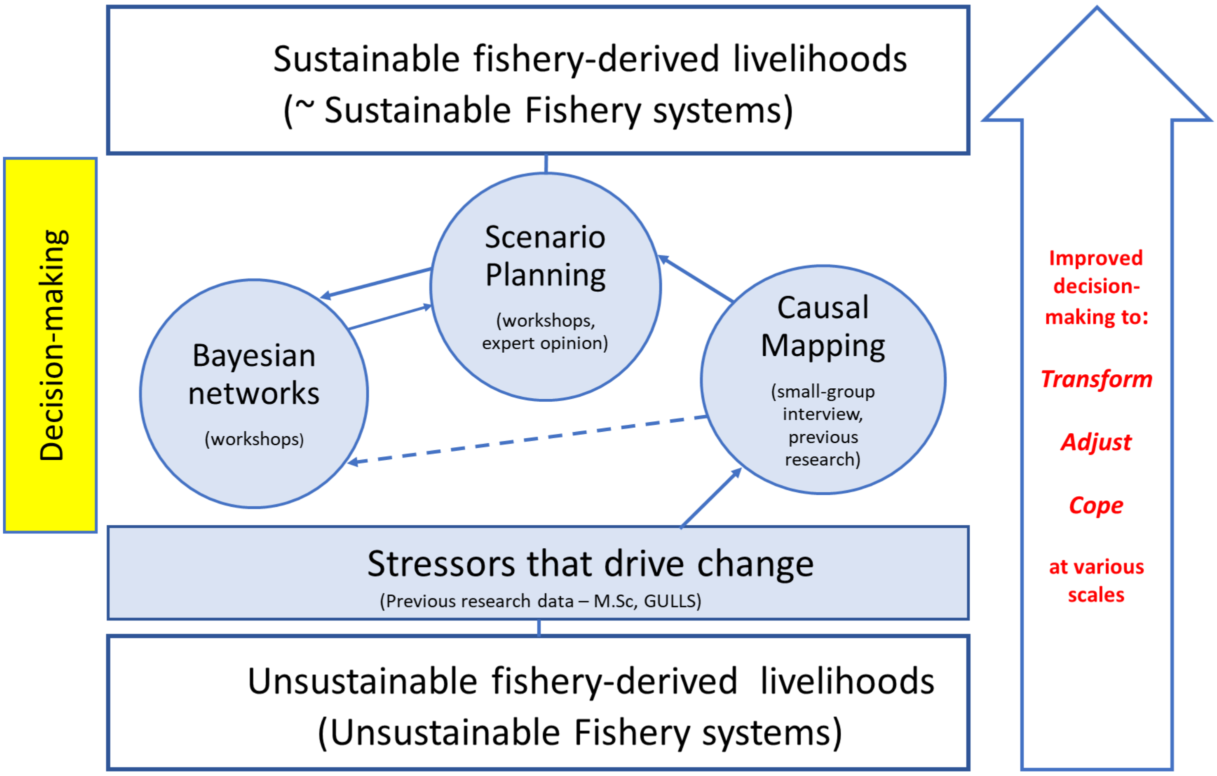

Figure 2.8. Graphical overview of the methods used in this research. To achieve more sustainable livelihoods and more sustainable fishery systems, fishers need to move beyond merely coping with change towards adjusting and transforming their fishery systems at various temporal and spatial scales. Using structured decision-making tools, stakeholders' knowledge of stressors that make them vulnerable to change are used in a layered, iterative and inductive approach to address the various aims of the research.

There are four components to the methods used in this research (of which more details are provided within Chapters Three, Four and Five). The first one is a qualitative and quantitative analysis of small-scale fishers' - who act as crew in the small-scale commercial linefishery - knowledge of stressors that drive change. This knowledge is used to refine and reinforce a thematic framework of the stressors that result in change identified in previous research (Gammage, 2015). The addition of the small-scale fisher's knowledge allows for more accurate system description and filled a previously identified knowledge gap. Secondly, casual mapping, implemented throughout the research area (see Table 2.5), provides the tool to represent the identified variables and their interactions graphically and served as a conceptualisation of the marine SES. This graphic representation of the qualitative stressors' data allows for the identification of hidden feedback loops and indirect stressors[11] not immediately apparent. Thirdly, a workshopping process has been used to gather the data required for the BBN. This runs concurrently with the fourth component, a prototyping scenario planning exercise in Melkhoutfontein.

Table 2.5 presents an outline of the specific methods used per chapter. Broadly, data gathered are used to gain insights into and understanding of the fisheries system or future response strategies. Not all the towns in the research area were involved in all the research steps, and the tables detail how each town was involved. The researcher also facilitated all the interactions, with a research assistant taking notes were appropriate. Table 2.6 presents the timeframes attached to various data generating processes shown in Table 2.5.

Table 2.5. Sources of data for empirical Chapters

Thematic Theme	**Gaining understanding and insights into the fisheries system**		**Future response to change**	
Methods	**Chapter 3: Stressors***	**Chapter 4: Causal Mapping***	**Chapter 4: Bayesian belief networks**	**Chapter 5: Scenario planning***
Town/Community from which data was sourced and fed back to	Mossel Bay, Bitouville, Melkhoutfontein, Slangrivier, Vermaaklikheid	Mossel Bay, Bitouville, Melkhoutfontein, Slangrivier	Melkhoutfontein for construction and sensitivity analysis.	Melkhoutfontein for construction and feedback per Chapter 5
Social Vulnerability Survey (GULLS) (preliminary feedback)	√			
Semi-Structured interviews	√			
Thematic (qualitative) analysis	√	√		
MDS plots	√			
Small Group interviews (focus groups)		√		
Semi-structured Interviews			√	
Expert Opinion (literature)		√	√	√
Workshops			√	√

*results of these processes fed back to all participants per Chapter Three, Four and Five

[11] Indirect stressors (or drivers of change) 'operate more diffusely than a direct driver, by altering one or more direct drivers' (Nelson et al., 2005). Within the context of this thesis, indirect stressors are those stressors which fishers do not normally account for as the interactions and impacts happen through other stressors.

Table 2.6. Data collection timeline

Process	Period
Collection of initial stressors data (previous research)	July 2013 to February 2014
GULLS social vulnerability survey	October– November 2014, May/June 2015 & October 2015
Causal diagram group interviews (general feedback on preliminary GULLS survey results	November/December 2016
Workshop One & Two	February 2017
Workshop Three (Bayesian network: CPTs) & Feedback on SSFP implementation	May 2017
Scenario Story Feedback	August 2018

To develop a better understanding of drivers of change - which include the identification of feedback loops and indirect stressors that drive change in the southern Cape linefishery - causal mapping is used in this thesis as a modelling technique that aids problem structuring. Although causal maps have successfully been applied in other fishery contexts in South Africa (e.g. Belton & Stewart, 2002; Basson, 2009) these tools have never been used with the line fishers from the southern Cape. In this research context, the BBN is largely utilised as a problem reframing tool. Following the causal mapping process, the information required for the BBN and scenario construction was gathered through convening a series of workshops with participants who reside in Melkhoutfontein. The iterative BBN construction process (which included the construction of a weighted hierarchy), allows for the reframing of questions regarding drivers of change. The BBNs also provide an opportunity to synthesise the responses from various participants into one, coherent model (Barton et al., 2008; Mäntyniemi et al., 2013; Smith et al., 2018).

The prototyping scenario planning exercise developed in the present research uses the principles of a transformative scenario planning process (TSP) (Kahane, 2012a). Time and scale do not allow for the implementation of a complete TSP necessitating the implementation of the TSP as a prototype. Prototyping also allows for the refinement and reconsideration of the objectives of the process (Starfield & Jarre, 2011) under constraints of time and budget. The insight regarding system interactions, dynamics and complexity gained from the development and use of the SDMTs inform the scenario story development. The final stories are a synthesis of inputs from the participants overlaid with research knowledge and scenario outputs from national scenario planning exercises related to economic development, social cohesion and climate change. Feedback has been provided to participants in the form of short informal interaction and a pamphlet produced for feedback purposes.

At the core of the data analyses approach used across this thesis is building a narrative account and interpreting the results through a mixed-methods approach (although the discussions and analyses are more qualitative in nature). Generally, mixed-method research provides strengths that offset the weaknesses of both quantitative and qualitative research. It has been argued that quantitative research is weak in understanding context, in providing a voice to research participants and for ignoring the role that the researchers' bias and assumptions play in the research process (Creswell & Plano Clark, 2011; Newing & Contributors, 2011). Qualitative research on the other hand, while making up for these weaknesses, is criticised for the personal interpretations made by the researcher and the ensuing bias created as well as the difficulty in generalising the findings due to smaller sample sizes. Through using mixed methods, the strengths and weaknesses of both approaches can be addressed (Creswell & Plano Clark, 2011). Mixed methods also answer questions that cannot be answered by either approach on its own, providing a bridge between the quantitative and qualitative, encouraging the use of multiple worldviews or paradigms and is often more applied or "practical' as the researcher is free to use any method possible in addressing a research problem. Using mixed methods does have its disadvantages – it requires a certain amount of both quantitative and qualitative skills, time and resources for extensive data collection and analysis (Creswell & Plano Clark, 2011).

In Chapter Three, quantitative data from household social vulnerability surveys have been used to better describe the experiences of a group of stakeholders. In Chapters Four and Five, insights gained from both the product (model outputs and scenarios) and the process are discussed. This is accomplished through a careful interrogation of the data, through triangulation between different data sources and examining them for common threads and patterns (Newing & Contributors, 2011). Triangulation - which seeks convergence, corroboration and correspondence of results from different methods - is crucial in this study where there has been triangulation within the subject, between subjects and between methods (Creswell & Plano Clark, 2011; Newing & Contributors, 2011). This means that data has been collected in more than one way and by using different sources. Triangulation between sources is key in inductive research. A short-coming and critique of the approach to data analysis used in this thesis that the more qualitative nature of the analysis can be seen as being less objective than more quantitative analyses. However, through careful coding, cross-checking and triangulation, one can ensure a measure of objectivity (Creswell & Plano Clark, 2011; Newing & Contributors, 2011).

The implementation of the overall approach provides valuable information in terms of both what is learned from the SES interactions (product) and the process used to develop the tools. The feedback loops, indirect drivers of change and uncertainties in the local SES are exposed and explored through the use of the causal maps and BBNs, thereby enhancing system understanding. At the same time, participants engage in an exercise which builds capacity and enhances learning at the level of the person, household and community of fishers. The scenario stories further contribute to this capacity building by providing participants with plausible future options. Viewed holistically, the implementation of the approach addresses issues of complexity and scale of decision-making in SES specifically within the context of the implementation of an ecosystem approach fisheries management in South Africa.

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Chapter Three

A changing fishery system: perspectives from the crew in the southern Cape's linefishery

3.1. Introduction

Fisheries are part of complex social-ecological systems (SES) that exist in dynamic environments (Ommer & Team, 2007; Dorner et al., 2014). Multiple drivers of change which interact at various geographical scales result in poorly understood multi-scalar change. Effective fisheries management requires significant advances in research (Ommer & Team, 2007; Sowman et al., 2013; Dorner et al., 2014), particularly for the effective implementation and promotion of an ecosystem approach to fisheries management (EAF) (Garcia & Cochrane, 2005; Shannon et al., 2010). Difficulties with policy implementation coupled with poor social data availability have made it difficult for coastal fisheries to achieve sustainability both globally and in South Africa (FAO, 2010; Sowman et al., 2013). Importantly, improving our understanding of fishery systems is critical when considering fishing-dependent communities' future responses to change.

The food security, income and livelihoods of many coastal communities the world over are dependent on the availability of marine resources (FAO, 2012, 2016b; Aswani et al., 2018). Predicted human population increase will result in increased pressure on marine resources (FAO, 2012, 2016b) , with natural system variability and the direct and indirect effects of anthropogenic climate change adding further strain on marine resources and the coupled SESs (Miller et al., 2010; Hobday et al., 2016). Natural system variability, together with anthropogenic challenges such as poverty, marginalisation of communities of fishers and regulation (to name a few) add layers of uncertainty and complexity, of which a better understanding must be developed to ensure effective and sustainable management of fisheries and coastal zones while promoting sustainable livelihoods and wellbeing of coastal communities which depend on marine resources. The effects of climate change introduce even more uncertainty - warming of sea surface temperature (SST) in specific regions are occurring at several times the global rate (Hobday et al., 2016). The identification of these hotspots (Hobday & Pecl, 2014) and associated biological impacts suggest that coastal communities adjacent to these hotspots may be even more vulnerable to change than others (Hobday et al., 2016).

The Benguela Current Large Marine Ecosystem (BCLME), introduced in Chapter One, is an eastern boundary current system dominated by coastal upwelling and is a highly productive region that sustains important fisheries for Angola, Namibia and South Africa (e.g., BCC, 2013). The Agulhas Bank subsystem of the southern Benguela overlaps with one of the climate change hotspots identified by Hobday & Pecl (2014). It is situated off the southern Cape coast in South Africa and includes the roughly triangular Agulhas bank, extending approximately 117 km off

Cape Agulhas within the South African exclusive economic zone (EEZ). Its coastal waters represent the fishing grounds off the southern Cape for the linefishery (see Figure 1.2).

Previous research into stressors that drive change in the southern Cape linefishery (Gammage, 2015; Gammage et al., 2017a) identified a thematic framework of stressors using the perspectives from various user-groups (more specifically skippers and fishing rights' holders) and scientific knowledge. Using semi-structured interviews and focus groups, data on knowledge and perceptions regarding stressors that affect the fishers' ability to fish successfully, were gathered. By grouping these drivers of change into major, mid-range stressors and minor stressors (Table 3.1), valuable insights into the day-to-day experiences of fishers contribute to the understanding of the SES in the southern Cape while exposing various knowledge gaps that exist in micro-scale interactions that influence the fishery system. Stressors identified by the thematic analysis include the impacts of and responses to climate variability, challenges presented by policy and regulatory frameworks, social and economic considerations, challenges presented by infrastructure, as well as political considerations.

Table 3.1. Stressors that drive change in the linefishery of the southern Cape (from Gammage et al., 2017a). Stressors were divided into minor, mid-range and minor stressors. The percentages indicate the frequency of responses per the total sample (n=50) who identified the stressors. Stressors identified by more than 80% of the sample were classified as major stressors, stressors identified by more than 50% but less than 80% of respondents were classified as mid-range stressors, while minor stressors were those identified by less than 50% of the population

Major Stressors		Mid-range stressors		Minor Stressors	
Stressor	**%**	**Stressor**	**%**	**Stressor**	**%**
Policy & Regulation	92%	Enforcement & implementation of policy	76%	Geography of area	48%
Climate Variation	90%	Economic (ito capital)	76%	Infrastructure	46%
Other Fishing sectors (Inshore Trawl)	84%	"Political issues" (amongst fishers & sector)	76%	Social factors	46%
		Socio-economic	70%	Lack of knowledge (financial planning, literacy level etc)	44%
				Fishing methods	26%
				Other Marine Species (e.g. seals)	14%

Importantly, although the previous research endeavoured to engage with a wide range of linefish stakeholders in the research area, the crew component was poorly represented (Gammage et al., 2017a). For this thesis to effectively build on the previous research, it is important to ensure representation of the perceptions of change in the southern Cape linefishery for all user groups. To this end, the research presented in this chapter seeks to address Aim 1 in Section 1.9 by addressing the answer to the question "What are the drivers of change in the fishery system of the southern Cape from the perspectives of the crew component?"

Previous research by Gammage et al. (2017a) forms part of the southern Cape Interdisciplinary Fisheries Research (SCIFR) project. Important for the context of this chapter, this project's research takes place at smaller, localised scales, specifically within the context of the southern Cape marine SES. At the larger (national) scale, a cross-country comparison carried out by the Belmont Forum-funded project "Global Understanding and Learning for Local Solutions (GULLS) (see Chapter One) has presented an opportunity for comparisons among different coastal communities between and within the different hotspot countries (Hobday et al. 2016). For the purpose of this research, data collected in the southern Cape for the comparative GULLS social vulnerability assessment at the household scale (Aswani et al., 2018) presents the opportunity to reanalyse participant responses at a finer resolution. To this end, the GULLS social vulnerability responses have been reanalysed in the context of the previously identified thematic framework of stressors that drive system change (Gammage 2015; Gammage et al., 2017a). By reanalysing the GULLS survey responses, it becomes possible to supplement and complete the knowledge base of fishers' perspectives of change thereby filling a knowledge gap from the previous research. The insights from the crew are also vitally important as these fishers are the most vulnerable to change due to their historical marginalisation and lack of adaptive capacity (Sowman et al., 2014). In short, the present analysis is an essential addition to previous research (Gammage et al. 2017a, b) required for both the current (this thesis) and future research under the SCIFR project into responses to change and system transformation.

As such, the analysis presented in this chapter specifically presents information from the perspectives of the fishers who did not take part in the earlier research but who did take part in the GULLS household survey (generally referred to as 'participants' hereon). These are fishers who mostly act as commercial linefish crew and who have recently been identified as small-scale fishers (Chapter One). The results for those survey questions where the answers displayed a significant variation in responses (i.e. responses that were not even across the response categories). The frequency of responses to selected questions (shown in Appendix C) is discussed and analysed to gain insights into the knowledge and opinion of this group of fishers.

3.2. Methods

The GULLS project has focused on countries adjacent to five of the (mostly) southern hemisphere hotspots identified in Hobday & Pecl (2014)– South Africa, south-east Australia, Mozambican channel, southern India and south-east Brazil (Hobday et al. 2016). The GULLS social vulnerability project team developed a framework for the assessment of the social vulnerability of coastal communities within hotspots across cultures, oceans and scales through a country-scale comparison based on standardised interviews (see Aswani et al., 2018; Hobday et al., 2016). The GULLS household surveys - carried out over a period which overlapped with the research by Gammage et al. (2017a) – took place in small (≤ 5000 inhabitants), marine-dependent communities with participants in non-industrialised fisheries (Aswani et al., 2018). For South Africa, households who self-identified as fishery-dependent from the towns of Mossel Bay (particularly KwaNonqaba), Bitouville, Melkhoutfontein, Vermaaklikheid and

Slangrivier (see Figure 1.1) were surveyed (Aswani et al., 2018). Table 3.2 shows key demographic statistics associated with these communities.

Table 3.2. Key demographic features of the communities in which the fishers reside (source: STATS SA Census 2011 data)

	Area	Population	Number of Households	Predominant population group	Predominant first language	Estimated number of fishing dependant households (n=111)	Number of households surveyed (n = 59)
Bitouville (Gouritsmond)	3,2 km²	515 (158,9 per km²)	206 (63,6 per km²)	Coloured (54%)	Afrikaans (93%)	13	10 (77%)
Melkhoutfontein	0,9 km²	2 533 (2710,0 per km²)	614 (656,9 per km²)	Coloured (99%)	Afrikaans (95%)	35	25 (72%)
Mossel Bay (KwaNonqaba)	5,2 km²	27 561 (5271,7 per km²)	8791 (1681,5 per km²)	Black African (67%)	isiXhosa (54%	45**	12*** 27%
Mossel Bay (greater excluding KwaNonqaba)	36,8 km²	29 887 (813,2 per km²)	9033 (245,8 per km²)	Coloured (52%)	Afrikaans (81%)	(included in KwaNonqaba estimate)	(included in KwaNonqaba sample)
Slangrivier	11,4 km²	3011 (265,1 per km²)	688 (60,6 per km²)	Coloured (96%)	Afrikaans (96 %)	6	3 (50%)
Vermaaklikheid*	124.0 km²	356 (2,9 per km²)	99 (0,8 per km²)	Coloured****	Afrikaans	12	9 (75%)

*Vermaaklikheid forms part of small Emulation area no 1750031
**This number includes fishers active in the inshore trawl fishery. Linefish dependent households are estimated to be between 18 and 25)
***18 households initially surveyed – participants were excluded from this analysis. One participant's survey was not complete and therefore not usable while five participants were inshore trawl crew fishers with no experience in the small-scale linefishery".
****Unable to give the specific statistic for Vermaaklikheid proper as the emulation area significantly larger than a hamlet.

The complete South African survey consisted of a total of 253 questions (Aswani et al., 2018). As the surveyor was not a native Afrikaans speaker, a trained translator assisted with the completion of the surveys as most participants were Afrikaans-speaking. The survey was pre-tested to ensure the accuracy of the translated survey and to ensure the survey participants understood the questions. Answers were translated *in situ*, audio recorded, written down by the surveyor and later transcribed. A total of 65 household surveys were conducted across the research area, of which 59 have been used in the present study (see Table 3.2).

For the present analysis, the survey questions were reorganised to fit the thematic framework (described in Section 3.1 and Table 3.1) identified by Gammage et al. (2017a), with 163 questions being relevant (Appendix C, Table C1). The causal diagram shown in Figure 3.1 presents a graphical representation of this thematic framework. Questions from the survey included in the analysis include questions regarding weather patterns, environmental change, impacts on fishing and extreme events, and crew member's knowledge, attitudes and perceptions of the marine environment.

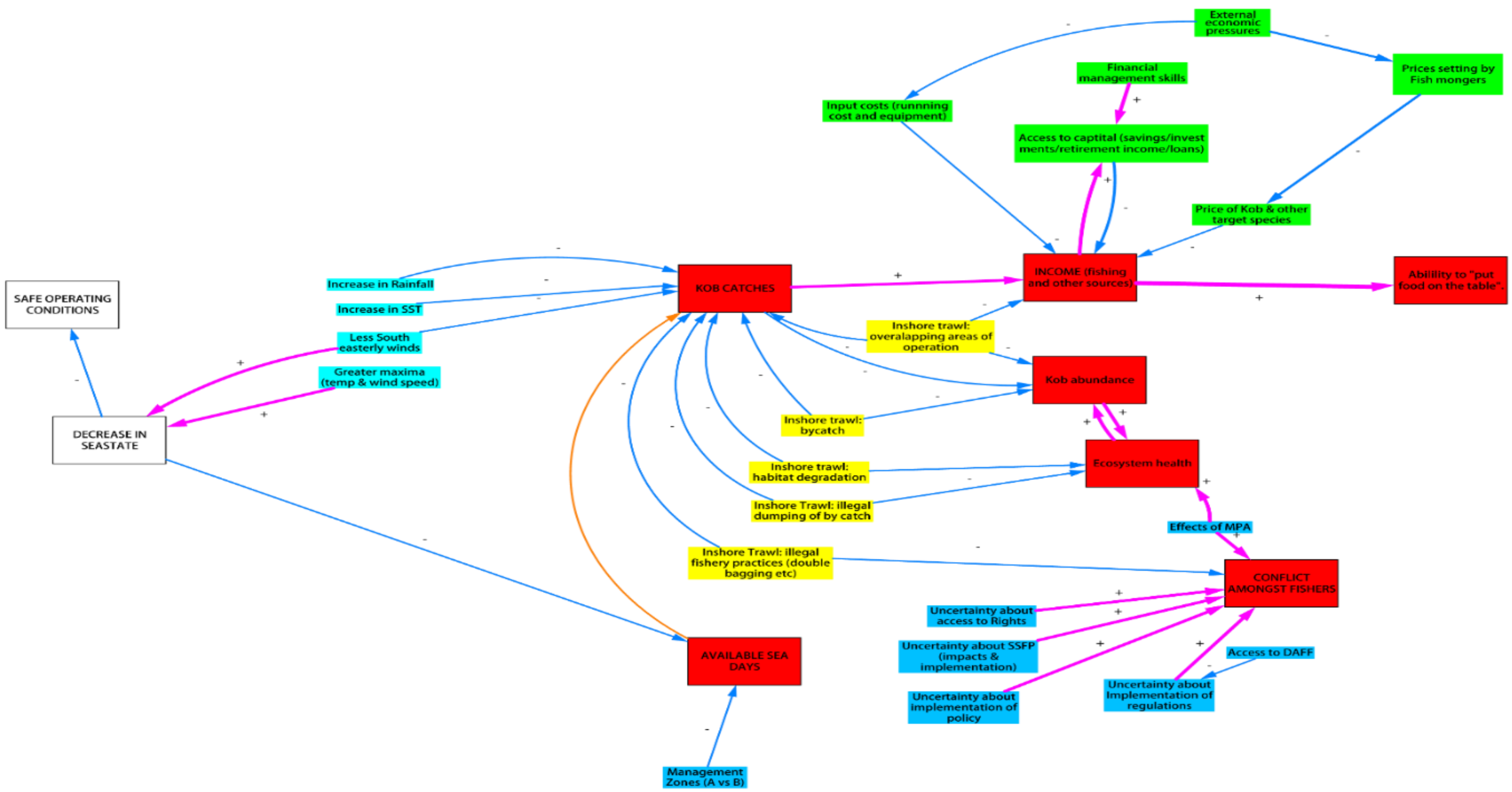

Figure 3.1. Causal map showing the thematic framework and associated interactions identified by Gammage (2015) and Gammage et al. (2017a). Connections between variables are show by arrows, where dampening effects are shown in blue, amplifying effects in pink. Interactions which are neither amplifying or dampening are shown in orange.

To complete the reanalysis of the original GULLS survey, survey responses were rescored. This rescoring was necessary as respondents did not keep to the original, coarse response categories of the comparative study. Open-ended questions were also rescored to reflect response ranges, and new categories which fit the recorded responses were created. An example is Q 1.6 where participants were asked the average distance that they fished from the coast. This was an open-ended question, and the responses were rescored to fit the categories that reflect the range of responses from participants. The resulting dataset consists mostly of categorical data, with the frequency of responses expressed as a percentage of the total sample (n=59). The data from the survey are supplemented in the analysis by information obtained by the surveyors through informal conversations and through information obtained when feeding the preliminary results back to key informants in a group setting, where conversations were likewise recorded and transcribed. Appendix C (Table C2) presents the rationale table which shows the identified the broad- and sub-theme each question is aligned with, the original survey question number and associated indicator (per the survey design) as well as the rating/scoring method used in the present study while Appendix C (Table C1) details which questions were used in the reanalysis. Feeding back the preliminary results to key informants in informal contact sessions also presented an opportunity to clarify unclear responses. This was particularly useful to clarify ambiguous questions and served to refine the scoring as presented in Appendix C (Table C2).

A multi-dimensional scaling (MDS) analysis[12] was conducted to ascertain whether (1) there was a variation in response between age groups and geographical location and (2) there was variation in the answers provided by respondents within geographical areas. This MDS analysis was carried out using the Gower similarity index in R (version 3.2.5), to provide insight into the variation of responses per town and age group and internal variation per town.

3.3. Results and Discussion

As mentioned in Section 3.1. the analysis presented highlights the responses for which there were clear indicators (questions where there was a majority answer for one or more category). Notably, numerous questions were not answered by all participants, and many answers had an even distribution among the answers with no discernible pattern in responses. Using the MDS analysis, it was possible to ascertain whether responses to questions varied per town of age group (Figure 3.2) or whether there was internal variation within responses per community (Figure 3.3.) Importantly, no clustering pattern is seen in the plots, and thus no separation by community or age group is

[12](Non-metric) multidimensional scaling (MDS) "is an indirect gradient analysis approach which produces an ordination based on a distance or dissimilarity matrix…MDS attempts to represent, as closely as possible, the pairwise dissimilarity between objects in a low-dimensional space." (https://mb3is.megx.net/gustame/dissimilarity-based-methods/nmds). For these types of analyses any similarity or dissimilarity coefficient or distance measure can be used to build the distance matrix - in this case the Gower similarity index has been used. When interpreting or reading the resulting plots, objects that appear closer together or clustered are likely more similar than those that are far apart (https://mb3is.megx.net/gustame/dissimilarity-based-methods/nmds). For the MDS plots presented here, each data point represents an individual participants' responses.

apparent in these results. As there is no differentiation between responses per town and age group, the results presented represent all participants' responses across the entire research area in one grouping. Table 3.3 presents a summary of the key indicators and responses relating to demography, education and skills

a. **b.**

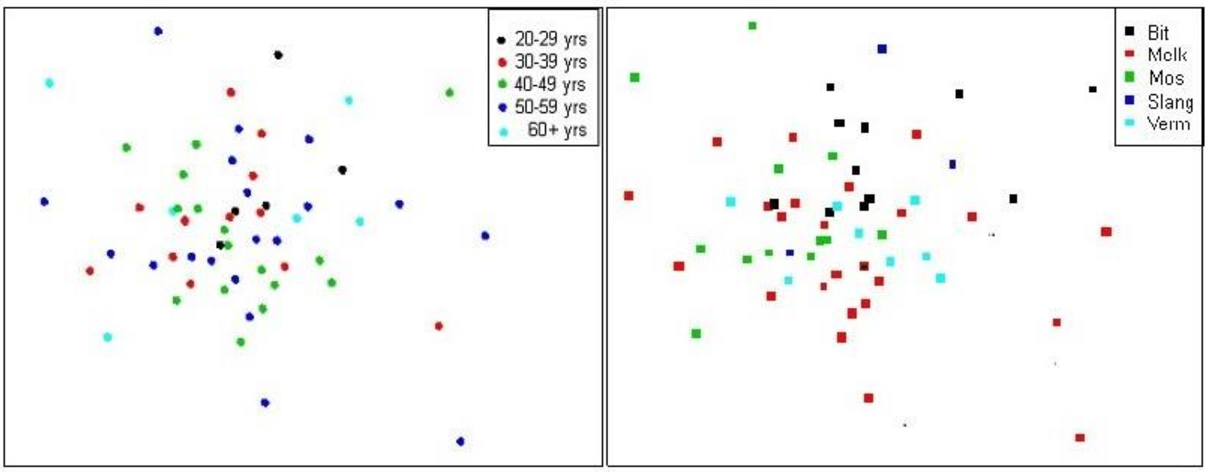

Figure 3.2. MDS plot showing variation in responses in age (a) and town (b). Note no separation by category. Towns included in (b) are Bit- Bitouville, Melk – Melkhoutfontein, Mos – Mossel Bay, Slang – Slangrivier and Verm – Vermaaklikheid. IsoMDS stress value for (a) & (b) ~26, 29403

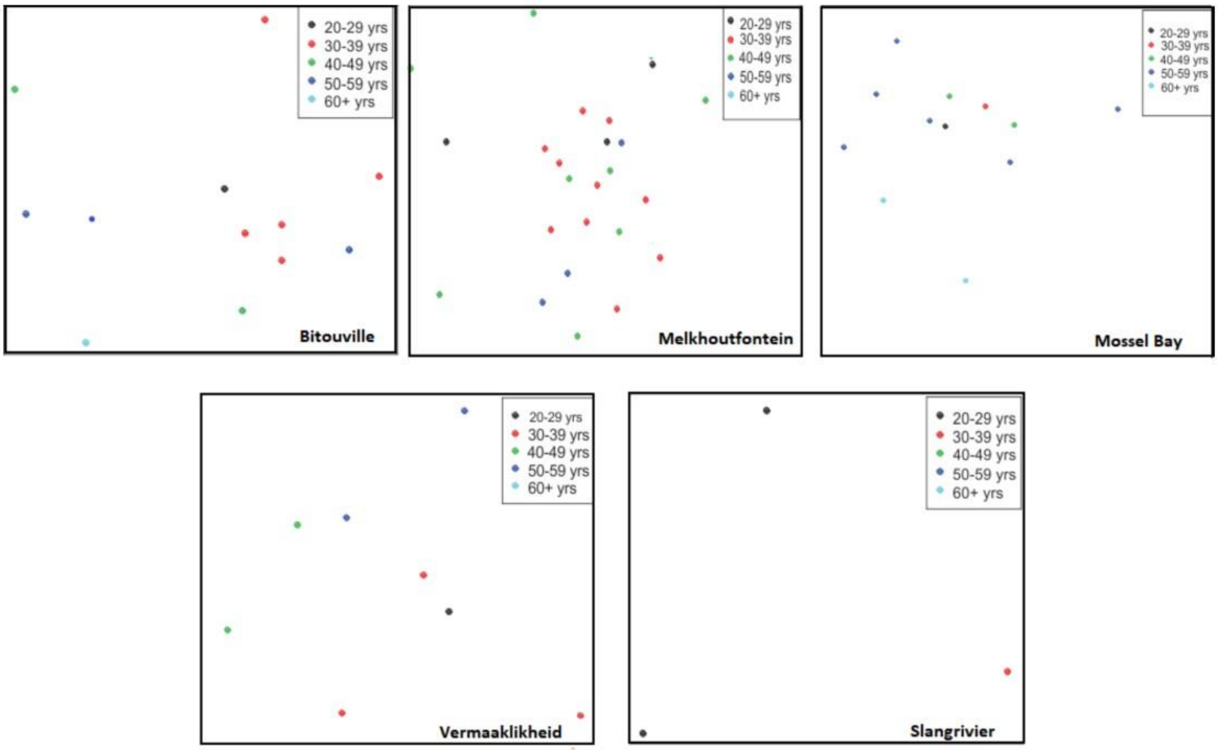

Figure 3.3. MDS plots per community reflecting the internal variation of responses according to age groups. Note the absence of clusters. IsoMDS stress value for Bitouville ~13,44301; Melkhoutfontein ~19,54759; Mossel Bay ~14,17029; Vermaaklikheid ~11,58357 and Slangriver ~0

.

Table 3.3. Responses relating to demography, education and skills

Demography	
Median Age	49 years
Role	85% crew. Rest of respondents can be either be classified as skipper/business owner/rights holder. No delineation between skipper/business owner/rights holder with some respondents.
Fishing main occupation & source of income	88% active fishers. The remainder of fishers is retired or inactive fishers.
Race	92% Coloured
Education	
Entered secondary school	49%
Completed secondary school	0%
Additional 'skills' courses completed	37%
Current non-fishing skills	49%: Gardening 17%: Welding 12%: none/NA 8%: First Aid 7%: Mechanics, building, masonry 7%: other (including wood cutting & thatching) 72% of the participants indicated an interest in learning new skills.
Fishing Activities	
Distance from the coast where fishing takes place.	10%: offered no response 8%: 0-5 km 14%: 6 – 15 km 17%:16 - 25 km; 8 %: 26-35 km; 22%: more than 35 km 8 % indicated that the fishing range was species dependent 12 % of fishers were unsure how far from the coast they were catching fish. 46% of all participants indicated that the average distance where fishing takes place had not changed in the time they had been fishing, 14 % indicated they were unsure.
Days spent fishing	37%: 2 - 3 days a week 31%: 3-5 days a week 19%: 1-2 days a week 8%: every day 5%: no answer/response 18% of fishers offered weather dependent qualifiers.
The average length of trip	Average time spent fishing per trip: 6%: No answer/response 9%: 1 – 6 hours 46%: 7 – 12 hours 23%: 12-24 hours 8%: 1 – 7 days (deck boats) 8%: More than a week (deck boats) Weather dependent qualifiers in all responses.
Target species	Top four target species: Kob, Sharks Redfish Carpenter/Silvers No change in the primary target species (Kob, Sharks, Redfish) have taken place in the past five years
Access to resources	75%: too many fishers involved in the fishing industry in their community 66%: too many fishers fishing in the area where they fish

The median age of the participants (49) suggests an ageing cohort with few new entrants. This is corroborated by oral accounts of some of the respondents and prior research (Gammage, 2015; Gammage et al., 2017 a,b). The towns and suburbs in which respondents reside can be classified as previously disadvantaged and are characterised by low-income levels, poor infrastructure and high unemployment typical of such fishing communities in South Africa (Isaacs, 2006). Low formal education levels seen are also typical for this community typology. Respondents are generational fishers of whom few have received alternative skills training (formal or informal). Where alternative skills training has taken place, half were for skills linked to fisheries and the marine environment. Although many engage in building activities as an alternative income, most had not received formal artisan training.

Interestingly, only 7 % of respondents indicated that they had building and masonry skills even though building work seems to be the favoured alternative livelihood activity (Gammage & Martins, unpublished data.). This may be due to the availability of building work and the salaries paid for such work. About half the respondents were not confident that their current skill set would add to their success outside the fishing industry.

Inadequate formal education and skills training limit fishers in several ways. Not only is access to alternative livelihoods constrained by educational and skill limitations, but so is decision-making at various scales of the person and household. Although much of the current educational and skill shortages within this group is mostly an apartheid legacy issue not easily solved, the role of inadequate quality education in previously disadvantaged groups in poverty eradication in South Africa is well recognised and in principle, a government development priority espoused by the national development plan (NPC, 2011). Unpublished GULLS results (Gammage & Martins, unpublished data) show that a lack of adaptive capacity across the region is a key component of the social vulnerability of this group of participants overall in a situation with limited fish availability (Gammage et al., 2017b). Improved and alternative skills training may, therefore, be the first step in improving the adaptive capacity of this group of fishers.

Most participants who are actively crewing on linefish boats in the area, are not involved in decision-making related to the fishing business and often not privy to business-related information. This is apparent when responding to questions that are related to fishing-business questions (see below). Mostly due to their extensive experience in the fishery, respondents provide valuable insights into day-to-day fishing activities. Although the reported average distance travelled from the coast to fish was more than 35 km, follow-up conversations indicated that this distance was often distance travelled from a port, parallel to the coast. Distance and not direction are the most important consideration – while travelling parallel to the coast may be safer, the distances covered results in an increase in fuel costs, leading to an increase in operating costs and decrease in profit margins. Fishers do venture further from the coast when specifically targeting carpenter/silvers (*Argyrozona argyrozona*) in the absence of silver kob (*Argyrosomus indorus*), although this does present safety concerns while not being the most economically efficient option (Gammage et al., 2017a). Local resource scarcity is, however, increasingly forcing fishers to diversify their target species and fishing grounds. These decisions are curtailed by physical constraints which include access to capital and infrastructure challenges (Gammage et al., 2017b; Gammage, 2015). Following numerous conversations with this group of participants carried out throughout this research process, the fishery in the area is currently oversubscribed concerning crew numbers. This is also evident in the survey responses where a majority have indicated that there are too many fishers' active in the fishery and the area where they fish. This result is further corroborated by prior research where Gammage et al. (2017a) identified crew boat site shortages as a probable future stressor. Gammage (2015) documented a high attrition rate of active skippers in the fishery. The impact of this attrition is an oversubscription of the crew, which contributes to livelihood and income risks. The implementation of the Small-scale Fisheries Policy No 474 of 2012 (SSFP) (DAFF, 2012) is expected to serve to mitigate some of the risks posed to the crew by skipper attrition through the empowerment of crew to manage fishing rights and fish processing through co-operatives. This policy, currently in the early implementation phase, seeks to empower traditional fishing communities to sustain and build livelihoods through the implementation and management of community fishing rights (see Sowman, 2011; DAFF, 2012; Paterson et al., 2014, Chapter One).

3.3.1. Stressors that make fishers vulnerable to change

Stressors in the Natural system. The thematic framework identified by Gammage et al. (2017a) shows that major stressors identified in the research area include the effects of climate variability. For this research, questions related to changes in the natural system were framed explicitly within the context of climate change as GULLS is concerned explicitly with social vulnerability to climate change (Hobday et al., 2016, Aswani et al., 2018). Tables 3.4, 3.5 and 3.6 provide a summary of the key results related to climate as a stressor within the natural system.

Table 3.4. Responses relating to climate-related changes within the natural system

Weather, climate- and perception of environmental change	
Weather patterns threaten fishing	46% (yes)
The climate in their area had changed over time	93% (yes)
Environmental change experienced/noticed	Sea level: Even response recorded; 14% gave no answer Rain: 72% (yes) Wind: 88% (yes) Air temperature: 59% (yes) Wave height: Even distribution in yes/no response Current strength: 61% (yes); 12 % no response/answer Rough seas: Even distribution in yes/no response SST: 68% (yes); 24% (no); 8 % no response Bottom Temperature: 58% (yes) 27% (no); 15% no response
Saw changes to the marine environment (which changes not specified)	78% (yes)
Climate change exposure	
Awareness of climate change	68% (yes- aware)
Climate changed in the area over time	93% (yes). Period not specific in question.
Perception of safety in current livelihood despite environmental/climatic exposure	No clear indicator in responses. 35% - safe 26% -somewhat dangerous
Effect of environmental change on fishing	
Fishing in danger due to changes in weather patterns	77% (yes)
More difficult to catch fish when compared to the past	81% (yes)
Fish abundance/availability in the past year	58% uncertain/no answer

Table 3.5. Extreme events and impact on fishing

The occurrence of extreme events in the last five years	Personally affected (y/n)	Number of fishing days lost
Storms – 54%, yes	Of those who answered yes, 80% were not affected	No clear consensus on fishing days lost – even distribution
Floods – 52%, yes	Of those who answered yes, 62% were not affected	Little to no fishing days were lost due to floods
Drought – 54%, yes	Of those who answered yes, 60% were not affected	Little to no fishing days were lost due to drought
Shoreline changes – 60%, yes	Of those who answered yes, 75% noticed changes in shoreline – 63% indicated moderate damage had taken place	

Table 3.6. Knowledge, attitudes and perceptions of the marine environment

Marine Environment	
Level of knowledge of the marine environment	87%: some level of knowledge
Ability to personally improve the marine environment	Even distribution across a 5-point scale
Responsibility to protect the marine environment	73% - big responsibility
Witnessed changes to the marine environment in a lifetime	85% (yes)
Perception of overharvesting of local marine resources	80% (yes)

While these participants acknowledge that the climate has changed in the area in the recent past (timescale unknown), less than half feel that the reported change impacts on their fishing activities. However, participants have, in follow up conversations and feedback sessions indicated that they are proceeding to sea less often due to increasingly unfavourable weather conditions (specifically during the austral spring and summer which is primary kob 'season'). In conversations, participants report changes in SST, variation in current strength and direction and changes in prevailing wind direction and strength in the recent past. Gammage et al. (2017a) provide an extensive discussion of recently observed variation in the physical environment. While some of the variation observed by participants can be attributed to the cyclic variation at various scales, anthropogenic stressors can be assumed to be increasingly present in the system (Mead et al., 2013). Participants from both the previous research and this research do not seem to be willing or able to recognise that current challenges in kob catches could be, in part, to blame on changing weather conditions and that the current status quo could become the new normal. A decline in local biomass due to fishing pressure (mostly from other sectors), must also be considered.

About half of the participants indicated that they had experienced extreme events, even though the impact on fishing activities were minimal with the most significant impact attributed to shoreline change. The changes in shoreline were attributed to beach erosion over the last five years. With extreme events in South Africa expected to become more commonplace as climate change advances, impacts on coastal communities and fishery activities will increase, and communities who plan for these future changes will be better equipped to sustain livelihoods (Mead et al., 2013).

Stressors in the social and economic (sub-)systems. Stressors in this system component were mid-range stressors in the framework identified by Gammage (2015) and Gammage et al. (2017a). Although integral to the optimal functioning of the fishing system, these stressors tend to be hidden and not foremost on the participants' minds. Survey questions utilised include those concerning income, employment, dependence on fishing (for income) and the fishing market/business, physical capital and the historical dependence on fishing (culture).

Table 3.7. Stressors linked to the economic component of the social and economic (sub-) system

Income	Employment	Dependence on fishing for income(livelihood)	Fishing Market
86%: variation between summer and winter income	78%: fishing is a very important local economic activity.	The biggest risk to fishing livelihoods: 34%: reduced fish abundance 25%: market 20%: environmental change 14%: no response 3%: Injury 3%: Other (not specified)	Fish either sold to: 44%: a large processor 49%: intermediary/middleman 7%: no response
Average total monthly income per household: 8%:< R1000 31%: R1000-R2500 42%: R2500 - R5000: 14%: R5000-R7500 2%: No answer	69%: not interested in changing jobs or working for someone else	63%: fish is an important source of food	85%: never sell to buyers outside the community
51%: not planned for any financial security, 19% planned a little 24%: well planned, 7% very well planned	31%: have held more than one job in the past year.	Ability to feed a family if not fishing: 46%: Not at all possible 24%: slightly possible 19%: possible 5%: highly possible 6 %: no response	53%: fish prices have increased over last year, 25%: stable 10%: unstable 2%: decrease 10%: no response
85% - no access to savings 64% knew where to access cash in an emergency.	73%: have not had employment changes in the past year	41% would source (financial) assistance from family 31% from loans; 17% other (unspecified); 5% neighbours & friends; 8% no response.	Relationships with intermediaries in the community: 69%: no response
90% - all working members contribute to a household's overall expenses.	57%: willing to relocate for employment if necessary	Changes to livelihoods due to changes to the marine habitat: 76%: no change 10%: change 14%: no response	
97% of respondents have indicated they have a bond repayment 68% indicate they service other debts	Ability to find work in another sector: 54% (yes) 8%: no answer/response. The degree of difficulty in finding alternative work if known as a fisher – 69% (easy).		
68 %: not extended loans to anyone in the last years 66%: not at all possible to access financial reserves if they were to cease fishing for extended periods	Employability: usefulness of skills in setting up a business other than fishing: 40% - useful, 54% - varying negative responses 6% -no response		
	employed in more than one job per year (level of occupational diversity throughout the year): 69% (rarely/never)		

Table 3.7 shows that many of the participants report they earn less than R5000 per month (per household) while half have not planned for any financial security and with more than 60% indicating that, should fishing fail as a livelihood activity, they would not have any access to financial reserves. The seasonality of the kob fishery means fishers have in the past earned more in the summer months which is kob season. Kob is a high-value fish and can be a lucrative livelihood when caught in abundance. However, in the recent past, kob catches have been consistently poor (Gammage et al., 2017a, b). Consequently, fishery participants are financially constrained with many having depleted savings and having to rely on alternative activities to secure livelihoods (Gammage et al., 2017a, b). The most significant impact is on the crew who face more financial constraints at the onset, with less access to financial resources and few alternative skillsets. Although most have indicated they have held alternative employment in recent years, most have done so out of necessity. Added to a desire to remain in the fishery, as indicated in follow-up conversations, is the lack of alternative formal employment opportunities in the area (Gammage et al., 2017b).

Regarding physical capital, 77% of respondents own homes, while 91% do not own boats — many participants own homes mostly due to national low-cost housing programmes. Also, most participants have access to essential services such as piped water and electricity. They own fishing gear, televisions stoves, cellular telephones, fridges, washing machines and gardening/power tools (as derived from their responses). As most do not own cars, those living in more remote towns such as Vermaaklikheid, Slangrivier and Bitouville, struggle with access to bigger centres where they need to purchase goods and access services. Demonstrating access to suitable vessels is an evaluation criterion per the guidelines to allocating fishing rights (DAFF, 2013) and is seen as being vital in securing a commercial linefish right. Crew feel that their inability to access the capital required to acquire vessels make them unable to transition to skipper and business owner if they wish to do so.

Table 3.8. Culture (historical dependence on fishing)

Indicator	Results
Time spent fishing (years of life)	10%: 0-5 years 19%: 6-15 years 20%:16-25 years 31%:26-35 years 15%:36-45 years 5%: 46-55 years
Generational fishing	81 %: earlier generations of their family were fishers 75%: identity as a fishing family
Parental assets	97%: parents had owned boats Parental home ownership: equal yes and no responses.
The feeling of belonging to a community	95%: feel like they belong or strongly belong. 94%: friendships within the community are very important and/or important.
Pride as fishers	83%: not proud to tell people they are fishers. 54% would not like for their children to be fishers 59%: do not feel concerned by the lack of young people entering the fishery in the area
Local Ecological Knowledge	82%: very important to pass on the LEK about fishing to younger generations, When asked whether LEK was currently maintained or lost in the community the responses on the 4-point scale were evenly distributed.

Table 3.8 shows that more than half of the participants have been fishing for more than 16 years, with 15% fishing for more than 36 years. Most are generational fishers who identify as fishing families. Interestingly, most participants indicated their parents owned their boats, although they did not necessarily own their homes. It is difficult to ascertain whether this generation of fishers are better off or worse off than the previous generations, since conditions, such as policy, political system, resource abundance, climate and weather have changed significantly. It is not clear whether this fishing tradition will be passed on to the next generation – 84% of participants indicated they are not proud to tell people they are fishers, although when asked whether they would actively discourage their children from entering the fishery, there was no clear indication across a four-point scale.

Similarly, almost half indicated they do not feel concerned by the lack of young people in the fishery in the area. While there seems to be a strong link to fishing as a tradition, it was not clear from the survey interviews whether they are still fishing because of the link to culture or whether it is their only livelihood option in the area. Most participants indicated that they felt strong bonds to and within the community, which is consistent with the attachment to place identified in other user groups (Gammage et al., 2017b). This is a manifestation of an attachment to a place which is shaped by their shared social experience as a group and as individuals. Further exploration of the patterns seen in the attachment to place can help to predict specific behaviours more especially during times of change (Masterson et al., 2016). A contradiction in the participants’ responses emerged when considering the lack of pride, they feel as fishers and the fact they do not seem to be actively discouraging their children from entering the business, although this is most probably due to the lack of alternative employment. Subsequent conversations with key informants indicate that some participants are passionate about fishing and view it as a calling. These participants indicated they would encourage their children to fish if they thought it was financially viable. Their lives have been fraught with financial hardships, and they want better for their children. By their parents' account, children are also not keen to enter the fishery after having seen and experienced the financial hardships and the consequences of poverty.

Policy and Regulation: Issues surrounding policy and regulation are a major stressor in this fishery system (Gammage et al., 2017a; Gammage, 2015). The GULLS survey framed questions related to policy and regulation as management and governance, although the focus of the questions did not take context-specific factors into account. Table 3.9. presents pertinent results.

Table 3.9. Management and governance responses as per GULLS crew survey

Management and Governance	
Marine resource management presence in community	95%: yes - government controlled.
Changing rules and practices in response to environmental change	66%: rules and practices have changed
Impact of Illegal fishing on community	68%: not concerned. When asked whether illegal fishing does occur, even distribution across a four-point scale.
Conflict amongst fishers	43%: slightly common
Decision-making surrounding MPA	74%: no involvement at all
Level of involvement in community decision-making	No clear indication

Previous research shows policy and regulation ranked as one of the most critical stressors for fishers in this fishery. As the GULLS survey did not place much focus on policy and regulation as a stressor and to ensure that the information captured by previous research applied to the crew component, aspects related to policy and stressor were discussed with key informants in follow-up interactions. Importantly, there was much parity between prior research (Gammage 2015, Gammage et al. 2017a) and the views expressed by the key informants from this group. In short, challenges were ranging from the implementation and enforcement of policy to the influence of other fishing sectors in the same area of operation. The interaction and consequences of the policy and regulatory stressors are complex with far-reaching consequences for fishers and have been extensively discussed in Gammage (2015) and Gammage et al. (2017a).

Additionally, key informants recognise that obtaining and exploiting their rights may hold the key to their financial emancipation. In future, this shift could be brought about by a change in policy, notably the successful enactment of the SSFP. If successful, fishers and their communities should at the very least be able to secure improved food security and at best, manage profit-making co-operatives which engage in a diverse set of livelihood activities for both current and future generations.

The successful enactment of this policy may be contingent on the resolution of the current stressors in the linefishery system. An example of this is the potential escalation of conflict amongst fishers and fisheries that already exist. The allocation of small-scale rights is seen to be placing the potential rights holders in competition with holders of commercial linefish rights which has already caused friction with some of the current linefish skippers and there have been reports of linefish crew being replaced due to their potential future involvement in the small-scale fishery (Gammage, unpublished data). The number of fishers active in the area is not large and competent crew may be in short supply on the commercial linefish boats, should they choose not to continue working as commercial crew. The future allocation of commercial linefish rights are also of concern – the linefishery is operated with a total allowable effort (TAE) and to allocate small-scale rights, the commercial linefish rights must be decreased to stay within the TAE. Minimising policy and regulatory stressors will require a delicate balancing act between current management objectives and user expectation to ensure the long-term sustainability of both the commercial linefishery and the co-operative based small-scale fishery.

3.3.2. Attitude to change and adaptation options

Tables 3.10 & 3.11 show pertinent results from questions participants were asked questions to gauge their attitudes to change and to respond to questions concerning possible changes in their livelihoods as a measure of attitude and approach to adaptation to change.

Table 3.10. Attitude to change responses as per GULLS crew survey

Attitude to change	
Response to changes in everyday life	57% slightly used to change, 25% not at all used to change
Future of fishing	85% only big companies will survive future changes in the fishing industry
Level of confidence that things will turn out well regardless of changes and challenges	Even distribution of responses
Level of risk posed by environmental changes to the community	46% high risk
Level of anxiety about changes in the environment	Even distribution of responses

Table 3.11. Responses to adaptation scenarios presented in the GULLS survey, where participants were asked to indicate their response in the case of possible changes in their primary livelihood activity (fishing)

Change response option	Response in the case of worsening or changing weather conditions	Response in the case of increasing difficulty in finding fish	Response in the case of a 50% decline in catches	Response in the case of a permanent 50% drop in fish price
No response to a question	7%	11%	8%	15%
Seek alternative employment/income sources	44%	49%	27%	39%
Keep on fishing, carry on per usual where possible	25%	20%	46%	19%
Relocate	2%	5%	0%	0%
Stop fishing/unsure	22%	15%	19%	27%

In addition to the high natural variability experienced along the South African coastline, regarded as one of the most naturally variable on earth (e.g. Mead et al., 2013); the coastline is affected by a range of anthropogenic stressors which include resource scarcity, poor socio-economic conditions and policy and regulatory challenges. The result is that fishery systems are becoming increasingly vulnerable to change, in turn posing a threat to fishing communities along the South African coast. Fishers will need to respond to these and other global changes within systems to become more resilient in the face of change (Berkes et al., 2003). The results show participants are not entirely comfortable with the change and variability experienced in everyday life. Elevated levels of uncertainty within the fishery systems and an absence of enough natural, social and economic capital identified within this group of participants, may prohibit them from responding to change proactively. Some of the recent changes may have been more abrupt than others (such as sudden changes in fish catches) resulting in fishers being caught off-guard. Many participants have indicated they think only big companies will survive. This result serves as an acknowledgement that while participants hope things may turn out all right, they do recognise that unless something drastic changes, their fishery may well not be able to survive on the long term and does not indicate a positive outlook for the co-operatives that will be established by the implementation of the SSFP. Research by Visser (2015) described a resilient fishery that has been operating in the area for the past 100 years, although this trait may not continue in a climate of rising input costs, resources scarcity and constraints imposed by policy. There are, however, several contradictions in the responses by participants within this set of questions. Given their views on the future of the fishery one would expect an overwhelming amount of pessimism when considering their level of confidence that things will turn out well over the long term. There was, however, no clear indicator over the 4-point scale. The cause for the contradiction is unclear, but it may well be a case of 'hope for the best, but plan for the worst' documented in previous research (Gammage, 2015; Gammage et al., 2017b). Important to consider is that the ability to 'plan for the worst' is constrained by lack of financial capital and the strong 'sense of place' (Masterson et al., 2016) may be a barrier to the change needed to ensure future sustainable livelihoods and wellbeing. Gammage et al. (2017b) provide an analysis of change response strategies implemented across the research area within the linefishery.

While stressors that lead to change do not display significant spatial variation, change response strategies do. Gammage et al. (2017b) identified three broad groupings – fishers who adapt, fishers who cope and fishers who react. Based on the grouping already identified, it appears that the participants in this study (crew) cope or react when responding to change because they typically do not have the necessary social and economic capital to diversify within or outside the fishery, even if they wish to do so (Table 3.11). Responses to the scenarios shown in Table 3.11 are a testament to the fact that fishers currently do not explore long-term and permanent options outside the fishery. The apparent unwillingness to proactively engage with employment or skills outside the fishery seen throughout the results are not only a reflection of structural constraints but also of the cultural and historical component attached to line fishing in the southern Cape. To only consider sustainable livelihoods in decision-making is insufficient - the associated aspects of human wellbeing, where quality trumps quantity must also be considered throughout (Masterson et al., 2016). Scenario stories such as those presented in Chapter Five, present a tool through which human wellbeing can be practically incorporated into decision-making processes at various scales.

3.4. Conclusion and outlook

This contribution fills a knowledge gap exposed by previous research and provides insight into the linefishery crews' perceptions and opinions of the various stressors that drive change in their fishery system. This has been accomplished by applying survey responses to the thematic framework of stressors identified in Gammage (2015) and Gammage et al. (2017a). Importantly, these results show that the stressors that drive change in the fishery system are consistent throughout the research area (no internal variation between towns were noted), with minimal variation between the perceptions of the crew reported on here and those described by previous research which focused on various user groups. The lack of internal variation in responses regarding stressors that drive change makes a case for research that is area-specific (at the scale of the southern Cape) as opposed to town-specific (smaller scale). Area-specific research is however, only applicable where context is similar. This is evident when considering responses to change, where there was much variation between geographical locations in how fishing communities either coped, reacted or adapted (Gammage & Martins, unpublished data; Gammage et al., 2017b). The results presented in this study add to previous research, which allows us to form a more holistic view of the complex system while highlighting the complexity and associated uncertainty of interactions of drivers of change in the SES. This complexity and associated uncertainty make it difficult for fishers who currently act as crew in the commercial linefishery to respond to future change in a proactive manner. The research presented in this Chapter, through explicitly addressing Aim 1, also contributes to Aims 2 and 6 of this thesis (see Section 1.9). It is also integral to informing the thematic framework used in the causal mapping process, developed in Chapter Four.

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Chapter Four

Making sense of wicked problems: Are structured decision-making tools useful with marginalised fishers in problem structuring in complex social-ecological systems?

4.1. Introduction

Adequate problem identification and framing[13] is an important start to any policy and modelling process (Haapasaari et al., 2012b). This suggests that the most essential elements and interrelationships within a system must be taken into consideration while facilitating the understanding of problems in their entirety, helping identify the right questions along with denoting the first steps in developing holistic knowledge, research and ultimately, management strategies (Young et al., 1999; Walker & Harremoës, 2003; Sluijs & Craye, 2005; Clark & Stankey, 2007; Verweij & Densen, 2010). Adequate problem framing involves all stakeholders and focuses on the socially constructed nature of potential management challenges and problems (Haapasaari et al., 2012b). This manner of problem framing moves beyond the values and interests of a particular group of stakeholders and strives to incorporate stakeholders' perceptions and lines of reasoning (Clark & Stankey, 2007; Jones et al., 2011). By making it explicit how various individuals and/or groups piece together a specific problem (such as resource scarcity) it becomes possible to facilitate reciprocal and social learning, but also enhance better and more effective communication and develop effective management approaches (Clark & Stankey, 2007; Verweij & Densen, 2010; Jones et al., 2011; Haapasaari et al., 2012a).

Holling (1973) in presenting his ecological theory of ecosystem dynamics and resilience (then defined as persistence in the face of change), provides necessary insight in management challenges in complex SESs. Recent resilience research recognises the need for systems to adapt to change and transform into more desirable development pathways (Berkes et al., 2003; Walker et al., 2004; Olsson et al., 2008; Österblom et al., 2011). The implementation of an ecosystem-based approach to fisheries management (EAF) (see Chapter One) is the preferred approach to deal with complexity in marine SESs (FAO, 2003; Garcia et al., 2003). System models assist in understanding the likely effectiveness of (eventual) alternative management decisions (Starfield & Jarre, 2011;

[13] A problem framing and structuring process is not only an important step in many decision support processes including (but not limited to) Integrated assessment (IA), multi-criteria decision analysis (MCDA) and structured decision making (SDM) (Belton & Stewart, 2002; Gregory et al., 2012). Problem structuring refers to the process of making sense of an issue and serves to identify "key concerns, goals, stakeholders, actions, uncertainties and so on" (Belton & Stewart, 2002: 35). It can more formally be defined as the "identification of those factors and issues which should constitute the agenda for further discussion and analysis" (Rosenhead, 1989). Belton and Stewart (2002:36) use this term to describe the process of "arriving at an understanding the situation…"

Barton et al., 2012). Varying contexts, objectives, priorities, knowledge, influence and stakeholders require that models be adaptable and thus flexible to include evolving bodies of knowledge as well as the incorporation of different bodies of knowledge (Starfield & Jarre, 2011). To do this and to be able to operate on multiple scales and levels of resolution (with the eventual aim to facilitate wise decisions and promote capacity building or social learning), various models which can address different questions and suit different purposes are required (Jarre & Moloney, 1996; Barton et al., 2012).[14]

Causal maps are a standard problem framing/structuring tool and an effective way to conceptualise a system. This tool provides a formal visual view of the system and is useful to identify key areas of concern, organise ideas to clarify goals and actions, and highlight knowledge gaps. It is a process that is particularly useful if the initial problem statement is very general and if the issues at hand are particularly 'messy' (Belton & Stewart, 2002; Özesmi & Özesmi, 2004). Specifically, causal mapping is used as a problem structuring tool to examine hidden interrelationships, feedback loops and multi-scalar interaction of stressors that lead to change in the selected fishery system. Examples of successful use of the tool in the southern African context include issues around southern African rock lobster fisheries (Basson, 2009; Stewart et al., 2009).

Causal mapping also provides the visual conceptualisation of the system which is helpful in the Bayesian belief network (BBN) parameterising process. BBNs are a tool that allows for a better understanding of the uncertainty that exists in a system but at the expense of feedback loops. BBNs define states for each model variable and, together with the probabilities attached to these states, use Bayesian statistics for a combined evaluation (Kjærulff & Madsen, 2008). BBN modelling techniques allow for the determination of probabilities of outcomes associated with multiple drivers of change. The technique provides synthetic insight into the uncertainties within the system and the knowledge held by participants.

The research area and nature of the fishery has been introduced in Section 1.7 of this thesis. Small-scale fishers, who act as crew on the commercial linefish boats of the southern Cape in South Africa are the focus of this research. This fishery is boat-based and conducts mostly day trips of six to eight hours on average. This fishery operates with single handline and carries minimal to no ice or refrigeration. The catch volume is more than subsistence (enough to sell) but significantly less than trawl or long line fisheries (DAFF, 2016). The fishery has been plagued by increasing resource scarcity, variability in physical systems and policy uncertainty in recent years. Previous research describes the fishers' inability to respond adequately to the various changes and ensuing uncertainty while suggesting that a scenario-based approach to change may be the most suitable risk-mitigation strategy for this group of fishers (and fishers in general) (Gammage, 2015; Gammage et al., 2017a,b). The causal mapping and BBN

[14] Appendix B presents a brief overview of the modelling principles adopted in this thesis.

modelling form an integral part of the prototype scenario planning exercise explored in this thesis. The use of decision-making tools in this research is two-fold. The broad question this chapter seeks to address, related to Aims 2 and 3 in Section 1.9, are "What can be learned about the fishery system and its interactions using the problem structuring tools and their outputs?" and "What can be learned through the iterative implementation process?"

These questions have further been refined to address the specific context of each tool (Section 1.10). The questions addressed that are specific to the causal maps are (1) What interactions, including indirect interactions and feedback loops, are revealed through the use and development of causal maps for the southern Cape linefishery? and (2) Is the use of the causal maps appropriate and beneficial in an iterative and interactive process with stakeholders who are unfamiliar to more structured decision-making processes? The questions being addressed by the BBN's are similar namely, (3) What are additional insights gained into the drivers of change and linked uncertainty that exists in the southern Cape linefishery system through the development and use of the weighted hierarchy and BBN? and (4) Is the use of the BBN appropriate and beneficial in an iterative and interactive process with stakeholders who are not familiar with the tool?

The chapter starts with a brief description of the overarching approach followed. The specific approach used in the development of the causal maps, the methods for the data collection and model construction follow. The results of each of the iterations are followed by a discussion on themes related to the use of causal mapping in a qualitative modelling process and completes the section on causal mapping. The BBN section follows a similar structure – first, the approach used in the development of the BBN and the model construction and sensitivity are described. The results relating to the construction process, the model outcomes and sensitivity testing follow. A discussion pertinent to the BBN process follows before the chapter concludes with key insights gained through the use of both the tools.

4.2. Qualitative modelling with stakeholder: approach, methods and results

The overarching methods and associated data collection methods and timelines have been presented in Chapter Two, Section 2.7 of this thesis. The methods presented here follow those that pertain directly to the development of the causal maps and Bayesian belief networks (BBNs) processes. The causal mapping process was carried out across the breadth of the research area, specifically in the towns of Mossel Bay, Bitouville, Melkhoutfontein and Slangrivier (see Figure 1.1). The basis for selection of participating towns was the availability of crew, most of whom had participated in the household survey described in Chapter Three. Importantly, key informants were relied upon to identify and advise as to which of their peers would be willing to engage with this 'next step' of the research process. This strategy was mostly successful but did result in the eventual exclusion of Vermaaklikheid from the process as these fishers remained largely unavailable and unwilling to participate. For the Bayesian belief network

(BBN) development, the fact that this was a prototyping process, together with time and resource constraints; necessitated that one community of fishers (from the same town) be selected for this part of the research process. Melkhoutfontein was chosen as it has a large, established group of small-scale fishers who act as crew on the linefish boats that mostly launch from Still Bay. Added to this, previous research conducted in the area for the GULLS project laid the groundwork in Melkhoutfontein that created the enabling conditions (specifically regarding building a trust base) required to carry out such research.

4.2.1. The approach used in the development of the causal maps

The causal map construction was an iterative process with the participants. Figure 4.1 outlines the approach followed in the process. At the start, causal diagrams, which show the drivers of change and interactions, and which also provide insight into the indirect drivers and feedback loops not apparent from the thematic analysis, were constructed using the thematic stressors framework identified by Gammage (2015), Gammage et al. (2017a) (Table 3.1). The first causal diagram (base map) was shown to stakeholders and key informants in various small group settings to allow for the generation of a second-iteration, town-specific map. As most participants were Afrikaans speaking, the first iteration of the was translated from English to Afrikaans *in situ* by the researcher. Subsequently, the researcher combined the town-specific maps to form one regional map, representing the third step of the process[15]. This combined map was informally shown to key informants from each town for validation and to ensure continued applicability to each town context representing the third iteration. The first workshop of the scenario-planning process (see Chapter Five) served as the final validation step in the mapping process. The regional map was used in the workshops which informed the BBN and scenario planning process.

[15] The rationale used for upscaling the map is that the Multi-dimensional scaling (MDS) plots carried out (described in Section 3.2) showed that there was no internal variability between towns with regard to stressors, corroborating prior research by Gammage (2015) and Gammage et al. (2017a).

Figure 4.1. The approach used in the Causal Mapping development process. Timelines are provided in Table 2.6

4.2.2. Data collection and causal map construction

Once the participants' knowledge of drivers of changes was captured in maps using the Vensim™ (Personal Learning Edition) software, research-based knowledge (Gammage et al., 2017a) was added. For ease of reference, the causal map was colour coded as per Tables 4.1 and 4.2. This first map (Figure 4.2) served as a graphical representation of the thematic framework previously described (Gammage, 2015; Gammage et al., 2017a). The second version of the map was developed through an iterative process where the map was shown to participants from the towns of Mossel Bay, Bitouville, Melkhoutfontein and Slangrivier. After a brief feedback session on previous research regarding stressors (Chapter Three), fishers were asked to adjust the base diagram as they saw fit. This was done through a process of discussion and reaching a consensus within the group. Discussions were in Afrikaans, the language spoken in the community, and the researcher guided the participants through the diagram. In each of the towns, small adjustments were made. These were drawn in on a hard copy of the diagram. Specifically, hidden feedback loops and indirect stressors which were not apparent and identified after the first iteration were added (specific changes made with associated reasoning are provided in Tables D1 - D4 in Appendix D).

Table 4.1. Colour coding for interaction between variables in the Causal mapping of stressors that drive change in the linefishery in the southern Cape

Colour of line	Coding
Orange	Non-directional interaction
Blue	Dampening interaction (-)
Pink	Amplifying interaction (+)

Table 4.2. Colour coding for variables in the Causal mapping of stressors that drive change in the linefishery in the southern Cape

Colour of box	Coding
Red	Key stressor (theme) identified by fishers
Turquoise	Biophysical stressors
Yellow	Biophysical: other fisheries
Light blue	Social Networks
Green	Social & Economic
Purple	Regulation/Management
White	Sea State

For the causal mapping process, key informants from each town who were seen to be in a leadership role (whether formal or informal) in the community were approached and asked to gather a group of four to six participants for a group discussion. This approach allowed for interaction with participants who were interested in the research process. These participants were knowledgeable as they were experienced in the fishers, and because they were often friends, there was very little friction or power imbalances present which allowed for open and frank conversations. The group interactions were audio-recorded, and notes made from recordings to aid the digitising and integration processes. The integration of the town-specific into regional maps was done by comparing the various inputs from the towns and finding the option - whether the wording of the variable or the connections amongst variables - to make it applicable to each town iteration. The resulting regional diagram was shown to key informants in each town to ensure that the regional diagram was acceptable locally. Once the regional map was finalised, a causes tree, which shows all the causes that affect the target node ('Ability to put food on the table') together with a verification of the various feedback loops involving key stressors, was compiled using Vensim™. Based on the outcome of the analysis involving key stressors, feedback loops involving policy and regulatory stressors and biological stressors (see Table 3.1) were also examined.

4.2.3. Results

4.2.3.1. Causal mapping process

Starting each session with the feedback of results from the GULLS household survey placed the participants in the right frame of mind, and when it came to be discussing the causal map, participants generally responded well. The Base map was found to be consistent with the participants' opinions, and adjustments made to the map were very much related to the place context (scale of the town/community). Throughout discussion with all the groups of participants, they needed to be guided away from falling into a repetition of the same issues, and it was reiterated throughout that the current research was a "next step" towards solving the various challenges outlined by previous research. Importantly, the issues highlighted by the participants throughout all the conversation echoed those raised in previous research (Gammage, 2015; Gammage et al., 2017a, Chapter Three). All groups extensively discussed the implementation of policy and regulation; specifically the implementation of the small-scale fisheries policy (SSFP) (DAFF, 2012). Views that are divergent to previous research and points or clarification are highlighted within these results.

4.2.3.2. Causal mapping outputs

a. Base map (first iteration)

The base map (first iteration) is shown in Figure 4.2.

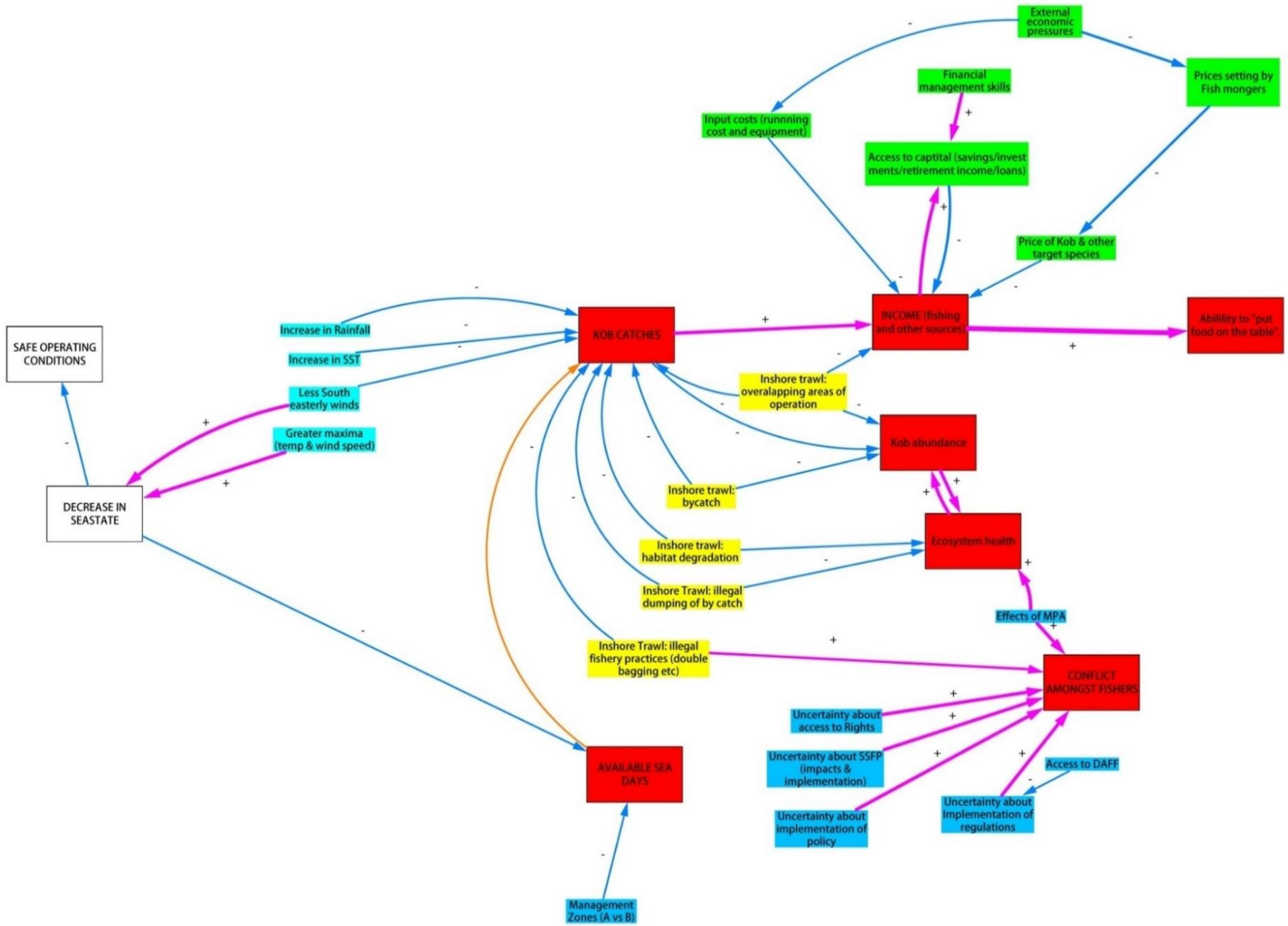


Figure 4.2. Base map (first iteration) derived from the stressor framework identified by Gammage (2015) and Gammage et al. (2017a). Although feedback maps are present in the map and visible to the trained eye, these feedback loops or indirect stressors are not explicitly highlighted in this first iteration of the map. See Tables 4.1. and 4.2. for colour coding

The target node on the far right, 'ability to put food on the table', is the central outcome of this diagram. All stressors identified have been framed regarding their influence on the fishery system and ultimately this outcome. As the indirect links have not been inserted into this base map, there are several variables with no inputs within the diagram namely 'decrease in sea state', 'increase in rainfall', 'management zone (A vs B)', 'uncertainty about access to rights', 'uncertainty about SSFP', 'uncertainty about implementation of policy', 'access to DAFF' and 'financial management skills'.

b. Second iteration

The second iteration maps (town maps) together with a description of the adjustments made to derive the map are provided in Appendix D1-D4. The following are key insights:

Mossel Bay

Most participants from Mossel Bay had previously worked in the Inshore Trawl fishery. It was necessary to highlight some of the possible indirect stressors and feedback loops to the fishers as a way of prompting them to offer their inputs. When the Inshore Trawl section of the causal map was discussed, participants became more animated and engaged. Fishers pre-empted many of the variables surrounding the inshore trawl – i.e. they mentioned the impacts/variable before the discussion moved to that point in the causal map. Key insights included that fishers may have to be subsidised by the State in the case of resource scarcity, the effect of inshore trawl on fish abundance on reefs, lack of crewing opportunities, skippers seemingly unwilling to share information thereby aggravating an existing culture of distrust amongst use groups, skippers not abiding by agreements made in the supporting documents during rights' allocation processes (in terms of percentage of catch for crew and rights holders) and shifting profit margins. The participants acknowledged the possibility that many of the problems with skippers and boat owners highlighted could be due to bad communication as opposed to a deliberate attempt by skippers to undermine crew.

Bitouville

The participants from Bitouville represented the biggest group interaction, although the leader of the group initially spoke for the group. This did, however, change as the interaction progressed and participants grew more comfortable. At the start, participants had to be prompted quite a bit, and the causal map (variables and interactions) had to be explained quite extensively and repeatedly before the participants became comfortable with the concept. Participants were also initially wanting to engage with the SSFP implementation challenges, and they needed to be continually encouraged to engage with the causal map. Notably, the discussion with the fishers from Bitouville was significantly more politicised than in the other towns, so the conversation initially focussed on policy and regulatory issues, most specifically problems with the SSFP implementation and the political issues attached to the SSFP itself. The participants from Bitouville were also addressed the climate stressor in the causal maps directly – most other groups just breezed through the climate interactions, choosing instead to speak about policy and the inshore trawl fishery. The discussion around the inshore trawl and associated variables were also quite in-depth. Key insights from this group of fishers included a recognition of the role of climate change in the local variability experienced, increased jellyfish abundance in area, the propensity of the trawlers to trawl close to the shore even though they are technically not allowed to operate on the bay scale, issue of by-catch and the dumping of by-catch by trawlers as well as a general perception that government are more likely to cater to the inshore trawl fishery than smaller fisheries such as the commercial linefishery and the small-scale fishery.

Melkhoutfontein

The participants from Melkhoutfontein were the least interactive group and needed to be talked through the causal map in its entirety before starting to engage with the issues at hand. Most of the participants participated equally, although the one skipper into the group; did initially provide more of the comments and inputs. At times it did not seem as if the participants understood the concepts under discussion, but once the group and researcher "talked around" the issue, a conclusion was reached which was mostly already reflected in the causal map. This 'talking around' was mostly a question of reframing the questions or asking it more indirectly. Key concepts highlighted by this group include the attribution of long-term climate variation to climate change, aseasonality of wind patterns (optimal ranges for wind) and the cessation of night fishing due to lack of catches at night (attributed to lower atmospheric pressures at night). Participants furthermore discussed the role of Coastal Links (a non-governmental organisation or NGO), who help to ease the communication issues experienced with DAFF by acting as a conduit for communication from DAFF. Lastly, the challenges experienced with coastal access, where easy coastal access is limited due to the distance between the town and the coast, were discussed.

Slangrivier

The sole participant from Slangrivier did not pre-empt any parts of the causal map, conversation; he mostly agreed with the variables and interactions in the diagram, but a few adjustments were made to the base map. The participant was actively prompted for his opinion by asking "how do you feel about…?" This way of questioning prompted the participant to speak more freely about the topics he felt strongly about. The participant was also excellent about asking clarifying questions where he was uncertain about anything and offered very balanced views and considered responses. Key concepts highlighted were the lack of financially viable, alternative target species– as the market for silvers is limited, the input costs are too high to justify targeting the species, concerns regarding the restriction to management zones, the size limit of the kob (after the increase of the kob minimum size limit, fishers complain they are unable to land enough legal-size fish), habitat degradation effected by excessive trawling in the area and the effect of unpredictable weather patterns on fishing.

c. Regional (final) map

The regional map was the last iteration in this process and is shown in Figure 4.3. For this map, adjustments were made to some of the variables and links to ensure that the map applies to all towns in the region. Most of the adjustments made were related to the wording of the variables. After the initial integration process and after further discussions and drawing from previous research and research knowledge; the map was further refined to form the final regional map. Key adjustments made are reflected in Table 4.3. Table 4.4 show the colour coding for feedback loops and indirect stressors. Importantly, the combined map was translated from English to Afrikaans by the researcher, and both versions were made available to participants.

Table 4.3. Key Adjustments made while integrating town maps to derive the regional map.

Action	Detail	Reason
Insertions	Indirect link between ‘catch limits (size)’ and ‘Implementation of policy and regulation’. Add word ‘Stringent’ to ‘Catch (size) limits for kob’	Catch limits imposed (ito size) is a function of policy and regulation.
	New main variable – ‘Uncertainty’	All participants described some level of uncertainty
	‘Historical conflict’	Conflict amongst Inshore trawl and linefishery in the area is historic and documented
	New Economic variable: ‘Access to craft’	Direct amplifying influence on ‘kob Catches’. Unable to catch fish if you do not have a boat
	Access to capital – amplifying influence on ‘Access to craft’	If you have access to capital, you can have access to a craft
Deletions	From Bitouville: ‘River mouth’ deleted – ‘safe operating conditions’	Not all towns are influenced by river mouths
	‘Inshore trawl – access to rights’	Incorporated into another variable
	Removed ‘management zones’	Added as a note on the link between policy & regulation and ‘Stringent catch (size) limits for kob’
	Some of the feedback loops without any directionality removed	Simplified the diagram
Adjustments	Increase in rainfall – amended to ‘changes in rainfall patterns’	Change of wording makes it applicable to all towns
	‘Kob catches’” amended to ‘Fish catches’	Wording changed to include all possible commercial fish catches
	‘Increase/decrease in SST’ - changed to ‘Changes in optimal SST temp range’	Change of wording makes it applicable to all towns and conditions
	‘Smaller fish size’ – changed to “Reduced catch size limits’	Not mentioned in Mossel Bay, but assuming this has an impact there, even if not as important
	‘Increase/decrease in the wind’ – changed to ‘Change in prevailing winds (directions, strength and seasonality)’	Change of wording makes it applicable to all towns
	Simplified Inshore trawl variables – now only: ‘Illegal fishing practices’ and ‘Effect on reef health’	Simplification of the diagram
	Link ‘Policy and Regulation’ to ‘Uncertainty’ (‘implementation, inshore trawl policy and SSFP implementation’)	Mainly uncertainty caused by SSFP implementation
	‘Access to DAFF’ moved and linked to ‘policy and regulation’	No directionality ito amplifying or dampening
	‘Conflict between inshore trawl & linefishery’ changed to ‘conflict amongst fishers & between fishing sectors’	
	‘Financial management skills’ - amended to read ‘specific management skills’	
	Different methods in linefishery (such as *Riemhou*) moved to feed directly into the kob (fish) catches	

Table 4.4. Colour coding for indirect stressors added to diagram during the second iteration (construction of ‘town maps’).

Indirect interactions (added during 2nd iteration)	Coding
Black dash	Non- directional indirect interaction/stressor
Blue dash	Dampening (-) indirect interaction/stressor
Pink dash	Amplifying (+) indirect interaction/stressor

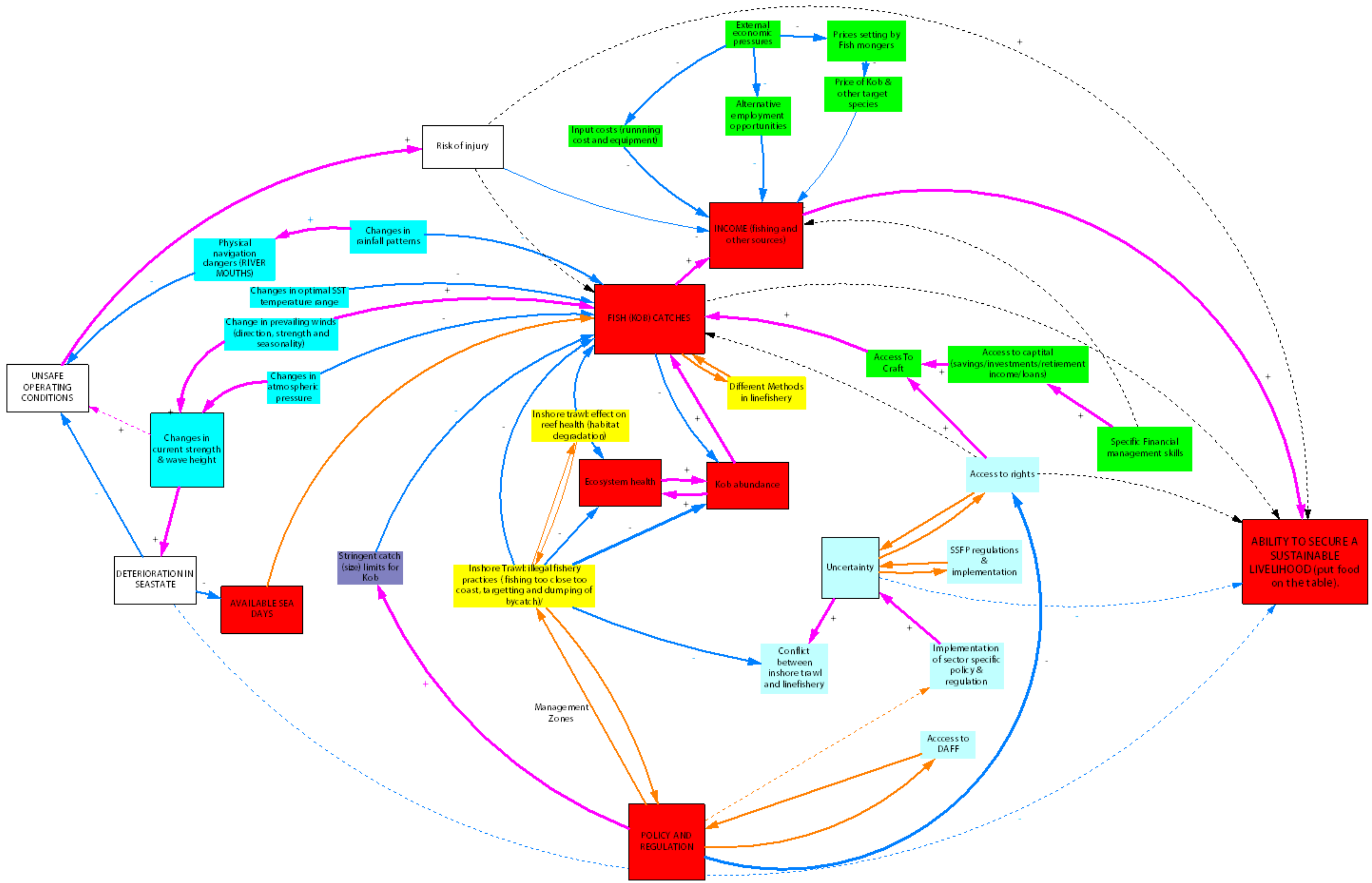


Figure 4.3. Final regional map derived from the inputs of fishers in the second iteration. This final map explicitly highlights feedback loops and indirect stressors. It portrays a view of the drivers of change derived from the original thematic framework together with information provided by participants in the second iteration. See Tables 4.1, 4.2 and 4.3 for colour coding

The final causal map did not reveal any new stressors in this fishery system. Through the process; it was possible to refine the wording used in the diagram to make the regional diagram applicable and relevant to the entire research area and all user groups. The final diagram highlights the complexity of the system by revealing feedback loops such as the loop between 'Uncertainty', 'Access to Rights' and 'Ability to secure a sustainable livelihood' and reiterated non-linear dynamics in the systems. This is especially true when considering all the indirect influences on the target node ('ability to secure a sustainable livelihood'), where only one direct influence was identified as opposed to the five indirect influences.

The final map further highlights the complexity of policy and the regulatory issues at play, which includes many of the identified feedback loops. As this is a participant-driven product, this goes to show the importance that fishers attribute to policy and regulatory issues when questioned directly on stressors that drive system change. The insertion of 'uncertainty' as a driver of change is a direct product of the iterative process, where many of the discussions centred on lack of information regarding the implementation of policy (specifically the SSFP) and related timelines. There was also an explicit recognition in the discussions that policy uncertainty has given rise to conflict amongst fishers (particularly, inshore trawl and all line fishers, as well as between skippers and crew in the commercial linefishery), which is expected in a climate of policy implementation uncertainty that is backdropped by increasing environmental variability and resource (specifically kob) scarcity. For many of the identified feedback loops, directionality (positive or negative) was not immediately apparent and has thus not been identified as such in the diagram. The causes trees (Appendix D5, Figures D5.1– D5.7) show the diagram expressed as hierarchies and reveal no surprises. The analysis of feedback loops and indirect drivers (see Figure D6), underlining that most feedback loops are present in the interaction within and between the policy and regulatory stressors in biophysical system stressors. The most prominent interaction between the human (social) and ecological is the effect that fishing methods (whether trawl or linefish) have on eventual kob catches, moderated by ecosystem and habitat health which influences overall kob availability.

4.2.4. Discussion: using causal mapping in a participatory qualitative modelling process

The development and application of causal maps in this research were multi-faceted. The tool offers insight into the complexity of the SES of the southern Cape, while providing insights into how participants viewed the system. The process followed to derive the maps contributes directly to the BBNs development (below) as it served as the conceptualisation of the system. It also directly contributes knowledge on methods that could eventually be applied to enhance EAF implementation in South Africa. Through the development process, it was possible to combine the knowledge and inputs from various participants. Lastly, a significant contribution was made towards a process of capacity building through the initiation of a mutual learning process that took place throughout.

Connecting the social and the ecological in the southern Cape linefishery

The causal mapping process in this research did not reveal new, unexpected drivers of change in the southern Cape linefishery. The process served to validate findings of previous research concerning the drivers of change within the system and was particularly useful for highlighting feedback loops and multiple stressors that were not immediately apparent from the previous, qualitative research, such as the link between 'changes in current strength & wave height', 'unsafe operating conditions', 'risk of injury' and the 'ability to secure a sustainable livelihood'. The feedback loops in the final diagram largely reflect and highlight points of interaction between the policy and regulatory and biological system components of the SES. This is not surprising as the research took place at a time where fish (kob) scarcity was a real concern (also highlighted by Duggan, 2018), coupled with policy uncertainty created by the delayed implementation of the SSFP. That these issues were top of mind is reflected in the fact that in all towns, the most time was spent on these issues in the small group interviews. In the case of this system conceptualisation, the feedback loops identified are most likely contributing to system instability. The diagram shows that fishing activities in the area have a definite impact on linefishery kob catches through the effect that fishing (specifically trawling and overfishing) has on the ecosystem (kob abundance) and benthic health (habitat destruction). Fishers have consistently over recent years reported continually declining fishery-derived incomes (Duggan, 2012, 2018; Gammage, 2015; Gammage et al., 2017a) with attrition rates in the fisheries (both in the linefishery and inshore trawl) (Greenston, 2013; Gammage, 2015; Gammage et al., 2017b), a likely reflection of the decline in fishery-derived income reported by participants. Notably, there are no feedback loops connecting the climate/weather system component to the biological component in these maps. It is unlikely that there is no such connection, but one can deduce that the climate/weather driver was not top of mind for this group of fishers. Although adjustments were made to the fishers' inputs, these changes were mostly concerned with the wording of the variables to ensure that they were worded in a way that applied to the overall system. This result is echoed by the results of the weighted hierarchy (see Figure 4.9) that was derived as part of the BBN process (Section 4.3.3.1). The decision not to add large variables or connections between variables in this causal map was made to stay in keeping with the principle of the participant-led approach and to ensure fishers identified with the causal map which was necessary for the workshopping process.

Many of the policy and regulatory drivers described were linked explicitly to uncertainty, and after some consideration and discussion, it became apparent that while there is a measure of policy uncertainty, the uncertainty of policy *implementation* posed the higher risk to fishers. The insertion of 'uncertainty' as a driver of change in place of the main 'policy and regulation' driver is a manifestation of a typical South African problem regarding policy and regulation implementation, which also has long been the case in small-scale fisheries in South Africa (e.g. Isaacs, 2006; Sowman, 2006; Sowman et al., 2014). Uncertainty about how and when the policy will be implemented has both short and long-term consequences, as fishers being caught 'in limbo' makes appropriate decision-making (in the short and long-term) difficult. Additionally, the uncertainty about how policy and regulation will be implemented exacerbates tensions that are already present by other uncertainties in the system, such as those created by changes in sea conditions (e.g. changes in current strength and wave height). This tension is not unique to South African small-scale fisheries as demonstrated by studies from other developing countries which highlight the role phenomena such as climate change are negatively impacting livelihoods in small-scale fisheries (e.g. Cinner et al. 2012, 2015; IPCC 2014; Marshall et al. 2010; Perry et al. 2010; Zou and Wei 2010. In the case of the southern Cape linefishery, this tension does not only apply to the individual and household scale but can also be seen in conflict between line fishers and amongst fishery sectors, notably the linefishery and inshore trawl fishery where a historical conflict in the area (Visser et al., 2015) is exacerbated by overlapping areas of operation (Greenston, 2013) exacerbated by target catch (resource) scarcity (Duggan 2012; 2018).

Throughout the research, policy and regulatory issues were identified as the most pressing concern for participants. Again, this is not unique to South Africa. Policy and regulatory challenges are identified by multiple authors (e.g. FAO 1995; Mikalsen & Jentoft 2003; Bene & Neiland 2006; FAO 2015), emphasising the need to include the actors from the sector in policy, legislative and regulatory processes The promulgation of the voluntary small-scale fishery guidelines by the FAO (FAO, 2015) not only recognised the importance of small-scale fisheries in food security and poverty alleviation , but also acknowledges the challenges with management within a sector where fishers often remain neglected and marginalised (FAO, 2015; 2016b; 2018). In South Africa, government, and especially the Department of Agriculture, Forestry and Fisheries (DAFF) inevitably became the face of the challenges that are related to policy and regulations. One could argue that the emphasis on policy and regulatory issues and the impact of the inshore trawl fishery - in place of the explicit recognition of the importance of other drivers of change such as climate variability and kob shortages - is because the government is a more real and familiar foe. This by no means absolves the government of responsibility – globally, governmental decision making is seen to be aligned with more extensive, industrialised fisheries (e.g. Ommer et al., 2012; Jarre et al., 2018). This rings particularly true when considering that the Small-Scale Fisheries Policy (SSFP) which was developed in response to the continued marginalisation of small scale fishers (Sowman et al., 2014), has not yet been fully implemented, about six years after its promulgation. However, given the importance of drivers in the physical system shown in various previous research (Duggan, 2012; Gammage, 2015; Gammage et al., 2017a; Jarre et al., 2018; Ward, 2018; Lyttle, 2019) and reiterated in the causal mapping and specifically shown by the BBNs (below), other drivers of change are as pressing and threatening as policy and regulatory issues. Importantly, failure to recognise the importance of other drivers of system change will hamper fishers' ability to make informed decisions in the face of future change. Tools such as causal maps, when used in participatory and iterative processes, can help build capacity as knowledge is expanded through social or mutual learning. The benefits and mechanisms of such learning in resource management contexts have been have been well described and discussed by various authors including Carpenter et al. (2006); Gaddis et al. (2010); Cundill & Rodela (2012); Oteros-Rozas et al. (2015);

Tuler et al. (2017). Measuring the amount of capacity building and/or learning that took place throughout this process is near impossible (see Tuler et al., 2017). That some form learning, or skills development, was taking place was however, evident in how the fishers were able to engage with increasingly difficult and unfamiliar activities as the research progressed.

Making sense of complexity while building capacity through adding to knowledge capital

To better understand complexity in SES, which include amplifying and dampening effects of processes (Holling, 1973; Cinner et al., 2011) through feedback loops and multiple stressor interactions at various scales; comprehensive system descriptions are required for problem structuring. Causal Maps provide a formal, yet visual way to carry out such problem structuring and framing (Belton & Stewart, 2002) and general advantages of using causal maps have been introduced in Chapter Two. Particularly useful in this research was the ability of causal maps to highlight and clarify areas of concern not immediately apparent from qualitative analysis, such as 'uncertainty'. The causal maps' ability to give insight into the organisation of ideas, and to clarify goals while revealing knowledge gaps (Belton & Stewart, 2002; Özesmi & Özesmi, 2004) have been specifically useful for research participants to form a more holistic picture of their fishery system: while participants considered aspects of the system in a piecemeal fashion, interactions with participants reveal that fishers often do not view the system in its entirety. In this instance, the process has been useful due to (what could be called) the poor 'formal' definition of problems by fishers at the local scale. However, for the linefishery in the southern Cape, it may be more a case that the relationships between drivers are not well-defined – in such a context the causal maps have provided a tool which was used to provide insight into the complex relationships between variables identified, as demonstrated by the complexity shown in the final regional map. This level of complexity is also evident in a causal map produced by Stewart at al. (2009) who describe the possible implementation of an MCDA process in the context of a fishing rights allocation process in the South Africa's Western Cape province. This demonstrates that the complexity seen in the southern Cape linefishery is not unique, nor the usefulness of causal maps in portraying this complexity.

Highlighting the indirect interactions and feedback loops have resulted in a diagram that better reflects the complexity known to exist in the southern Cape linefishery. This level of complexity is expected - small-scale fisheries across the world are increasingly framed as complex adaptive systems due to the nature of the problems that exist in these systems (Berkes, 2006, 2011; Folke et al., 2005; Gelcich et al., 2010; Mahon et al., 2008; McConney & Charles, 2010; Wilson, 2006). In the southern Cape and through the insights gained from the causal mapping process it was also possible to refine many of the processes identified in previous research: an example is the identification and use of optimal ranges in the climate drivers and being able to link drivers across themes. The result is a better-defined system of interactions linked to change. Better-defined systems are important for more effective management. As demonstrated by Folke et al. (2010), severe recurring management problems in natural resource use and stem from a lack of the implicit recognition of the inextricable links between ecosystems and social systems; especially since feedback loops can take important roles in system dynamics. South African fishery management is not excluded - despite legislation advocating for an ecosystem approach to fisheries management (EAF) (see WSSD, 2002), many social system components or their interactions with the ecosystems are disregarded in management decisions (e.g. Cochrane et al., 2015) thereby inadvertently basing decisions on overly simplistic views of the SES. While the causal maps described in this chapter have not been constructed at the scale through which management can be informed directly, the successful use of the tool demonstrates the it's usefulness in showing complexity, feedback loops, indirect drivers of change together with the ability to readily integrate the perspectives and knowledge from different sources (in this case participants from different towns). It should therefore be considered a useful tool in future management contexts.

While many of the changes made to the diagrams made were subtle, the changes offer valuable new insight into the system. These new insights can assist with reframing the reanalysis of data that has already collected by allowing for changing how questions are asked. An example would be to shift the focus in the analyses of current wind data from direction and strength to analyses that focus on the of the persistence of wind days. This is shown in recent work by Ward (2018) where, although found to be highly variable, significant changes in long-term trends regarding direction and extreme days of wind was not clear, although increased variability was noted since 2007 by Ward (2018) while Lyttle (2019) notes a small but significant increase in wave height. While this is not reflected in fishers' accounts, the hypothesis that the change is more with the pattern of wind days (persistence) is a new avenue of inquiry that has been revealed by the various iterations of the stressors research. The usefulness of such tools in reframing problems are one of the strengths of using participatory modelling processes such as causal mapping (Belton, 1997; e Costa et al., 1999; Belton & Stewart, 2002; Montbellier & Belton, 2006; Stewart et al., 2009). Not only are we able to gain necessary insights into the dynamics of the system in questions, but through the participatory modelling process, a process of social/mutual learning and capacity building is initiated amongst participants (van der Belt, 2004; Tuler et al., 2017). This has also been demonstrated in other natural resource management contexts such as with farmers in Chesapeak Bay in relation to participatory modelling around the impacts of climate changes on farming activities (Paolisso & Trombley, 2017) and participatory modelling with stakeholders concerning nature conservation planning and maintenance in Ria Formosa (Videira et al., 2017).

Contribution to managing scale mismatches

Parity between the results of the mapping process and the results of previous research is significant because the user groups (particularly skipper vs crew), towns and timescales differ. This has important implications when considering the scaling of data in the context of the linefishery system of the southern Cape. The issue of scaling is essential and complex – large models are often not applicable in the local context, and the specificity of work at local contexts can get lost in larger scales resulting in models that are ill-fitting to local details (e.g. Gibson et al., 2000). This is particularly problematic when considering that management decisions are often made at large (national) scale in a top-down fashion (e.g. Jarre et al., 2018) with no mechanism in place for the bottom-up flow of information that would be required to make decisions that can better address localised contexts. Various authors (e.g. Armitage et al., 2017, Dorner et al., 2017) suggest and advance the use of approaches that promote co-management of fisheries resources, although effective implementation remains problematic within South Africa (Sowman et al., 2014) and elsewhere. The parity between the results related to drivers of change seen throughout suggests that geographic scale is not essential where the contextual scale (or conceptual scale – see Gibson et al., 2000) is the same. This assertion is echoed when considering the MDS plots presented in Chapter Three which showed that there was no internal variation per town in the responses offered. Instead, the internal variation is seen when considering user groups change *responses* (Gammage, 2015; Gammage et al., 2017b) to the same stressors. This contextual scale is what must still be accounted for in decision-making and management. Contextual scale for the linefishery could relate to an ecosystem scale related to linefish assemblage delineation zones as suggested by Winker et al. (2014) and Blamey et al. (2015), where management zones used to manage the fisheries should likewise follow the ecosystem scale to ensure fisheries are managed within the most suitable ecological context. Such spatialised approaches for management have been suggested for the management of South African fisheries by authors such as Blamey et al. (2015).

Suitability of the tool

The causal maps have been extremely useful in refining the drivers of changes in the marine SES of the southern Cape. Previous research (Gammage 2015, Gammage et al., 2017a) was qualitative and while the rich descriptions provide important insights into the SES; the structure offered by the visual system depiction has highlighted feedback loops and hidden interactions not immediately apparent. The maps are very user-friendly qualitative models with the most resource users easily interacting with them. This is one of the main advantages of using the causal maps (Marttunen et al., 2017) and the overriding reason for selecting the tools for use in this research. The research participants in Melkhoutfontein, Bitouville, Mossel Bay and Slangrivier were able to easily adjust the variables and interactions. The maps provide the means for fishers to take more of a system-oriented view of their fishery, providing them with insight into how different system components interact in unexpected ways. This is important because participants were also able to enhance their understanding of their reality, and the visual aid helped to connect drivers in ways that were not previously possible.

The advantages of the use of causal maps in problem structuring and framing are numerous (for a broad overview see Chapter Two). Most importantly, the causal maps allow for feedback processes to be depicted in the diagram. Variables from various social-ecological subsystems can be included in the diagram, and it is possible to show the relationships between variables which were often not well defined and uncertain. It is also not necessary to have complete descriptions of these variables and relationships. Another vital advantage is that it is possible to model a system that has limited information at the scale at which the fishery operates using fisher (local) knowledge. Causal map construction was quick and easy, as demonstrated by Taber (1991) and Kosko (1992a,b). Causal mapping also presents an opportunity to combine knowledge sources as shown by Kosko (1992a) – in the process described here it has been possible to successfully combine the knowledge held by fishers from different communities (towns) into one consolidated map. In future, it would be possible to combine knowledge from more diverse stakeholder groups through similar iterative and participative processes. The ability to combine the knowledge from fishers from different communities into one regional map also suggests that the causal maps will be helpful when addressing scale-specific challenges using context-specific data.

As will all models, the use of Causal maps has its limitations, reflected upon in Chapter Two. The map, being participants derived, is not only encoded by the participants' knowledge but also any misconceptions and biases they hold of the system (see Kosko, 1992b). In the case of the causal maps developed here, bias towards policy and regulatory issues have likely resulted in the stressors and interactions from the biophysical subsystem being neglected or omitted completely. This is pertinent when considering some obvious interactions and feedback loops, such as those between 'kob catches' and the different climate/weather related variables. These misconceptions/biases are also evident when considering the weightings assigned in the weighted hierarchy and the results from the BBN sensitivity analysis (discussed in Section 4.3) where the results show a very different weighting. Through combining the causal maps from the different towns into a regional map, following Dickerson & Kosko (1994) and Özesmi & Özesmi (2004), errors would have been minimised, evident in the final regional map. Biases or misconceptions would also have been reduced by the iterative nature of the development process, together with the validation of the maps by key informants throughout which reinforced the robustness of the research through constant triangulation of the data (Creswell & Plano Clark, 2011; Newing & Contributors, 2011). Adding other stakeholders (such as marine biologists) would likely complete the links between climate and fish abundance and further strengthens the robustness of the research.

The maps as such do not provide any information on the causation (the 'why' aspect) associated with the drivers (see Kim & Lee, 1998). In this map, this has partly been circumvented through the indication of the dampening or amplifying effect the stressors have on other, related stressors (i.e. the causation). This has assisted with the interpretation of the map from a research perspective, although research participants did not engage with the causality of the drivers beyond the initial discussions that took place to derive the maps. (i.e. the information was not used or helpful in the workshopping process). Lastly, the map does not have a temporal component – although the temporal component was roughly defined when gathering the initial data used to construct the base map, this was a 'loose' definition as most fishers do not clearly define the temporal component associated to drivers of change in discussions. This results in maps that do not have a sense of any transient behaviour in the system (Schneider et al., 1998; Hobbs et al., 2002). Having a better idea of such transient behaviour would be useful especially considering the uncertainty that presents due to the high variability in the local climate (see Ward, 2018). While it is possible to better quantify causal maps (see, e.g. Steward et al., 2009), in this case, the causal maps have served as the conceptual framing of the system and as a tool for fishers to consult and use in the BBN process described in the following section.

4.3. Semi-quantitative modelling with stakeholders – approach, method and results

4.3.1. The general approach used in the development of the Bayesian belief networks

A Bayesian belief network (BBN) is a graphical model depicting a set of variables which are linked by probabilities (Amstrup et al., 2008). In this prototype model, the nodes represent the causal variables that affect the outcomes of interest (in this case 'achieving a sustainable fishery-derived income'), while the links between the nodes serve to define which specific variables directly affect which other specific variables. Constructing a BBN enhances the understanding of the relationships and sensitivities that exists between the various elements of a causal web. At the same time insights are provided into system functioning that would not otherwise be apparent. Building on the causal mapping, the BBN modelling process formed part of the scenario planning workshops with a group of fishers (participants) from Melkhoutfontein. Figure 4.4 outlines of the approach adopted.

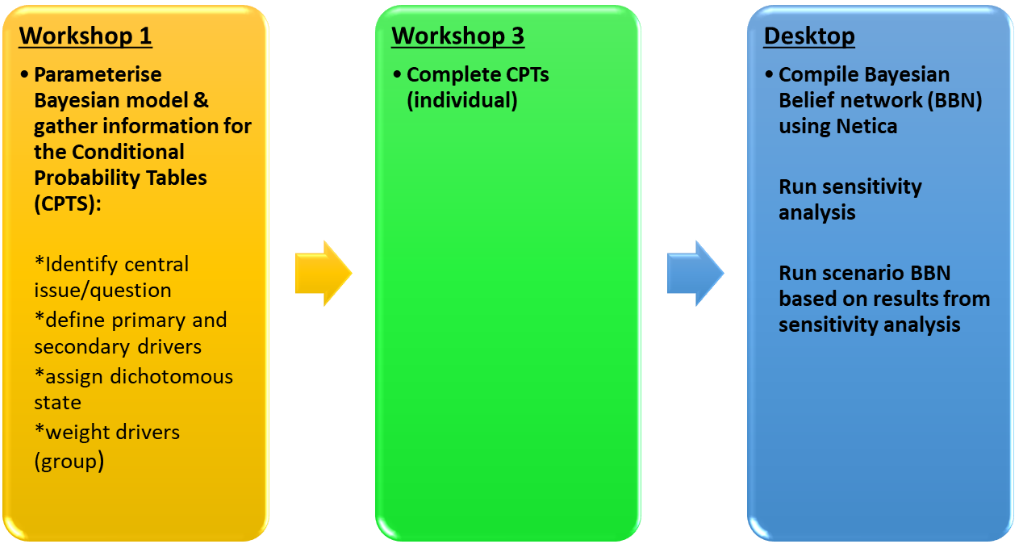


Figure 4.4. The approach followed in the Bayesian belief network development process. Workshop One provided the opportunity to parameterise the model and gather information required for the construction of conditional probability tables (CPTs). In Workshop Three, participants completed individual CPTs for input into the final model. Timelines are provided in Table 2.6.

The first workshop provided the opportunity to validate the final regional causal map and start the BBN modelling and scenario planning. The second workshop focused specifically on the actual scenario planning process and is discussed in Chapter Five. A third workshop provided the opportunity to provide for participants to populate the individual conditional probability tables (CPTs) required to construct the BBN. While all three workshops ultimately form part of the scenario planning process, Workshops One and Three were directly related to the BBN development process and are discussed in detail here. To this end, an initial group of 14 fishers engaged in a workshopping process aimed at deriving BBNs as part of the evolution of a scenario planning process.

4.3.2. Model construction & sensitivity testing

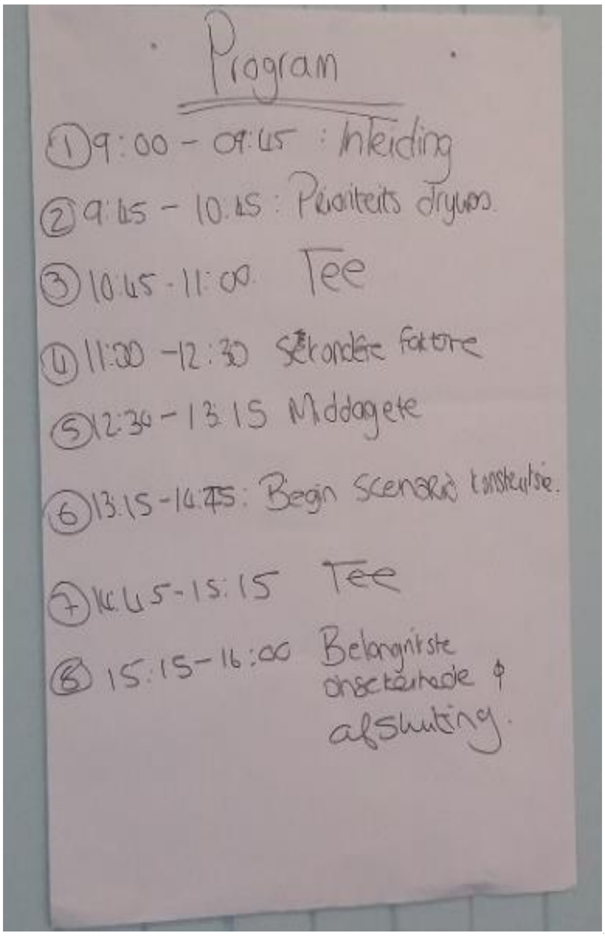
The model described in this section, highlights three principal drivers of change and their contributing factors, which participants see as important. These principal drivers and contributing factors form nodes in the BBN. For this first prototype, the number of possible states in each node was limited to two. The BBN described here required four CPTs to parameterise the model: one for the output and one each for the three principal drivers. Of the 11 participants who started the third workshop, 10 completed the CPTs, but four of the completed CPTs were excluded from the final BBN as they were either completed incorrectly or incomplete. The six remaining populated CPTs were combined into a single BBN model through the addition of an auxiliary node 'Participants', which represents the (evenly) weighted input of each participant (Kjaerulff & Madsen, 2006). The 'contributing factors' were assigned probabilities of 50% for the identified states because there are no other influences on these nodes in the model. The Bayesian modelling software package, Netica™ was used to compile the BBN.

As the model incorporated the judgment of a homogenous group of fishers (as opposed to a diverse set of stakeholders), there is a requirement to question how robust the results may be to input variability. It is necessary to determine whether the model outputs are over-sensitive to any specific node and to ask the extent to which the model/outcomes could be altered by manipulating the states of the nodes. Sensitivity testing using 'Income' as the indicator node (where Network > Sensitivity to Findings) was carried out as a start. The BBN was tested under different scenarios (possible system states) by manipulating the three nodes identified by the sensitivity testing as being the most influential on 'Income' (Figure 4.14). Sensitivity tests (using 'Income') for the inputs of each of the individual participants were also carried out. These analyses determined the degree to which each node (input variable) could influence the 'Income' in both the combined model and in each of the six participant models. The sensitivity was calculated in Netica™ as the degree of entropy reduction (reduction in the disorder or variation) at one node relative to the information represented in other nodes of the model. The sensitivity tests indicate how much of the variation in the node in question is explained by each of the other nodes in the model (Amstrup et al., 2008; Tiller et al., 2013). Lastly, the model was tested to see how sensitive it was to inputs from additional participants. For this analysis, the model was run three times with an added seventh (ghost) participant. For each of these model tests, a duplicate set of existing CPTs was used.

4.3.3 Results

4.3.3.1. The Bayesian belief network construction process

The aim for Workshop One was to obtain data needed to parametrise the BBN and doubled as the groundwork for the scenario planning process described in Chapter Five. An informal dinner for all participants was hosted on the evening preceding the workshop. This not only served as an icebreaker but also as an opportunity to provide background information on the project in general and specifically, the purpose of the interaction. The first workshop, which was scheduled to take place throughout a full day, was shortened as participants grew fatigued as the programme progressed and eventually ended just after lunch. The planned programme was amended as participants had difficulty with some of the more abstract thinking required for some of the exercises planned to derive the hierarchy and system states. The initial (planned) programme is shown in Figure 4.5.



Workshop 1 programme

09:00 – 09:15:	Welcoming and introduction
09:15 – 09:45:	Overview of research project and research
09:45 – 10:45:	Identification of priority drivers of change in the Melkhouttfontein fishery system. **(Use index cards and flipchart paper)**
	(Proposed central issue: ability to sustain livelihood bmo income derived from fishing activities)
	(Income from fishing activities – enough/too little
	In groups (09:45 – 10:20)
	What 3 primary factors influence fishing income? (What needs to happen for you to be able to earn enough from your fishing activitie?) (**Use causal diagram as aid)**
	How important are each of these factors (drivers)? (percentages) Identify 2 states for each factor. (**Desirable and undesirable**)
	Feedback from Groups (10:20 – 10:40)
	Consolidation (decide which factors and percentages must be used) (10:40 – 10:45) (Write final drivers onto new index cards and stick it up in room).
10:45 – 11:15	Tea
11:15 – 12:30	Secondary Factors
	In groups (11:15 – 12:00)
	Identify 3 factors that influences each of the primary factors (percentages and states). Are there more factors that must be identified? Same as step before tea.
	Feedback from groups (12:00 – 12:20)
	Consolidation (decide which factors and percentages must be used) (12:20 – 12:40) Write final drivers onto new index cards and stick it up in room
12: 40 – 13:30	Lunch
13:30 – 15:00	Start with scenario construction process.
	Have now identified the drivers that has influence on your ability to sustain a fishery derived income. Are there any factors that need to be added? (**Brainstorm a bit, refer to CD, Identify enablers/inhibitors, group factors and drivers together**). **Use index cards and/or post-it notes.**
	To construct the stories, we must first speak about that what we are sure about and that what we are unsure about. How sure/unsure are we about the drivers we have identified? **(Arrange drivers into certainties/uncertainties).**
	Let look 30 years into the future (2046) – how do we want Melkhoutfontein must look as a town? What must be here? How must people be living? How must people be earning a living? Is it sustainable?
	We need to decide what three drivers are the most important for Melkhoutfontein's future.
	Rank categories of issues - each Participant issued with (3 sticky dots per person) on grouped/categorised issues. Discuss pattern of ranking and decide which issues they would like carried forward
15:00 – 15:20	Tea
15:20 – 15:50	Decide 2 of the most important uncertainties for Melkhoutfontein (group discussion). What uncertainties have the biggest impact on the future? These uncertainties are what we will use in our stories.
	Whole group brainstorms the critical uncertainties. Possible uncertainties - interaction of social and biophysical phenomena, changes in political influence, coastal development, catchment flooding. **Flipboard paper; note down uncertainties**
15:50 – 16:00	Reflection and closing (Inputs from participants).

Figure 4.5. Planned programme for Workshop One –the left panel in Afrikaans for participants, the right panel – the detailed programme in English. The programme had to be amended as the day proceeded in keeping with the principles of participant-led research.

As a start, the regional causal diagram (see Figure 4.3) was made available to all the participants in Afrikaans. The diagram was briefly explained to all participants, although at least half the group had had prior exposure to the previous research and ensuing diagram development process. Participants were advised that they could consult the diagram throughout. In this way, the map served as a tool to assist participants to refine their thinking about the variables that drive change in the fishery system. This workshop also presented another opportunity for the participants to verify the accuracy of the map. After some discussion of the drivers of change and their interactions, the central issue 'Sustainable fishery-derived income' for the BBN was identified. This was done via group consensus. Participants were asked to assign this central issue with a dichotomous state to discretise each of the variables. Next, principal drivers of change that directly influence participants' ability to earn a sustainable fishery-derived income (central issue) were identified and discussed.

Participants were required to identify three principal drivers of the central issue (sustainable fishing-derived income). They were then asked to assign a dichotomous state to each driver and assign a percentage influence that the driver has on the central issue. It was reiterated to participants that the states had to be discrete, exhaustive (all possible outcomes covered by the states) and mutually exclusive – all of which are fundamental principles of BBNs (e.g. Tiller et al., 2013). Restricting the states to dichotomous states implied that the states were a broad qualitative description, however, this way of limiting the sizes of this first prototype BBN states strengthened the manageability of the associated CPTs. Figure 4.5 shows the basic hierarchy identified without states or weightings. Participants were informed that the states should reflect a desirable and undesirable state. This first step was done in a small group setting. Each group was asked to discuss and agree on the three principal drivers, their states and percentage influence.

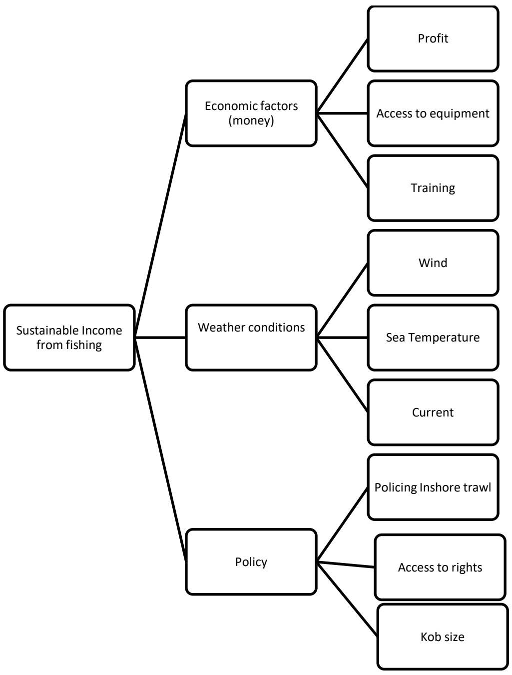


Figure 4.6. Hierarchy of drivers identified by participants. This hierarchy, with no weightings and states, provide the blueprint for the BBN structure. Note however, that the influences of the principal drivers become the root nodes in the BBN.

The facilitator moved between groups and had to prompt participants numerous times to obtain the required information. It was also necessary to explain the task to each group numerous times, as many participants remained unsure of what was required. It is important to note that, as the participants were new to such a process, most remained very unsure of themselves in these initial stages of the process. As groups reported back, the principal drivers were discussed and agreed on before putting them up on the wall using post-it notes (Figure 4.7). Once the principal drivers were identified and the weightings assigned by the respective small groups, participants were asked to vote for their preferred principal drivers and weightings.

Figure 4.7. Results from the voting process (in Afrikaans). Participants were asked to identify three principal drivers that affect the central issue (in this case the ability to secure a sustainable fishery derived income). The three drivers identified (from left to right) are Policy, Weather and Capital

The next step required participants to identify the next level of causality by identifying the three contributing factors that would influence each of the principal drivers already identified. These variable (called 'contributing factors') were also assigned a percentage influence and a dichotomous state. This part of the exercise was done, upon request from the participants, in a large group setting. Extensive discussions took place on each variable and then the state and weighting were decided on by group consensus. The participants' knowledge and insights on the variables that affect the fishers' ability to earn a sustainable fishery derived income, and the relationship between these variables was used to populate the CPTs. The variables identified as well as the states assigned and percentage influence on the central question for the three sub-groups are shown in Table 4.5

Table 4.5. Weightings identified by groups

Principal drivers identified	Group 1 weighting	Group 2 weighting	Group 3 weighting
Policy and Regulation	80%	60%	25%
Climate (weather)	10%	20%	25%
Capital (disposable income)	10%	20%	50%

The CPTs associated to each driver in the hierarchy (including the central theme) was constructed using the states assigned by the group in Workshop One (Figure 4.8).

Figure 4.8. Principal drivers and contributing factors with final weighting as agreed on by group consensus (in Afrikaans). Contributing drivers (from left to right) – Access to rights, Regulation of the inshore trawl, Size of kob, Wind, Current, Sea Temperature, Skipper training, Access to rights, Access and maintenance of equipment, and Profit margins

Table 4.6. shows the CPTs that were constructed based on the participants' input in Workshop One.

Table 4.6. (a-d) Set of CPTs for completion by participants in Workshop Three. These CPTs were compiled using the hierarchy of drivers and associated states identified in Workshop One. Each participant completed their own set of CPTs on their own pace and using their understanding and interpretation of the system dynamics

a. **CPT1: What is the percentage probability (0-100%) that fishing-derived income will be "HIGH" for the following 8 scenarios?**

Rank	Policy	Economic/Socio-economic	Weather/Climate	Probability % of fishing income being high	
				High	Low
	Unfavourable	Insufficient	Unfavourable		
	Unfavourable	Insufficient	favourable		
	Unfavourable	Sufficient	Unfavourable		
	Unfavourable	Sufficient	favourable		
	Favourable	Insufficient	Unfavourable		
	Favourable	Insufficient	favourable		
	Favourable	Sufficient	Unfavourable		
	Favourable	Sufficient	favourable		

b. **CPT2: What is the percentage probability (0-100%) that the implementation and effect of POLICY & REGULATION will be "FAVOURABLE" for fishers for the following 8 scenarios?**

Rank	Access to Rights (fisheries resources)	Size of Kob	Policing of Inshore TRAWL	Probability % of POLICY & REGULATION	
				Unfavourable	Favourable
	No Access	Too big	Inadequate		
	No Access	Too big	Adequate		
	No Access	Small Enough	Inadequate		
	No Access	Small Enough	Adequate		
	Access	Too big	Inadequate		
	Access	Too big	Adequate		
	Access	Small Enough	Inadequate		
	Access	Small Enough	Adequate		

c. **CPT3: What is the percentage probability (0-100%) that the effects of the WEATHER (CLIMATE) will be "GOOD" in the following 8 scenarios?**

Rank	Wind (strength and direction)	SST	Current (strength & Direction)	Probability % of WEATHER (CLIMATE) being	
				Unfavourable	Favourable
	Unfavourable	Unfavourable	Unfavourable		
	Unfavourable	Unfavourable	Optimal		
	Unfavourable	Optimal	Unfavourable		
	Unfavourable	Optimal	Optimal		
	Optimal	Unfavourable	Unfavourable		
	Optimal	Unfavourable	Optimal		
	Optimal	Optimal	Unfavourable		
	Optimal	Optimal	Optimal		

d. **CPT4: What is the percentage probability (0-100%) that SOCIO-ECONOMIC & ECONOMIC constraints result in Income being "ENOUGH" in the following 8 scenarions?**

Rank	Training (skipper etc)	Access to Equipment	Profit Margin	Probability % of having enough money	
				Insuffiecient	Sufficient
	Insufficient	Insufficient	Insufficient		
	Insufficient	Insufficient	Sufficient		
	Insufficient	Sufficient	Insufficient		
	Insufficient	Sufficient	Sufficient		
	Sufficient	Insufficient	Insufficient		
	Sufficient	Insufficient	Sufficient		
	Sufficient	Sufficient	Insufficient		
	Sufficient	Sufficient	Sufficient		

The Third Workshop started by providing some feedback on the research progress and the implementation of the SSFP. The purpose of the CPTs was introduced before the CPTs were completed individually. As participants were not familiar with the concepts or method, the researcher guided participants through each of the permutations to complete the CPTs. This was a protracted process that lasted the duration of the workshop. CPTs were populated by allocating the probabilities of an outcome for a child variable which has been assigned a combination of states for the parent(s) variables that directly influence it. The expert opinion of the participants provided these probabilities through the Workshop Three engagement.

4.3.3.2. Bayesian belief network model outcomes

Identification of principal drivers:

All three small groups identified the same variables (Table 4.5) with discussions centring around the weighting of the variables. For policy and regulation, the second group felt that the management zones were more of a stressor because of the limited set of species that could be caught within the current management zone configuration. A greater variety of species (basket of species) is desired. The third group argued that the management zone must be enlarged to include the Cape Infanta-Port Nolloth zone. For climate, participants felt that sea conditions are not necessarily conducive to fishing, even though the weather is favourable and there are only eight to nine fishing days in a month. Windy days are not conducive to fishing. While all groups recognise the importance of capital, there was not much discussion on the topic apart from the assignment of the weighting.

All groups found assigning the dichotomous states problematic as the participants were not familiar with the process and found the decisions hard to make, and most variables were assigned with good/bad states. An agreement was reached that the researcher would finalise the wording if required. Groups presented the reasoning used in the identification and weighting process. The ensuing discussion allowed for consolidation between the groups and allowed all participants to air their views where some rigorous debate took place around the weighting of the drivers, most specifically, climate. After discussions were concluded, participants were asked to cast individual votes to indicate their preferred combination of weighting, the only instruction being that total combined weighting per individual could not exceed 100%. The final consensus weighting as determined by the whole group is shown in Table 4.7. Note that this weighting represents the specific results from Group 2 (Table 4.5), which had also been the ‘intermediate’ one earlier.

Table 4.7. Final weighting and dichotomous states assigned for principal drivers

Principal Driver	Positive state	Negative state	Percentage influence
Policy and Regulation	Favourable	Unfavourable	60%
Climate (weather)	Favourable	Unfavourable	20%
Capital (disposable income)	Sufficient	Insufficient	20%

Identification of contributing factors (to the principal drivers)

Again, while the states of each driver were discussed, it was agreed that the researcher would finalise the wording of the states at a later stage. Assigning and weighting of drivers was done using group consensus. While this method is not considered to be ideal, participants were decidedly more comfortable in this setting. This could be because they could rely on the opinions of the leaders within the group, which made it a more comfortable exercise for some of the participants who were struggling with the process.

The contributing factors 'Climate' include the wind (specifically direction), current and sea temperature. An ideal climate would entail a balanced wind regime blowing in a particular direction depending on season (discernible patterns). Currently prevailing winds are unpredictable and unseasonable. The current is often not flowing in the direction and with the strength that is expected. Sea temperatures also need to be optimal for fish to bite. Table 4.8 presents the contributing factors related to climate, weightings and states assigned. Note the overwhelming reliance on wind.

Table 4.8. Contributing factors, final weighting and dichotomous states assigned for 'Climate'

Variables identified	Positive state	Negative state	Percentage influence
Wind	Optimal	Unfavourable	80%
Current	Optimal	Unfavourable	10%
SST	Optimal	Unfavourable	10%

The contributing factors of 'Policy and regulation" include access to fishing rights, regulation of the inshore trawl sector and the catch size limit of Kob. Most of the crew do not have commercial linefish rights which largely removes their direct access to marine resources. They also feel the rights are too fragmented and want access to broader range of species (basket). It was agreed that this external factor has the most substantial impact on the livelihood of fishers because the fragmentation limits fishery derived income. Regarding the enforcement of the inshore trawl regulations, fishers feel that the inshore trawl operate outside their designated area of operation and target kob as bycatch. Fishers also again lamented the increase in the legal kob minimum size limit as this reduced the amount of catch they could land in contrast to the inshore trawlers, who are not expected to adhere to such a limit. Table 4.9 presents the contributing factors of the policy and regulation, the associated weighing and states.

Table 4.9. Contributing factors, final weighting and dichotomous states assigned for 'Policy and Regulation'

Contributing factors identified	Positive state	Negative state	Percentage influence
Policing inshore trawl	Adequate	Inadequate	30%
Access to Rights	Access	No Access	60%
Size of silver kob (legal minimum size limit)	Big Enough	Too Big*	10%

*The legal minimum size limit for silver kob was increased from 500 mm to 600 mm in recent years. Participants are unhappy with this change as they need to release much fish which they would have been able to land given the previous, smaller size limit especially since this minimum size limit does not pertain to the inshore trawl. The 'too big' state of the kob in this context thus refers to the fact that the participants feel the new size limit is too big and should be lowered to a size deemed to be 'big enough'.

The contributing factors related to 'Economics' identified were (unaffordable) skipper training, profit margins and access to equipment, specifically boats. Fishers believe that access to equipment and the required skipper training will place them in the position to successfully apply for commercial rights. The profit margin of the fish catches paid to crew is also seen as too small. The fact that the percentage allocation of the catch to the crew is not standardised by DAFF is deemed problematic. Table 4.10 presents the contributing factors of the economic driver, the associated weighting and states.

Table 4.10. Contributing factors, final weighting and dichotomous states assigned for 'Capital' (disposable income)

Contributing factors identified	Positive state	Negative state	Percentage influence
Skipper Training	Sufficient	Insufficient	60%
Profit margin	Sufficient	Insufficient	30%
Access to Equipment	Sufficient	Insufficient	10%

The hierarchy, along with the final attributed weighting and associated states as derived from the parameterisation process followed in Workshop One is shown in Figure 4.9. Where applicable, states and names of drivers were adjusted without changing the meaning as agreed upon in the workshop. The final BBN is shown in Figure 4.10. The final BBN is a combination of each of the six participants' individual BBNs (the completed CPTs are shown in Appendix D7). The BBN shows that when each of the contributing factors (root nodes) is assigned a default value of 50%, along with the equally weighted belief of the six participants (input using the auxiliary node), the probability of achieving sustainable fishing derived income is 24.9%.

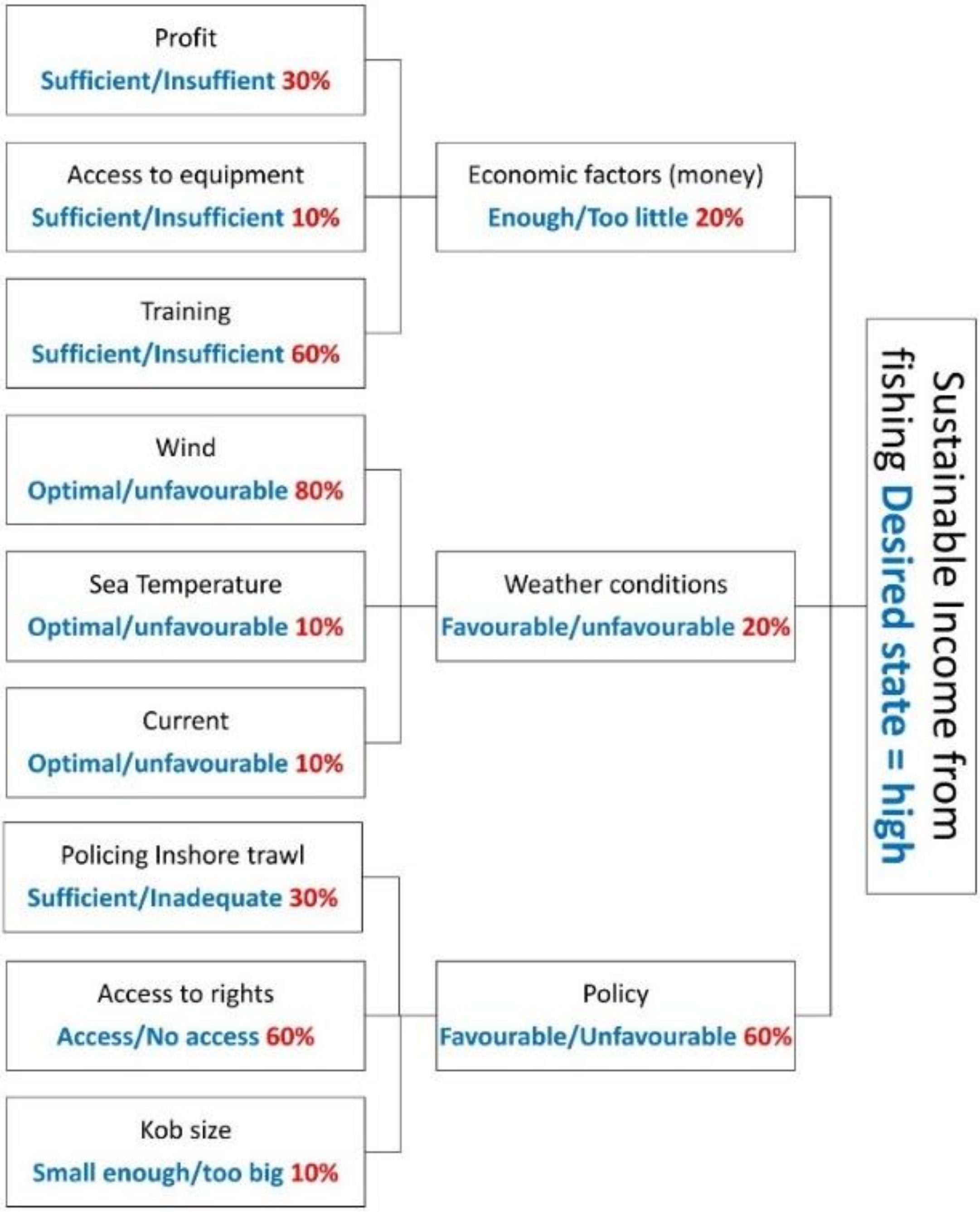


Figure 4.9. Weighted hierarchy, showing states and associated weightings, derived from fisher's inputs in Workshop One. The desired outcome is a sustainable fishery -derived income (high/low). Drivers at the first hierarchy are 'Policy (and regulation)', 'Weather conditions' and 'Economic factors (money)'. At the second hierarchical level, the size of the kob (fishers are permitted to catch), (Access to) fishing rights and policing of the Inshore trawl inform the 'Policy' driver. Wind, Current and sea temperature inform the 'Weather conditions' driver while (skipper) training, access to equipment and profit (margin) informs the 'Economic factors' driver

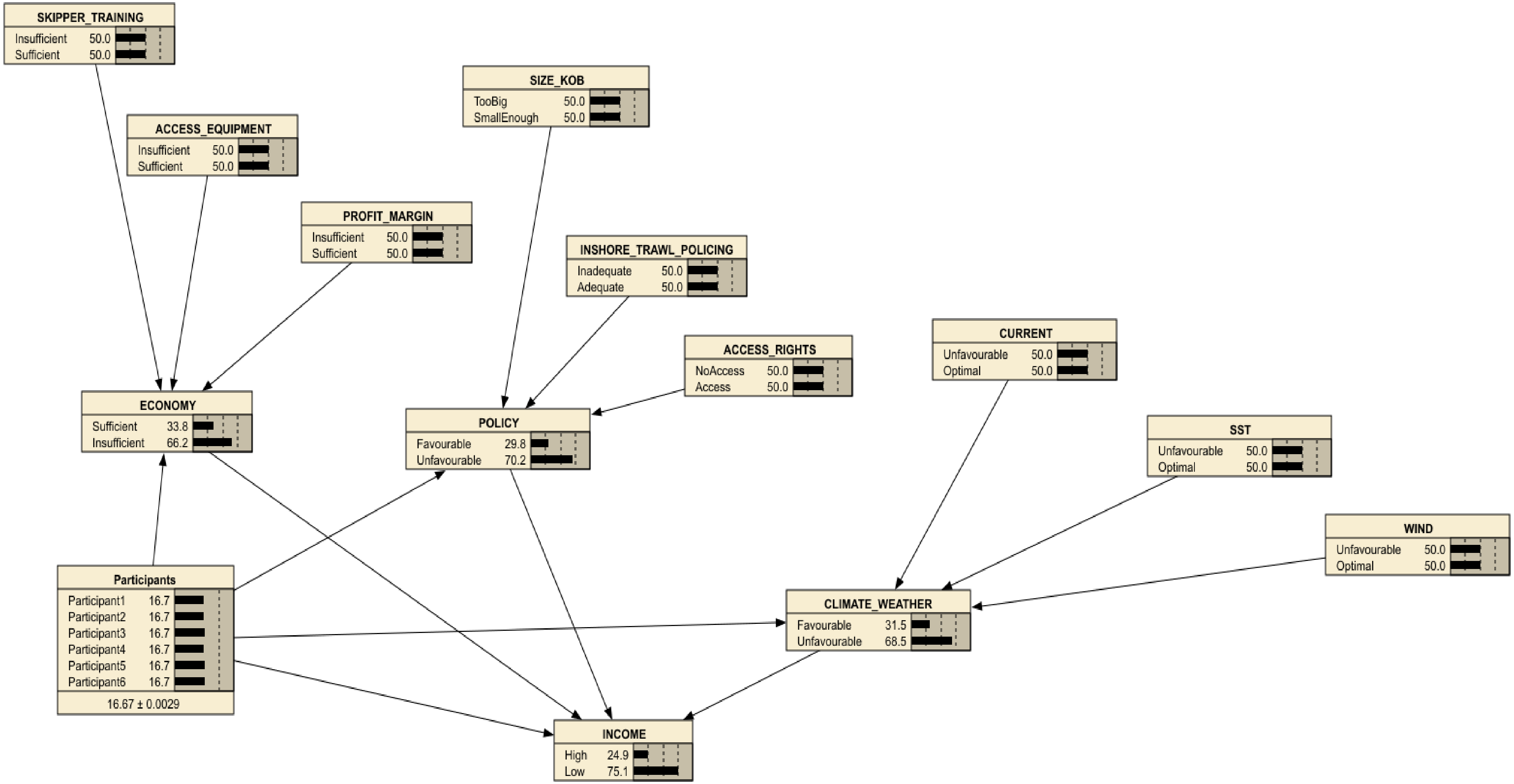


Figure 4.10. Modelled probability outputs of six BBNs. Each participants' set of CPTs is integrated into the BBN with an auxiliary node 'Participants'

4.3.3.3. Sensitivity testing

Sensitivity testing, a formal test of the variability of the priority variable relative to changes of all other variables within the BBN - three principal drivers, nine contributing factors (root nodes) and one auxiliary variable – provided an indication of which variables were most influential on the central issue sustainable fishery-derived income ('Income'). The sensitivity of the model was tested in various ways. Firstly, using Netica's sensitivity analysis function, the sensitivity of the model to 'Income' was tested. The results, provided in Table 4.11, show that among the principal drivers, 'Income' is more sensitive to 'Economy' and 'Climate_Weather' than to 'Policy'. Interestingly, this result is at odds with the group consensus from the hierarchy exercises where 'policy' was assigned a 60% weighting (i.e. the more dominant driver) by participants in the weighted hierarchy. Furthermore, the sensitivity analysis showed that 'Access to Equipment' and 'Profit margin' were the two contributing factors which would have the most influence on 'Income' (next three highest values for mutual info), followed by the three climate-related nodes with approximately equal influence. Interestingly, these contribute to 'Economy' rather than 'Policy'.

Table 4.11. Sensitivity analysis of the BBN shows the variability of the priority variable to changes in the settings of all other variables in the BBN.

Sensitivity of 'INCOME' to a finding at another node:

(Network > Sensitivity to Findings)

Node ----	Mutual Info	Percent	Variance of Beliefs
INCOME	0.80892	100	0.1867557
Participants	0.13666	16.9	0.0369977
ECONOMY	0.06376	7.88	0.0171821
CLIMATE_WEATHER	0.05550	6.86	0.0150977
POLICY	0.01622	2.01	0.0043694
ACCESS_EQUIPMENT	0.00750	0.927	0.0019338
PROFIT_MARGIN	0.00437	0.54	0.0011282
WIND	0.00306	0.379	0.0007922
SST	0.00284	0.351	0.0007335
CURRENT	0.00277	0.342	0.0007149
ACCESS_RIGHTS	0.00242	0.299	0.0006259
SIZE_KOB	0.00100	0.123	0.0002584
INSHORE_TRAWL_POLICING	0.00080	0.0993	0.0002078
SKIPPER_TRAINING	0.00047	0.0577	0.0001209

For further sensitivity testing, the three most influential contributing factors were manipulated (Figure 4.11). These manipulations were specifically that (1) there is sufficient access to. equipment, (2) the profit margin is sufficient and (3) wind is within optimal ranges (i.e. all set to 100%). The results of this manipulation demonstrate that under this 'scenario', the probability of fishers earning a sustainable fishery derived income increases from 24.9% to 38.6%. It must be noted that the mutual info for the 'SST', 'Current' & 'Access_Rights' in the BBN were all close to each other in value and although not in the top three drivers of the second hierarchy, the values were very close to the 'wind' mutual value.

There are some discrepancies between the influence weighting from the sensitivity analysis and the weightings assigned by participants in the weighted hierarchy. Notably, 'Access to equipment' was weighted as the least important contributor to 'Economy', while 'Profit margin' was given a 30% weighting. 'Skipper training', although regarded as the most critical factor to 'Economy' in the weighted hierarchy, is shown by the sensitivity analysis to have less influence on both 'Economy' and 'Income' (Appendix D8). For the weighted hierarchy, participants assigned an 80% weighting to 'Wind'. However, the sensitivity analysis shows that although wind does play the most prominent role within the climate drivers, 'SST' and 'Current' contribute similarly. This means that the influence of the three drivers was more evenly-weighted in the BBN than initially suggested by participants through the weighted hierarchy.

Further sensitivity analysis explored how 'Income' would be influenced if more changes were made to the states in the second hierarchy of the BBN. The results of this analysis, shown in Table 4.12, show that the probability of income being high when all the contributing factors are set to 100% favourable state is 91,7%, inversely, when the states are all set to a 100% negative state, the probability associated to earning enough income is 2,04%. This result is expected. The range between the high and low state is also expected considering that participants inputs into the CPTs were often extreme – i.e. very high or low probabilities were assigned to the different permutations (See Appendix D7 for all completed CPTs). The columns showing the 50/50 contributing factors states of the root nodes in the final BBN (see Figure 4.10) have been included to make the comparison between the Income (low/high) results easier.

Table 4.12. Results of the sensitivity analysis where all the contributing factors were first all set to 100% insufficient (low) as well as the 100% sufficient (high). The differences in the high/low ranges of the probability of the 'Income' variable is shown

Principal Driver	Contributing Factor	Sufficient (high) (% probability)*	Sufficient (high) (% probability)	Sufficient (low) (% probability)
Economy	Skipper Training	0	50	100
	Access	0	50	100
	Profit	0	50	100
Policy	Size_Kob	0	50	100
	Inshore Trawl	0	50	100
	Access	0	50	100
Climate_ Weather	Current	0	50	100
	SST	0	50	100
	Wind	0	50	100
Income (% probability)		2.0	24.9	91.7

The sensitivity of each participants' input to the BBN (Appendix D8) showed that, for the principal drivers, the mutual information indicator showed different ranking of the drivers per participant. Participants one and five's BBN showed that the 'Economy' driver placed the most influence on 'Income'. The BBN derived from participants two and six showed that 'Policy' had the biggest influence on 'Income', while Participants three and four's BBN showed that 'Climate_Weather' carried the most influence on 'Income'. Note the deviation from the group consensus results provided in Tables 4.7 – 4.10 and Figure 4.10, discussed below.

To test how sensitive the BBN would be to additional participants' input, three additional analyses were run (also see Appendix D9). This was done by adding a duplicate of the CPTs of participants one, two and three in three separate model runs, i.e. in run one, a duplicate participant with CPTs which favoured the same variables as participant one was added to see how this would influence the BBN. The same was done for participants two and three. The results (Table 4.13) show that adding the duplicate participants did not influence the BBN outputs to a substantial extent, indicating that the model is not over-sensitive to additional participants' inputs.

Table 4.13. Results from the sensitivity testing where duplicate participants were added to the combined net in three separate runs.

Duplicate participant added to:	Probability 'Income' High	Probability 'Income' Low
Economy	24.3%	75.7%
Policy	22.27%	77.8%
Climate_Weather	26.1%	73.9%

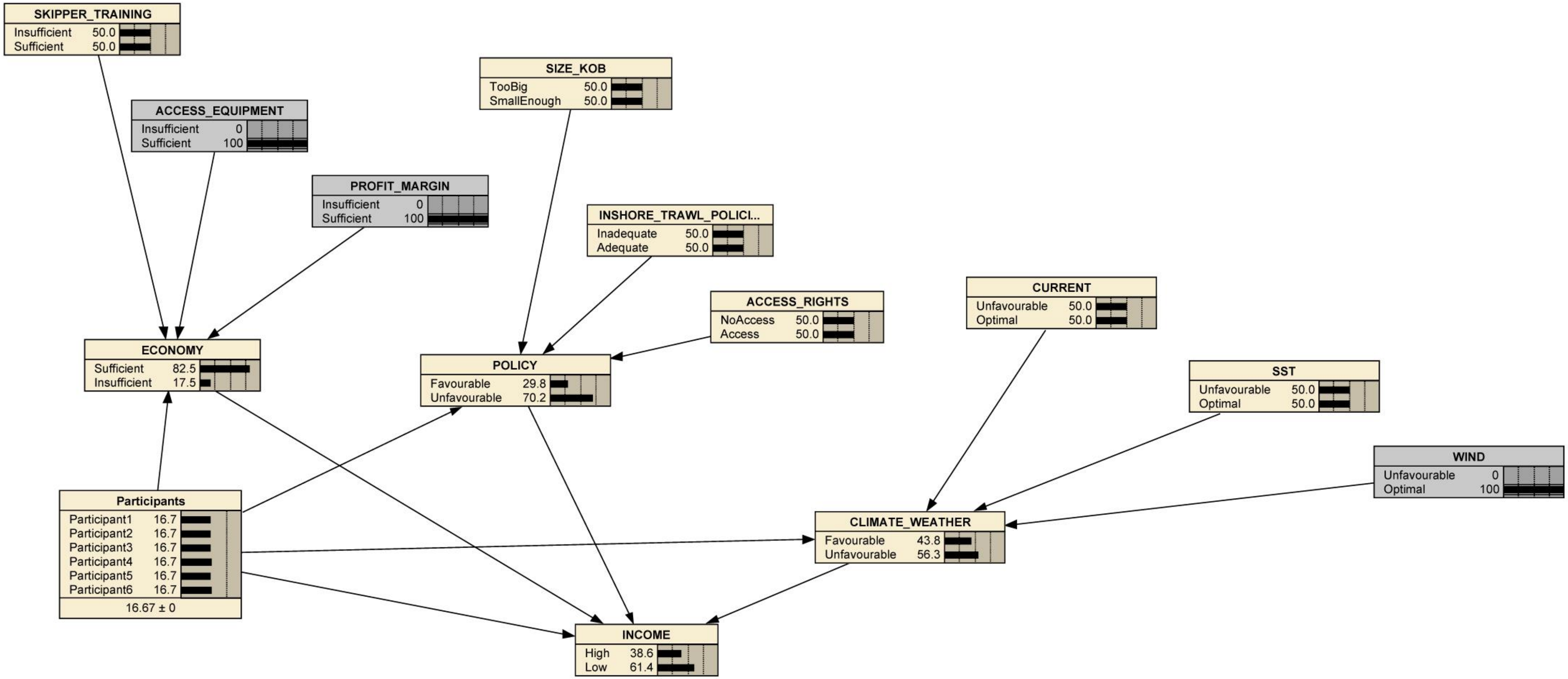


Figure 4.11. Manipulated probabilities with specific contributing factors (root nodes) set to a 100% favourable condition. The stem variables adjusted (shown in grey) are the three contributing factors which contribute the most influence on 'Income' per the sensitivity analysis carried out, namely 'Access to equipment', 'Profit margin' and 'Wind'

4.3.4. Bayesian belief network discussion

The prototype BBN described here is a graphic and probabilistic representation of the relationships between key contributors to change (variables) on sustainable fishing-derived income within the southern Cape's linefishery. The general advantages and disadvantages of using BBN modelling have been discussed in Chapter Two. The contribution made using the BBNs in this research specifically insights gained into the drivers of change in the system and the suitability of using the tool in a context of high uncertainty, and with marginalised stakeholders. Specifically, the chapter has set out to address Aims 2 & 3 (see Section 1.9) through answering research questions (iii) and (iv) provided in Section 1.10. I sought to establish what additional insights are gained into the drivers of change and system uncertainty through the development of a weighted hierarchy and BBN and to evaluate the suitability of developing the BBN in an interactive and interactive process with stakeholders.

Insights into the drivers of change

The set of principal drivers identified by participants held no surprises, and the results are consistent with all the previous research into drivers of change in the SES of the southern Cape linefishery as well as with the final causal map. The BBN development process provided valuable insights into how this group of fishers view key drivers of change central to achieving a sustainable fishery derived income. While these results cannot be viewed in isolation, they provide an essential perspective on what fishers consider important drivers of change that influence their income. The CPTs and the subsequent sensitivity analyses are not only tools which allow for an assessment of the different drivers of change and their interactions that impact on a sustainable fishery-derived income (as the outcome of this model) but also provide important insight into system uncertainty.

A distinct contrast was revealed between the weighting in the hierarchy and the model outputs. To derive the hierarchy, the questions were asked more familiarly and directly. Fishers tended to respond to these questions in the same manner as they have done in the past. The BBN development process allowed for the reframing of some of these questions by asking for the same information in a more indirect way. The resulting BBN and subsequent sensitivity analysis provide insight into what drivers of change the *individual* participants feel are the most important concerning the central issue. The diverging opinions about the direct and contributing factors on 'Income' showed up at odds with the group consensus weightings that were established when deriving the weighted hierarchy. The drivers of 'Income' in the BBN presented a more balanced influence than that assigned in the 'weighting by consensus' process. In this case, asking the question more indirectly has allowed for the conversation to move beyond rhetoric and formulaic answers, providing a reflection of the participants' views and priorities. This is an advantage of using BBNs specifically highlighted by Haapasaari et al. (2012a). Issues of trust and power highlighted within the skipper cohort by Duggan (2012; 2018) were also negated somewhat in this this way of questioning.

As with the causal maps, policy and regulatory issues remain top of mind and fishers thus tend to attribute more weight to this driver. When considering the BBN model outputs and the sensitivity analyses performed, it is clear that the influence the policy and regulatory issues have on 'Income' is much less than the weighted hierarchy suggests. Furthermore, the results of the sensitivity analysis revealed that the influence of principal nodes is relatively evenly weighted as is the case in the contributing factors. Figure 4.11 shows the outputs when the three most influential nodes on 'Income' are set to the most favourable state – however, the influence exercised on income is not overwhelming with the probability of earning a sustainable fishery derived income under these conditions increasing from 29,4% (see Figure 4.10) to 38.6%. This could be due to several factors - the probabilities the fishers assigned in the CPTs were absolute as they tended to select extreme probability percentages (i.e. 0-100%, 10- 90%, 20-80%) with no moderate probabilities assigned to the combinations of variables where the likelihood of a favourable /unfavourable outcome could be assumed to be a bit more equal. The research also took place at a time where there was a large amount of uncertainty regarding policy implementation (discussed by amongst others Sowman et al., 2014, Gammage et al., 2017a and Duggan, 2018) and where fishery resources were constrained resulting in this model essentially being run in a state of 'low fishery resources'. By implication; if there are no fish to catch, it does not matter what is driving the change in the system, no fish equates to no income with certainty. Fishers are, however, not inclined to highlight the issue of resource scarcity, which is consistent with previous research (Gammage, 2015; Gammage et al., 2017a) and the results of the causal mapping. One can only speculate on why this is the case, but it may well be there is a fear that if resource challenges were addressed directly, fishers would be forced to confront the fact that even if all other conditions in the fishery were favourable, very little would change for the better given the limited scope for alternative income.

Overall the sensitivity analysis results indicate that this is a system where there is increased variability which leads to an increase in uncertainty thereby exposing the fishers to high risk. When considering the sensitivity analysis of each participants' BBN (Appendix D9), it is clear that fishers' have different perceptions/understanding of what the dominant principal-level drivers are. This result is more consistent with the first steps in the hierarchy setup where the small groups were asked to give their weighting of drivers before group consensus determined the final weighting. In that first round, there was a group (see Table 4.5) of fishers who provided an equal weighting to the 'Policy and Regulation' and 'Climate (weather)' variables while the 'Capital' variable was rated as the most important. Although all the fishers agreed on the final weighting through a voting process, the differing view of these fishers can be seen in the sensitivity analysis of the individual participants. Interestingly, none of the groups weighted 'weather/climate' as being the most important principal driver even though the sensitivity analysis shows that two participants did consider this to be the most important. This could be because these participants were not dominant voices in their groups, or that the small group consensus opinion may have been divided from the start. This aggregation of data is to be expected in this manner of scaling from the individual to the group level. Importantly, the BBN presents an aggregated model that best fits all the individual fishers' views previously shown by Haapasari et al. (2007); Haapasaari & Karjalainen (2010) & Levontin et al. (2011) in various studies carried out in the Baltic Salmon fisheries. While it could possibly be used to influence group discussion in the future, the model's ability to easily combine different knowledge streams and data has demonstrated (corroborating the findings of Varis & Kuikka, 1997b; Kuikka et al., 2011; Barton et al., 2012; Haapasaari et al., 2012a) while retaining the uncertainties arising from discrepancies in individual views.

Suitability of using BBNs in this context

The overall scenario-planning process, which was the backdrop against which all the research has taken place, is generally a solution-driven and orientated approach (Petersen et al., 2003a; IPCC 2014; IPBES, 2016; Oteros-Rozas et al., 2015; Bennett et al., 2016a). In this setting, the BBN construction process created an important dialogue space for 'top of mind' issues to be spoken about in a constructive, forward-thinking setting. While the use of the BBN as a participatory tool was not formally evaluated by participants in this research, such an evaluation carried out by Zorrilla & García (2010) shows that stakeholders generally agreed to the usefulness of the tool in the structuring of meetings while encouraging communications and discussions. Added to this the authors highlight the use in identifying stakeholders' level of knowledge and uncertainty. Previous research in this fishery system consistently highlights the uncertainty brought about by a high variability within the system (e.g. Ward, 2018). This uncertainty not only exposes fishers to risk but also hampers decision-making as fishers do not know what to plan for. Through the compilation of the BBN and the ensuing sensitivity analyses, it becomes possible to identify areas of uncertainty from the perspectives of the research participants. Other authors, including Rieman et al. (2001); Ghabayen et al. (2004); Uusitalo (2007) and Haapasaari & Karjalainen (2010) highlight the use of the tool when addressing uncertainty in environmental systems. The prototype model designed in this research provides a snapshot where key uncertainties lie by providing insights into how the participants view the system. For the purposes of this research, the importance lies in the fact that the tool was implementable in this fishery context. Additionally, the insights into uncertainty gleaned from the BBN has been applied in the ensuing scenario-planning prototyping exercise (Chapter Five).

While the BBN described here cannot be used to inform a decision-making process as such (the research question was not framed in a way that the resulting model could be used as a decision analysis model), the sensitivity analyses carried out delivers important insights. In exposing the uncertainty in the system, this BBN highlights the spaces where there is commonality in the fishers' opinions. The process used to derive the BBN would, in a bigger setting; provide an important opportunity for diverse stakeholders to learn from each other's point of view. This BBN then also has the potential, if expanded, to be used for the understanding of the nature of policy problems (in both the context of the SSFP and regulations governing other sectors) in the southern Cape linefishery. An example of how a simulation model and BBN can be combined in decision-making context is provided by Levontin et al. (2011) for the Baltic salmon fishery. Although their BBN draws on alternative management strategies, the principal drivers explored in the present thesis could in a similar way be combined in a simulation model and the stakeholder experience documented here would contribute to the evaluation of the likelihood of attaining a sustainable fishery-derived income. Even in its current form, the prototype BBN presented here demonstrates the views and priorities which participants hold – a characteristic which will be most useful for combining more extensive knowledges and perspectives in future planning processes.

As with the causal maps, the capacity building and social/mutual learning in the context of this research cannot be overlooked. The fishers were not at all used to having to think about their system in this manner, nor were they used to the abstract thinking required in the CPT completion process. Although this slowed down the research process considerably, it also provided the opportunity for social learning. Social learning in this setting is especially important as it adds to the capacity building required to mitigate long-term risk. Importantly, after the first workshop, it was not clear if fishes would be able to complete the CPTs required to parameterise the model. Through the workshopping process, where participants and the researcher could exchange ideas and knowledge, conditions were created where most of the fishers were able to complete the CPT process successfully. This demonstrates the value of continued engagement with fishers and other stakeholders to create enabling conditions such as spaces for active dialogue and learning, required for transformation in the marine SES.

4.4. Key insights

Apart from the tool-specific questions addressed within this chapter, the research also addressed two over-arching questions (see Section 1.10). The first question, addressed within Sections 4.2.3 and 4.3.4, is related to new insights into the SES which came to the fore through the use of causal maps and BBNs. The second question is related to knowledge that was gained through the iterative implementation process. Following from previous research (Gammage, 2015) and the causal map and BBN construction processes, fishers (and participants) may not always explicitly recognise the importance of several drivers of change in the SES. Failure to account for important system interactions and the role played by such stressors on the short term can severely impede their ability to proactively respond to future change in the long term as outlined by e.g. Walker et al. (2004) and Folke et al. (2006; 2010). From conversations with fishers through the mapping and BBN modelling processes, it became clear that although issues concerning policy and regulation are foremost in the participants' minds as they see it as the most direct and pressing threat to their livelihoods, stressors such as availability of fish are neglected in the discourse. As discussed in Section 4.2.4, this is not a challenge unique to South African fisheries. While the causal mapping process helped to highlight many of the issues that remain hidden in a narrative of drivers of change; it did not effectively help move participants beyond what could be called 'standard responses'. The visual nature of the causal maps did, however, assist fishers with piecing together the drivers of change into a view of the system that moved beyond the abstract to something more concrete. This highlights the need for adequate problem (re)framing and (re)structuring when embarking on policy and management processes, also highlighted by Haapasaari et al.

(2012b). It remains impossible to employ good decision-making (at any scale) if social constructs of management problems and challenges are not accounted for (Belton & Stewart, 2002). The use of the decision-making tools in this context (specifically BBN), has allowed for questions regarding topics very familiar to fishers, to be reframed. This has helped to move beyond superficial, standard responses and has been very successful in helping move the conversation along from a problem-orientated space to a solution-space. Not only does this prototyping process provide a blueprint for future planning processes using SDMTs, but importantly for this research, it informs the development of the scenario stories as described in Chapter Five.

While the participants engaged relatively quickly with the Causal Maps, the BBN mapping process was more challenging to complete, as the process was more abstract and complicated than that of the causal maps. After the first workshop, it was not clear whether it would be possible to complete the BBN process as planned, especially considering that these participants have low levels of formal education and had never participated in such a structured decision-making process. The second workshop (discussed in Chapter Five), did not contribute at all to the BBN as such, although the discussions contributed to learning and enabled to complete the CPTs in Workshop Three. An important contribution made by the development of the BBN is to the process of capacity building, and possibly social learning, at the smallest scales of interaction. This was true for both the workshop participants and the researcher alike. The usefulness of such participatory modelling methods in the promotion of mutual learning and in providing insights into values and knowledge held by participants are highlighted by various authors, including van der Belt (2004); Gregory et al. (2012) and Tuler et al. (2017). Importantly, learning and capacity building was facilitated in that fishers, through the various interactions, gained knowledge, thereby contributing to capacity building within the context of the individual and the group. This learning will be extremely beneficial to fishers when embarking on a larger scale scenario-planning process – if they do not feel empowered to speak up when they are in a diverse stakeholder setting which will likely result in some heated discussions, their voices and opinions will get lost due to the unequal power relations at play.

In summary, this chapter has addressed the use of the causal maps and BBNs in the present research to enhance our understanding of drivers of change within the marine SES of the southern Cape, specifically feedback loops and indirect interactions. Additionally, through the implementation process, the suitability of the tools in an iterative and interactive participatory modelling with disenfranchised fishers have been reflected on. Overarching themes emerging from this chapter, and discussed in Chapter Six, are related to semi-quantitative modelling, the use of such modelling techniques to address issues of scale, and the contribution the development of these tools can make towards EAF implementation in South Africa. Importantly, the causal maps and the BBN development process both played an important role in the Scenario planning process described in Chapter Five.

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Chapter Five

Failing to plan is planning to fail: lessons learnt from a scenario-based approach to change in fishing communities in the southern Cape.

5.1. Introduction

The failure to appropriately recognise integrated marine ecosystems has resulted in depleted ocean resources, negatively affecting resource-dependent communities (Van Sittert, 2002; Ommer et al., 2012; Jarre et al., 2013). Added to this, increasing environmental variability due to the effects of climate change, result in systems filled with uncertainty and increasingly vulnerable to change (see Perry et al., 2011). The southern Benguela is no exception. Previous research (Gammage, 2015; Gammage et al.,2017a and Chapter Three of this thesis), describe the localised drivers of change in the coupled social-ecological system (SES) of the southern Cape from the perspective of the linefishers. The research exposes drivers of change and the resulting uncertainty, as documented in Chapter Four. Varying change response strategies (coping, reacting, adapting) implemented by fishers highlight the effect of increasing variability and ensuing uncertainty on fishers' decision-making (Gammage, 2015; Gammage et al., 2017b) while showing how difficult it is for linefishers to respond to variability and change proactively. Having identified the fishers' inability to respond to change adequately and discussing the related uncertainty (Gammage et al., 2017a,b; Gammage, 2015), a scenario-based approach to change has been identified and proposed as a suitable risk-mitigation tool. To avoid potential future maladaptation, continued disempowerment of already disenfranchised communities and to secure sustainable livelihoods well into the future, a toolbox approach to management and change is thought to be most suitable.

A scenario is a structured account of possible futures and describes what 'could be' whilst providing a systemic method for thinking creatively about complex and uncertain futures (Peterson et al., 2003a; Amer et al., 2013; Bennett et al., 2015; Oteros-Rozas et al., 2015., Vervoort et al., 2015). The method aims to unleash the imagination to explore and embrace the future as opposed to just enduring it (Vervoort et al., 2015). The process of imagining future worlds should empower resource users to recognise ways in which they can overcome challenges and envision and pursue better futures. Furthermore, the practice of considering a wide range of futures can ideally reveal important aspects of the present (Vervoort et al., 2015). Scenario-based approaches offer a useful way to respond to change by allowing stakeholders to envisage possible futures in the pursuit of a pre-determined and common goal and provide a useful alternative to predictions and forecasts as stakeholders can consider the type of future they deem desirable (Haward et al., 2013). Unlike forecasts, scenarios emphasise complex uncertainties that are not controllable by decision-makers. The determination of trends, predictions, future visions and models remain part of any planning process, however these must not be mistaken for the scenarios themselves. Scenarios can compromise realistic predictions of current trends, qualitative predictions and quantitative models although the value often lies in developing a qualitative and quantitative understanding of the system and in stimulating and encouraging participants to evaluate and reassess system beliefs (Greeuw et al., 2000). A suitable and useful scenario incorporates imaginative speculation with a wide range of possibilities, scenarios that are based only on current system knowledge and understanding have limited power in assisting resource users and stakeholders when planning for an unpredictable future (Peterson et al., 2003a). The process furthermore creates opportunities for stakeholders to engage in a learning process that can result in developing an enhanced understanding of the structure of and dynamics within (Haward et al., 2013). In the end, when a system's structure, causal relationships, driving forces and assumptions are better understood, it becomes increasingly possible to avoid unsustainable reactive responses. A more in-depth analysis of the uses and limitations of the scenario planning process is presented in Chapter Two (Sections 2.4 & 2.5).

Transformative scenario planning (TSP) makes use of backcasting techniques to create normative scenarios which explore possible futures. These scenarios are exploratory and speculative (Wiebe et al., 2018) and are designed to for all participants (or actors in the system) to work cooperatively and creatively to get a complex problem untangled and moved forward (Kahane, 2012 a, b). The conceptualisation of the scenario planning exercise outlined in this chapter has been informed by the principles of the TSP (outlined in Chapter Two) and takes the form of a prototyping exercise (Starfield & Jarre, 2011). There are, however, critical differences between the steps described by Kahane (2012a, b) and the steps followed here. Importantly the process outlined by Kahane (2012a, b), calls for a heterogeneous group of stakeholders to participate in a planning process convened at a large (e.g. regional or sectoral) scale. In the context of this fishery, this would include stakeholders from industry, decision-makers at the local, provincial, and national government branches, various NGOs, various sub-groups within the fishery, researchers and other interested parties. The scenario planning exercise described here has been conducted within the community of fishers from the town of Melkhoutfontein and forms part of the same workshopping process introduced in Chapter Four. Convening the scenario-planning exercise on a smaller scale was done to develop, together with fishers, four stories of what the future may hold for Melkhoutfontein using an iterative scenario planning exercise based on the principles of TSP.

Specifically, this chapter aims to address Aim 4 of this thesis (Section 1.9), by addressing two broad questions (Section 1.10): (1) What are possible pathways (future stories) for the future development of Melkhoutfontein within the context of key driving forces as identified through an interactive, participatory scenario planning process? and (2) Does this process promote learning, thereby building capacity for disenfranchised (and often powerless) fishers to not only create adaptive capacity at the smallest scale of operation but also to empower them to be able to participate meaningfully and confidently in larger scale scenario planning and governance processes?

This chapter provides the methods used to arrive at the scenario stories as well as the results from the workshops. The initial and refined scenario stories are presented, followed by a discussion of the implications of the results.

5.2. Scenario planning approach

The overarching methods and associated data collection methods and timelines are presented in Chapter Two, Section 2.6 of this thesis. The methods presented here follows those that pertain directly to the scenario planning process. The process followed in this prototyping exercise was extensive and multi-faceted. Figure 5.1 outlines the various steps in the scenario construction process, while Table 5.1 shows the number of participants who took part in the various interactions. The method and process followed in Workshop One and Three are detailed in Chapter Four, Section 4.3.3.

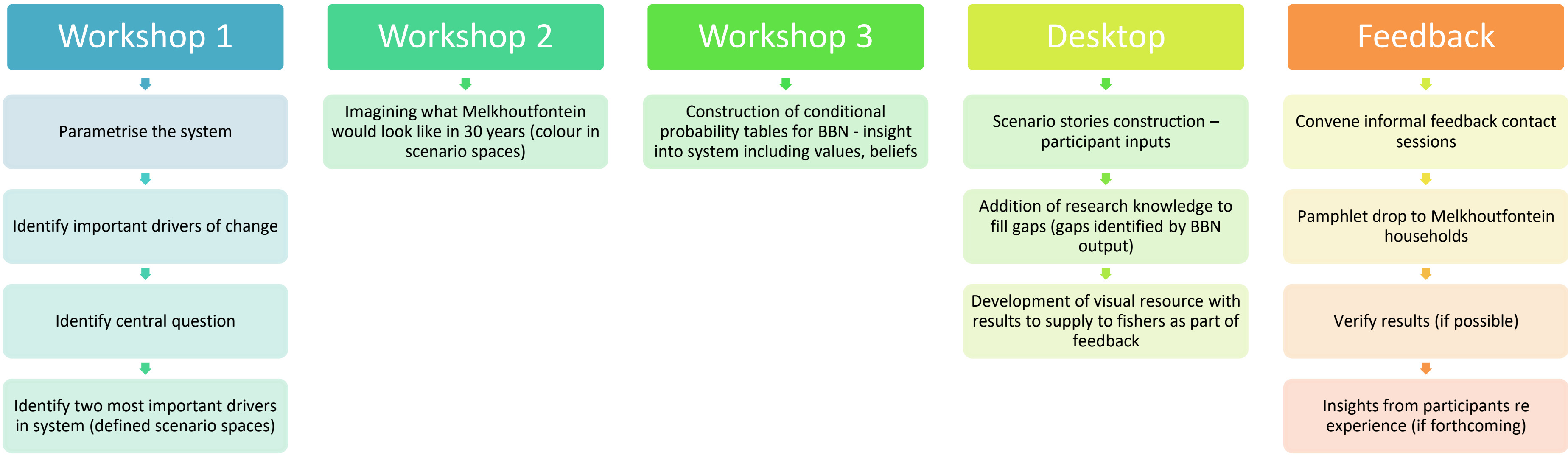

Figure 5.1. Scenario development process followed in the Melkhoutfontein prototyping exercise. The Causal map and Bayesian belief network development process in Workshops One and Three (described in Chapter Four), delivered their own, separate outputs while forming part of the overall scenario development process

For the scenarios, the outcomes from Workshop One allowed participants to identify their key (central) concept and four Key Driving Forces (KDFs) central to this concept. Participants were then asked to vote to determine the two KDFs around which they would build the scenario spaces which were discussed in visioning exercises in Workshop Two. As with Workshop One, the programme for the day for Workshop Two (Figure 5.2) had to be adjusted as it became clear that participants were not willing to engage with many of the workshopping tools that were planned and instead preferred to talk through the issues at hand in a large group setting. The day also had to be shortened to accommodate the participants and to ensure they would stay engaged. Due to these constraints, some of the planned outcomes were not realised.

Workshop 2 programme

09:00 – 09:15: Welcoming and introduction

09:15 – 09:30: Overview from previous workshop, insights from participants

09:30 – 10:30: **Developing explorative scenarios – *What can happen* to Fishers' income *if* the current governance and management framework is maintained? Flipboard paper, ideas recorded**

For the purposes of this exercise, climate change is a given. Name scenarios around the 2 key uncertainties evocative titles /positive and negative. Refer to values, issues, drivers

10:30 – 10:45: Tea

10:45 – 12:30: Develop scenario narratives. Each group has one scenario. LEGO & Newspaper headline exercise.

10:45 – 11:30: LEGO – build a depiction of what Melkhoutfontein may look like in the future under given permutation.

11:30 – 12:00: Newspaper headlines – what would the newspaper headlines be on the journey to the future you have constructed?

12:00 – 12:30: Feedback and discussion.

12:30 – 13:15: Lunch

13:15 – 14:15: Step back – construction of CPTs (guided completion of questionnaire).

14:15 – 15:00: Next steps regarding scenario planning (follow up workshop for feedback mid-June).

15: 00 Tea & Closing

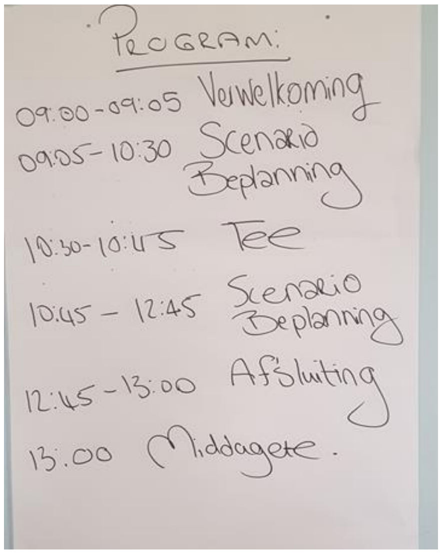

Figure 5.2. Programme for Workshop Two – detailed plan on left panel. The workshop had to be shortened to keep to the ethos of participant-led research resulting in many of the planned activities, notably the LEGO, newspaper headline exercise, and the construction of the CPTs. The amended programme (in Afrikaans) is shown on the right

While the discussions emanating from Workshop Three did not directly feed into the scenario spaces, they did serve to complete the CPTs required to develop the Bayesian belief network (BBN). The BBN outputs informed the final scenario stories by identifying other important drivers (specifically climate) which are central to fishers' ability to earn sustainable fishery derived incomes (see Chapter Four, Section 4.3.3.2.).

Table 5.1. Workshop participants numbers per interaction

Interaction	Number of Participants
Invited participants	20
Workshop One attendees	14
Workshop Two attendees	8
Workshop Three attendees	9

Figure 5.3 shows a summation of the process used to construct the final scenario stories, as well as the data sources used. In constructing the final scenario stories, the information from the fishers (from Workshop Two) was collated into four broad scenarios. Research knowledge and expert opinion regarding two KDFs (climate change and changes in resource status), that were not included in the workshop discussion (see Section 5.3) have been included based on their importance to the functioning of the fishery as identified by the outcomes of the BBN sensitivity analyses. They were synthesised with the fishers' scenario stories for the final scenario stories.

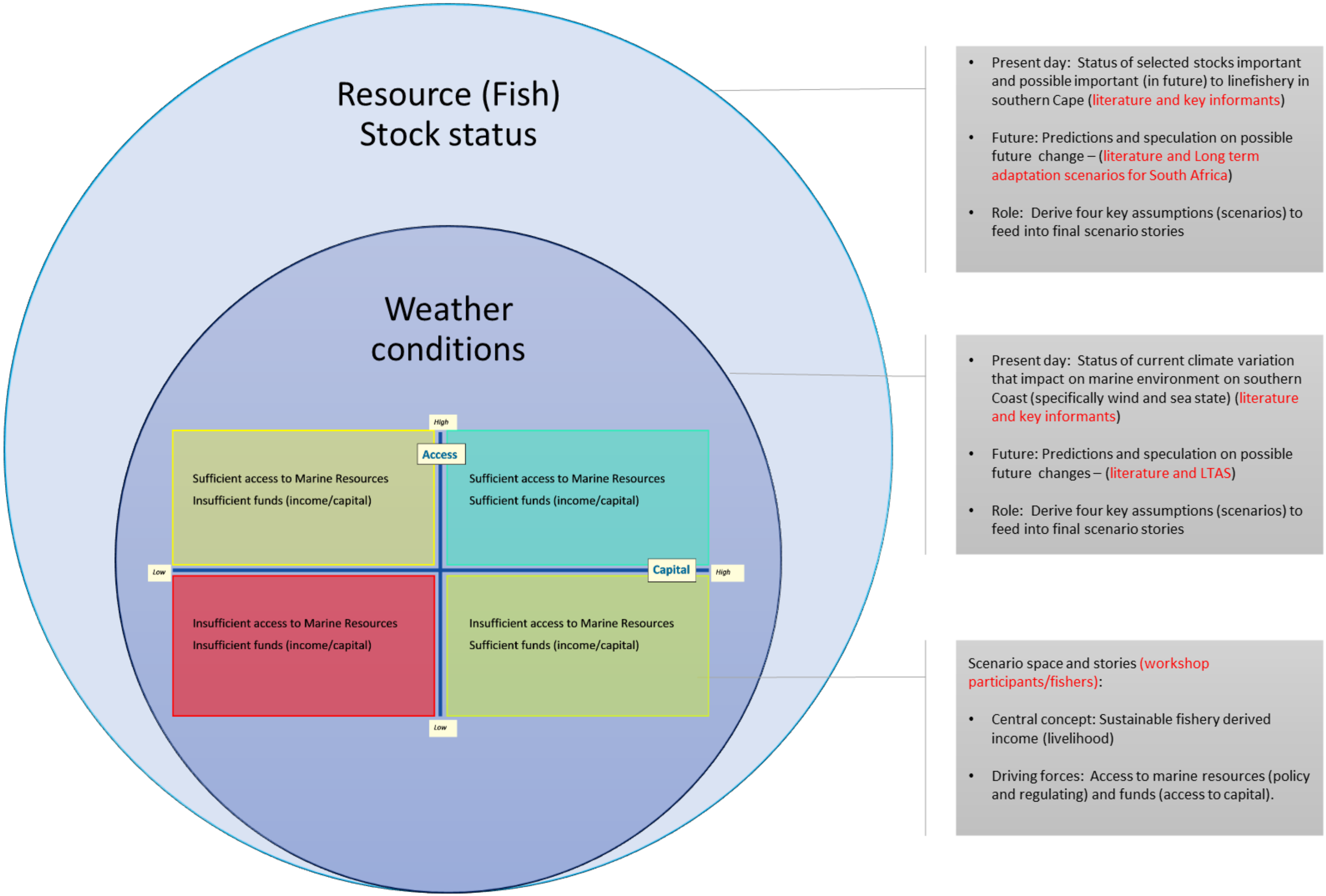

Figure 5.3. Methodology involved in deriving the final scenario stories. Participant derived scenario stories were backdropped with predictions and assumptions (scenarios based on current data). These backdrops concerned Climate change (in the context of prevailing weather conditions) and Fish stock resource (in the context of pervasive resource scarcity in the area). Data sources are shown in red text

The final stories were included in a pamphlet designed as a feedback resource to fishers in the southern Cape. The feedback session with fishers took place August 2018, more than a year after the conclusion of the workshops (see Table 2.6). The purpose of the feedback was to present the final scenario stories to the participants and provided an opportunity to reflect on both the stories and process. It took the form of informal feedback provided to one-on-one contact sessions. Where fishers were not available, a personally addressed pamphlet was hand-delivered.

5.3. Results: scenario planning process

The scenario planning process took place in of Melkhoutfontein with the associated community of fishers as the key stakeholders (further referred to as participants). The first two workshops were used to gather the information required for the development of the BBNs (see Chapter Four) and initial scenarios. The third provided the opportunity to feed some results back to participants and complete the BBN construction.

5.3.1. Workshop One - defining what is important

The first workshop primarily focussed on the BBN construction and is described in more detail in Chapter Four, Section 4.3.1. The latter part of the workshop was devoted to the scenario planning process which was started with a general discussion regarding the drivers that influence fishery-derived income. Fishers were asked to identify four KDFs they felt were most important when considering their future fishing-derived income. Climate change (variability), changes to the biophysical system, sufficient disposable income and access to marine resources were identified by group consensus. The final two drivers to be used in the scenarios were determined by an individual voting process with 'Disposable income' and 'access to marine resources' (see Figure 5.4), receiving the most votes. This was a surprising choice, given that a big case had earlier been made for the inclusion of climate change as the more pertinent threat to livelihoods (see Chapter Four).

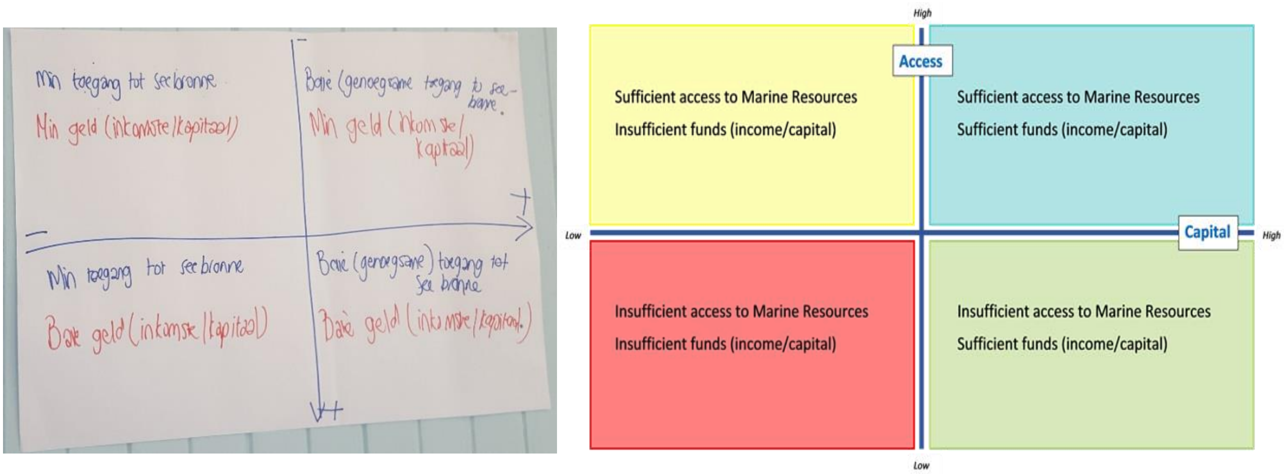

Figure 5.4. Key Driving Forces (KDFs) identified by participants. Access to marine resources and access to capital (funds) were identified as the two most important driving forces when considering the ability to attain a sustainable fishery-derived income. On the left, the possible scenarios and states as determined in Workshop One are shown, the right panel shows the same drivers and states in English

5.3.2. Workshop Two – exploring the future

Workshop Two was a one-day workshop with the same invited participants as per Workshop One, although fewer participants attended (see Table 5.1). The workshop aimed to construct potential future stories around the scenario spaces created by the two drivers selected by participants in Workshop One (Figure 5.4). As with Workshop One, some adjustments to the pre-planned programme were made, and pre-planned exercises such as the building of future Melkhoutfontein using Lego and newspaper headline exercises were replaced with large-group discussions at the request of participants. The programme adjustment was made to ensure that the concept of participant-led and inductive research was not undermined. This resulted in data that were not as detailed as anticipated. This data scarcity has been addressed in the final scenario story construction process by supplementing workshop data with other data sources (stressors and GULLS data, the outcomes from other scenarios, modelled projections for fisheries and climate, research literature and expert knowledge).

As this was the first-time participants were formally involved with any 'forward-thinking' approach, an initial reticence to engage was noted. Participants initially appeared uncertain about what was required and defaulted back to describing current circumstances. As discussions progressed, participants became increasingly comfortable, and they engaged with increasing confidence. It was also more comfortable for the participants to engage with the more positive scenario spaces (notably those where disposable income was not a problem). This may be because the low-income scenario spaces were closer to the resent day reality. Previous research (Gammage et al., 2017b) has shown that fishers feel powerless and unable to change current circumstances and this hopelessness was reflected the first (low income, low access to resources) scenario space. In the scenario spaces where disposable income was low, there was parity between current and future livelihood activities. The development trajectory for infrastructure development in the town was the same for all four scenario spaces. The pace and scope of the development varied, with the high-income scenario spaces showing the most significant improvement over the shortest period. Themes/drivers included in the general discussions of the four scenario spaces include the biophysical environment (fish abundance and climate), other fishery sectors (inshore trawl), policy and regulation (small-scale fishing policy; linefishery) and socio-economic considerations (local and national economy). Figures 5.5 – 5.8 show the participant-derived scenario spaces. These are described in more detail in Section 5.5.

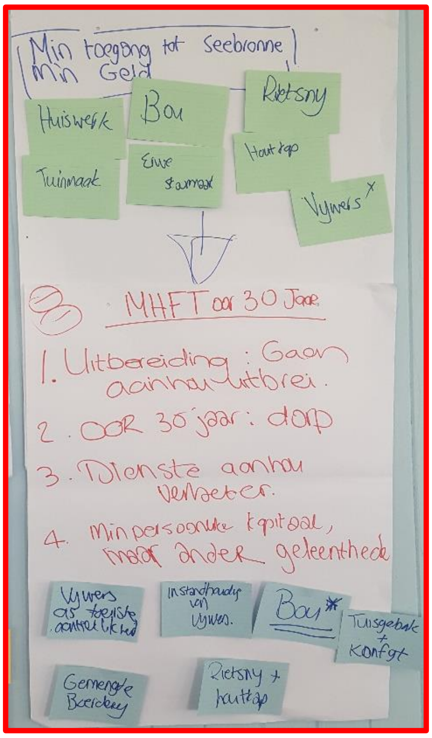

Figure 5.5. Insufficient access to marine resources/Low disposable income scenario: Green cards depicts current and potential activities that participants engage in the present time. The red text reflects the town in 30 years; blue cards indicate future livelihood activities that could be engaged in

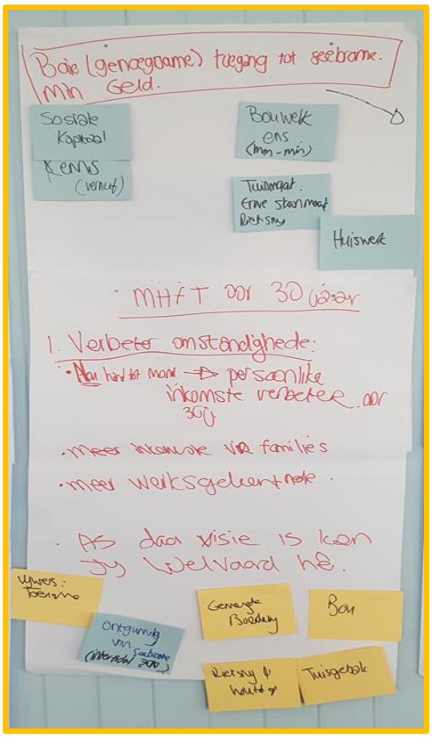

Figure 5.6. Sufficient access to Marine resources/low disposable income scenario: Blue cards depicts current and potential activities that participants engage in the present time. The red text reflects the town in 30 years, and yellow cards indicate future livelihood activities that could be engaged in

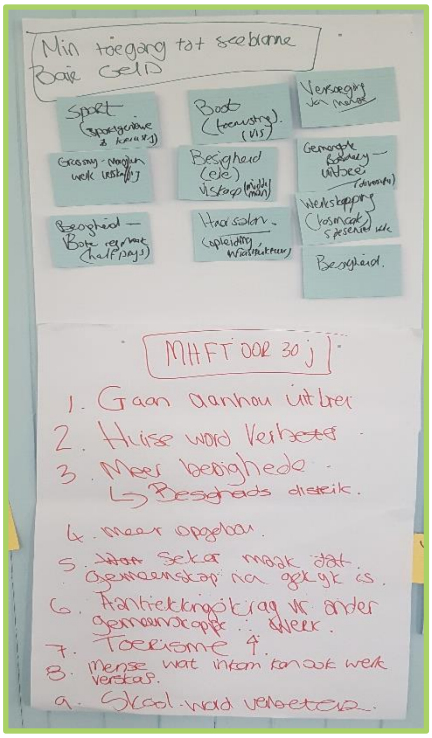

Figure 5.7. Insufficient access to Marine resources/Sufficient disposable income scenario: Blue cards depict future livelihood activities that participant could engage them. The red text reflects the town in 30 years

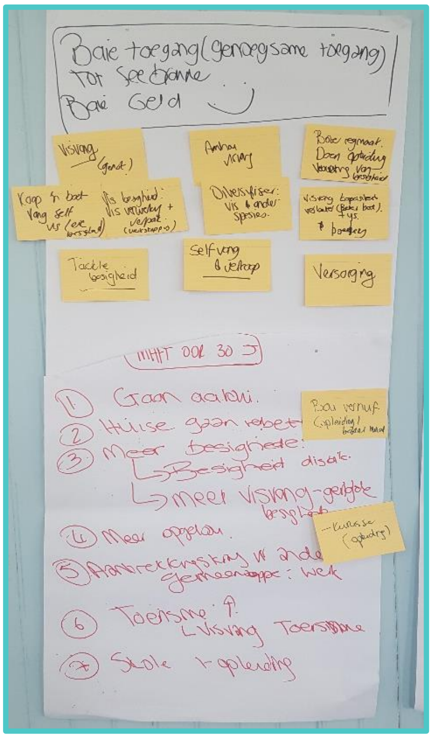

Figure 5.8. Sufficient access to Marine resources/Sufficient disposable income scenario: Yellow cards depict future livelihood activities that participant could engage them. The red text reflects the town in 30 years

5.3.3. Workshop Three

The main aim of Workshop Three was to complete and populate the BBN Conditional Probability Tables (CPTs) as detailed in Chapter Four. The workshop also provided the opportunity to revisit any issues that required clarification and for the researcher to provide feedback on the progress being made in the overall research process.

5.3.4. Desktop work: final scenario construction

The fisher's scenario stories have been 'backdropped' with predictions regarding fish stock availability and changes as well as general climate predictions (see figures 5.3 and 5.9). The decision to include these two drivers is based on the BBN model outputs where the importance of climate variability and change driver was highlighted. The impact of resource scarcity was also discussed extensively by fishers throughout the workshopping process and the decision made to include this driver was made as the fishery is already experiencing resource shortage and is in effect operating in a state of resource scarcity. The following section presents the background information future changes in KDFs not included in the participant's stories and that have been integrated in the final stories.

5.3.4.1. Additional background: changes in weather patterns in the southern Cape

While fishers often attribute the current and pervasive failures of kob catches on drivers like policy and regulation, lack of funds (capital) and the impacts of the inshore trawl fishery in the area; the underlying cause appears to be kob scarcity. These shortages are most likely due to a combination of the effects of anthropogenic climate change and fishery impacts (specifically historical over-exploitation) which place severe pressure on the southern Benguela including the distributions of marine species (Blamey et al., 2015; Currie, 2017). Discussions with fishers throughout the workshopping process highlight the importance of weather on their ability to proceed to sea. Fishers specifically note a change to long-established weather patterns, especially when considering wind and sea current (Ward, 2018; Lyttle, 2019). The analyses in Chapter Four show that although some drivers (like climate variability and change) are not always 'top of mind', it does not mean that the effect of those drivers is not felt and that they do not exist. The BBN outputs (see Chapter Four), highlight the importance of climate drivers in this fishery system.

Status of climate variability/change in South Africa and the southern Cape

South Africa's climate is regulated by the ocean on three sides of the country. The southern coast is warm-temperate with varying rainfall regimes that include summer, winter and bimodal peaks in rainfall (DEA, 2013). For South Africa, the mean annual temperature in South Africa has risen at least 1.5 times more than the observed global average of 0.65˚C between 1960 and 2010. Although an overall increase in the frequency of extreme rainfall events has occurred over the same period (Ziervogel et al., 2014) with LTAS model outputs indicating a significant increase in future flood risk (DEA, 2013); trends in rainfall indices show a decrease in the number of rain days which could indicate a drying trend (MacKellar et al., 2014). Recent research into rainfall and temperature trends in the southern Cape by Ward (2018) found no clear trends in time for changes in rainfall amounts although high variability has been noted. Farmers interviewed have, however, indicated that while the amount of rain has not changed significantly, the rainfall patterns had been changing over time. The coastal temperature in the area displays more variability than that interior temperatures. There were more prevalent outliers for warmer temperatures, particularly in austral winter. These observed trends are consistent with longer-term predictions for the Western Cape where hotter, drier conditions are expected as climate change advances (MacKellar et al., 2014).

Climate and the marine environment

The South African coastline, one of the most naturally variable in the world, is approximately 3000 km long and incorporates ecoregions ranging from cool-temperate on the west coast, warm-temperate on the south coast to subtropical on the east coast (Mead et al., 2013). The continental shelf widens west of East London and east of Cape Point to form the roughly triangular Agulhas bank, which extends about 250 km (135 nm) off the coast of Cape Infanta (Gammage, 2015). Spatial and temporal changes in the Southern Benguela ecosystem (described in more detail in Chapter One) are attributed to various natural and anthropogenic drivers in the system such as biotic processes, changes in structural habitat, climate change and fishing (Blamey et al., 2015).

The research area and coupled fishing activities of fishers are found in the inshore of part of the Agulhas Bank. The hydrology of the Agulhas bank is primarily driven by the wind regime, the Agulhas current running along the shelf break and seasonal overturn of shelf waters (Jarre et al., 2015). Analysis by Rouault et al. (2009) indicates a strengthening of the Agulhas current's flow over the past 25 years, which results in warmer offshore water. Rouault et al. (2010) confirmed offshore warming and inshore cooling; corroborating findings by Roy et al. (2007). Blamey et al. (2015) however, indicate a consistent warming trend across all seasons with general warming most distinctive in the early southern hemisphere summer months. There is more disagreement between signals of different datasets for the Agulhas Bank than for the other subsystems of the Benguela (Jarre et al., 2015). The exact the interplay and trends concerning sea temperature are difficult to determine for the greater Agulhas Bank (Lyttle, 2018; Ward, 2018).

Two distinct ecosystem regime shifts, the 1960s and mid-1990s/early 2000s, have been identified and verified (Howard et al., 2007; Blamey et al., 2012), with Ward (2018) finding evidence of a potential third in the more recent analysis. Research into historical and prevailing wind regimes at the scale of the southern Cape has shown no significant and discernible trends at the small scale (near shore) (Ward, 2018) and thus accurate future predictions are problematic. However, Ward (2018) finds that off-shore wind drivers show more evident trends of increased wind speeds over time at the shelf scale. Lyttle (2019) show that this trend of increase in offshore winds influences swell which results in increased in wave heights on the inshore scale of the southern Cape, although both these analyses are dependent on National Centre for Environmental Prediction (NCEP) wind data.

5.3.4.2. Additional background: changes in the fishery system

Fishers identified changes in the biophysical systems as one of the four KDFs in their system. As this system is currently operating in a state of resource scarcity (Gammage & Martins, unpublished data; Martins et al., in review; Duggan, 2012; Gammage, 2015; Currie, 2017; Gammage et al., 2017a; Chapter Three), the focus of the biophysical KDF for the final scenario story will be placed on the current and potential future status of fishery resources in this area.

Status of fishery resources in the southern Cape: present day

Climate change and variability have direct and indirect impacts on marine resources. Direct impacts include changes in physiology (specifically growth and reproductive capacity), mortality, distribution and behaviour. Changes in productivity, structure, and composition of the marine ecosystems on which fish are dependent for food are indirect impacts. Fishing effort, biological interactions, and non-climatic environmental factors may also have similar effects (Brander, 2010; Hollowed et al., 2013).

Changes in species abundance and distribution are mechanisms by which fisheries resources in an area can change over time. It has, to date been difficult to determine linefish stock levels in South Africa accurately, but particularly at the scale at which the linefishery in the southern Cape operate (see Blamey et al., 2015). However, for this scenario exercise, we can assume some changes on the small-scale, based on larger scale change provided by previous research in the southern Benguela and Agulhas bank to establish potential future systems states (notably Blamey et al., 2015). For these scenarios, it is only necessary to ascertain what changes fish stocks may undergo in the broadest term. A synthesis of ecosystem change seen in the southern Benguela by Blamey et al. (2015) describe changes seen in the southern Benguela ecosystem, whilst Currie (2017) provides a comparison of historical baseline data from the demersal trawl fishery on the Agulhas bank to a data from a resurvey in three locations (Cape Infanta, Mossel Bay and Bird Island). Currie's research provides valuable insights into how fish assemblages in some species key to the linefishery in the area have changed regarding species abundance and distribution over the past 100 years and allow us to speculate on potential future trends (in the broadest terms).

Changes in the distribution of key fish species on the Agulhas bank

Changes in marine distributions for the southern Benguela are well-documented, although most of the knowledge of the physical and ecosystem change stems from the west coast of South Africa resulting in a poor understanding of the system dynamics on the Agulhas bank, particularly at small, localised scales (Blamey et al., 2015; Watermeyer et al., 2016; Currie, 2017). One of the most important distribution shifts seen in the southern

Benguela is the southward and eastward shift in distribution from the west coast to the Agulhas bank of Sardine (*Sardinops sagax*) and Anchovy (*Engraulis encrasicolus)* (Van der Lingen et al., 2002; Fairweather et al., 2006). As sardine and anchovy are important prey fish, it is thought that this shift may have had an impact on other ecosystem parts including distribution or abundance of fish and squid. Watermeyer et al. (2016) found evidence of increased catch proportions of amongst others, squid (*Loligo reynaudii*); kingklip (*Genypterus capensis),* round herring (*Etrumeus whiteheadi*) and chub mackerel (*Scomber japonicus*) east of 20°E (east of Cape Agulhas) following the documented shifts in sardine and anchovy distribution. Other significant eastward distributional shifts noted include west coast rock lobster (*Jasus lalandii*) (Blamey et al., 2012) and the eastward range expansion of kelp (*Ecklonia maxima)* (Bolton et al., 2012).

Changes in abundance of key fish species on the Agulhas bank

The analysis by Currie (2017) includes changes in abundance for fish species found on the Agulhas Bank. Specifically, declines in the kob abundance seen in the area are severe. Whereas kob catches in trawls were dominant (up to 25% of the catch) in the 1903/1904 baseline, they were absent in the repeat surveys of 2015. This evidence is in support of other studies (Griffiths, 1997, 2000) and fishers' accounts (Gammage, 2015; Gammage et al., 2017a; Martins et al., in review). Currie (2017) shows a substantial decrease in the kob catches in the inshore trawl in the first half of the 20th century which is likely indicative of early fishing pressure and resulted in the removed a sizable proportion of the pre-disturbed populations of kob (Currie 2017). This coupled with more significant pressure in the mid-1960s, and early 1980s has likely contributed to the severe depletion of stocks experienced in the present time. Other commercially exploitable species from the area which show declining abundance include silvers/carpenter which was found to be 0.1% of historical abundance and white stumpnose, which was found to be at 0.1% of historical abundance (Currie, 2017).

At the same time, the same comparative worked carried out by Currie (2017) has noted an increase in abundance in among others, gurnards (*Chelidonichthys spp.)* and horse mackerel (*Trachurus capensis)*. However, these species present little opportunity to the linefishery in its current format. Currie (2017) research carried out in the context of inshore trawl and did not necessarily overlap with the linefishery in the same area; however, conflict between these fisheries is well-documented; line fishers accuse inshore trawl of increasingly encroaching on their fishing grounds, and due to interconnectedness of the habitats in the southern Cape/Agulhas bank ecosystem, we can assume that ecological niche replacement has taken place in the inshore part of ecosystem.

Fishery resources in the southern Cape: potential futures

It is likely that the biggest drivers of change in this marine ecosystem will be fishing pressure and the effects of large-scale, long-term climate variability and change. While the examples of distributions shift and changes in abundance highlighted above are by no means exhaustive, it illustrates the current state of system flux and underscores the problem of resource scarcity regularly highlighted by fishers. Regarding fishing pressure on inshore marine species, even though inshore trawl effort has significantly declined in recent years, the after-effects of long-term trawling may have resulted in irreversible damage to traditional stocks. Historical, long-term trawling on the Agulhas bank has likely led to a reduction in habitat complexity. Modified energy flow pathways would benefit specific taxa but negatively affect others. Taxa that have declined on the Agulhas bank are associated with reef habitats while species that are displaying an increase prefer soft substrates or inhabit both hard and soft benthic substances (Currie, 2017). The survey sites used by Currie (2017) have remained commercial trawling grounds since the initial historical surveys took place and thus reef-like habitats, consolidated substrates structure forming communities that may have been present historically have likely been removed or degraded by trawling. This seems to have promoted a change from partially-reef associated assemblages to catch compositions that are dominated by taxa associated with unconsolidated benthic habitats. This support the belief that extensive trawl activity on the inshore trawl grounds bank has modified benthic habitats. If this is correct and the sediment structure has been modified by trawling, the benthic habitat, together with the part of the fishing community that is dependent on it, may be permanently altered and fail to recover, even if fishing were stopped (Currie 2017).

However, it remains challenging to predict marine ecosystem and fisheries responses to climate change accurately. Complex species distribution relationships, variation in abundance, the impact of overfishing couples with other system stressors create knowledge gaps that are difficult to circumvent. Effective modelling is limited by incomplete information on the functioning of biological resources and the physical changes in the oceans. Moreover, there is also much uncertainty about the future impacts of climate change, specifically at local scales such as the southern Cape (Ortega-Cisneros et al., 2017, 2018).

As described, several marine species have already shifted their geographic ranges. Regarding fish species' general response to warming, a (south) westward migration of warm temperate species such as Geelbek (or Cape salmon) (*Atractoscion aequidens*) could occur. The temperate regions may also contract, with south coast species potentially affected by increased upwelling, related temperature extremes, reduction in runoff and habitat loss which will result in a decrease in subtropical species diversity and abundance. Extreme rainfall and dry spells, together with sea level rise could result in the loss of nursery habitats. The positive impacts of increased rainfall could be offset by seasonal shifts that may confuse behavioural cues at critical life-history stages such as spawning and migration. For example, changes in freshwater flow, sea surface temperature, and turbidity may impact the squid fishery and endemic subtropical linefish such as white Steenbras (*Lithognathus lithognathus*).

For the Agulhas bank, if populations are pressured to move due to anthropogenic warming, some of these population may be facing a dead end. If the bank were to experience a net-warming effect, cooler-water species could move towards and into the upwelling ecosystem of the west coast, where cool shelf and inshore waters might be maintained (Lamont et al., 2018). It is, however, likely that if the highly-productive west-coast subsystem suits their habitat requirements, they already occur there. The southern edge of the Agulhas Bank together will serve to limit the possible poleward expansion of demersal and pelagic species and could signify a potential dead-end if changing environments force species to migrate southward (e.g. Currie, 2017). However, warm temperate species which could migrate south (east)ward due to warming could fill the niche created by the loss of the colder water species, presenting line fishers with alternative commercially exploitable species which would not necessarily necessitate a drastic shift in fishery or strategy (Blamey et al., 2015).

In another scenario, the bottom waters of the Agulhas Bank may cool due to an increase in coastal upwelling (Lamont et al., 2018) and/or greater shelf-edge upwelling, which we would expect to be driven by variability of the Agulhas Current (Rouault et al., 2009; Beal & Elipot, 2016). The likely impact would be on the cold eastern ridge; (Swart & Largier, 1987; Lutjeharms et al., 2000) and inshore parts of the bank through increased coastal upwelling. Species wishing to avoid the colder waters may move further east, towards the warmer bottom waters found near the slightly warmer inshore areas between Mossel Bay and Cape Agulhas. This area is narrow when compared to the greater (but cooler) Agulhas Bank and suggest that these distribution changes could result in the reduction of the geographic spread of the population. Furthermore, the increase in upwelling would likely increase productivity in certain areas which would cause further changes in the ecosystem (Roberts 2005). Along with the cooling trend, there would be potential for species such as yellowtail (*Seriola lalandii*) to migrate eastward into the fishing grounds of the southern Cape linefishery (Blamey et al., 2015), offering a potentially viable alternate linefish species to target.

5.3.4.3. Summary of scenarios derived from additional drivers

Figure 5.9 shows four possible scenarios based on current and potential changes in species distribution and abundance patterns on the Agulhas Bank. Climatic drivers have already been incorporated in that that fish stocks could respond to warming/cooling of the Agulhas Bank. Conversely, warming or cooling seen in the Agulhas bank will likely be a function of larger scale climate changes, and thus it becomes unnecessary to take specific climatic drivers into account for these scenarios.

Linefish (specifically kob and silvers) catches continue to decline, no commercially viable species take up the niche left by the decline in the main target species. Fishers keep targeting kob, silvers, sharks and other red (reef) fish when available. Fishers forced to diversify outside fishery to sustain livelihoods. No significant/observable cooling or warming trend on the Agulhas bank seen.

Current situation in the southern Cape linefishery continues as is - kob, silver and shark catches are landed when available. Although catches remain relatively low, fishers catch enough fish to 'get by' and whilst they engage in outside livelihood activities to supplement income; the 'die-hard' fishers do not permanently diversify out of the fishery. No significant/observable cooling or warming trend on the Agulhas bank seen.

Cooling on the Agulhas bank with increased upwelling sees eastward species distribution shift of species such as yellowtail, traditionally caught between Cape Point and Cape Infanta. The may also be an increase in offshore pelagic fish species. Should abundance of species such as Yellowtail be an hindrance to achieving a sustainable (line)fish derived income, fishers may be forced to diversify outside the linefishery by getting involved in the growing pelagic fishery in the area (crew on trawlers, employment at processing plants).

Warming in Agulhas bank triggers an south (west)ward migration of temperate fish species from the Garden Route and eastern Cape coastal waters to colder water. Warm temperate species (such as Cape salmon), migrate south(east) ward and fill niche left by loss of the temperate species. Line fishers are able to easily change their target species without major shifts in strategy and fishery structure.

Figure 5.9. Four future scenarios for the linefishery based on current and possible future species distribution and abundance changes in the Agulhas Bank. Warming and cooling trends in the Agulhas bank have been incorporated

5.4. Providing feedback to participants

The resource (pamphlet) – produced in Afrikaans and English - as part of the feedback is shown in Figure 5.10.

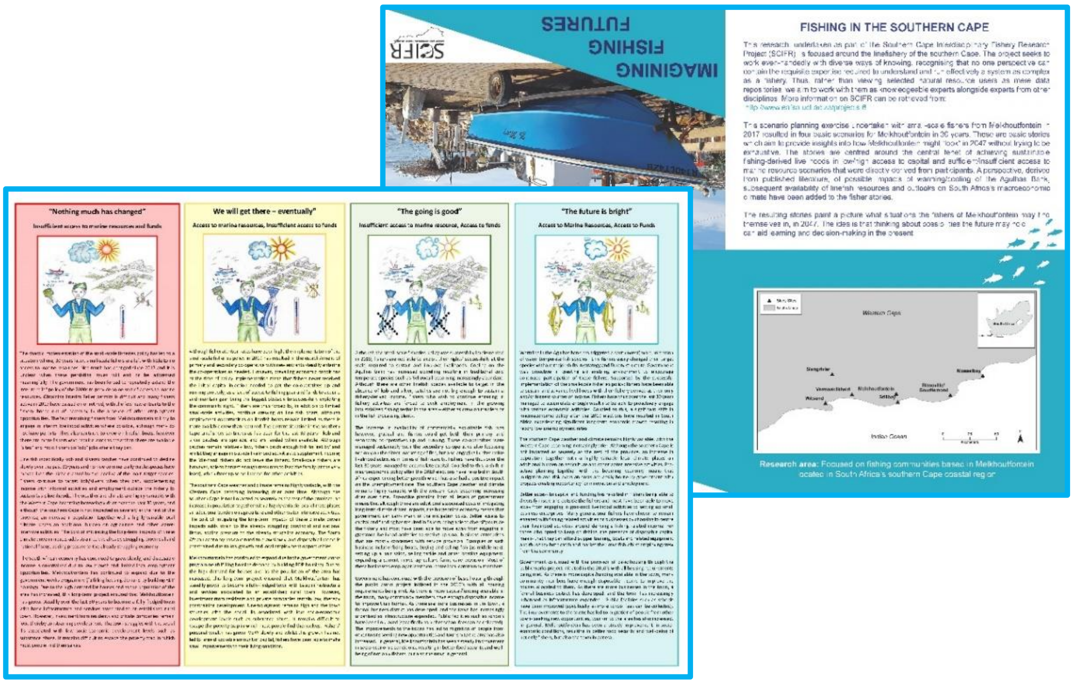

Figure 5.10. The pamphlet produced for the feedback session (presented folded twice over, i.e. A6 format). The pamphlet was made available both in English and Afrikaans

The timing for the feedback was not ideal - the fishing season had already commenced and those participants not crewing on linefishery boats from Still Bay were engaging with alternative livelihood activities - which impeded their participation in feedbacks interactions. Considering the time taken to develop the stories and the pamphlet, there was limited opportunity to present feedback within the timeframe of the project. Regardless, fishers who were available were engaged one-on-one at their homes and personally addressed pamphlets were distributed to those not in attendance by the local fishing association's chairman. Fishers did not immediately engage directly with the material in the pamphlet and instead preferred to speak to the researcher about other current issues in the fishery. Due to the length of the stories, it was expected that they would engage with the stories and reflect on them in their own time. This process will be followed through upon completion of this research. Importantly, those who were available were grateful that time was taken to provide feedback and took the opportunity to speak about 'top of mind' issues such as the progress of the SSFP implementation and related plans instead of the scenario stories. The intention is to produce more feedback pamphlets covering other aspects of this project and provide more comprehensive feedback in the first half of 2019. Those additional feedback sessions will present opportunities to revisit the scenario stories.

5.5. Scenario planning process outputs

While there are distinct differences in all the scenario stories developed by the participants, there was also a fair amount of repetition between them, specifically with conditions that they felt would not change between scenarios, for example participants indicated that government housing projects would continue regardless of the scenario space and interactions between KDFs.

5.5.1. Scenario Stories from the participants

"Nothing much has changed" - Insufficient access to marine resources /low disposable income

Participants agreed that this scenario space, where there is little access to marine resources and low levels of disposable income, most closely resembled the present situation. As a starting point, general discussions focussed on the difficulties that exist in an income-constrained environment. Notably, participants raised and reiterated the point that to make money, one must have money. Next, livelihood activities that could be undertaken in a resource-constrained environment were discussed. Most of the activities highlighted were activities that participants are currently engaged with. To promote the forward-thinking approach required for scenario construction, participants were particularly asked to consider what other activities they could presently consider engaging in.

The second part of the discussion required participants to reflect on descriptions of what Melkhoutfontein would "look like" in 30 years in this scenario space (Figure 5.6). When considering future Melkhoutfontein, participants foresaw that a current national government housing project would be ongoing. By implication, the town's infrastructure regarding housing would be improved from the current situation. Melkhoutfontein would be a fully-fledged town with improved amenities and services. Inadequate disposable income, however, means that people remain stuck in similar cycles engaging in similar tasks as in the present. The sentiment was that people would survive, but life would not have changed much. Participants did, however, indicate that alternative livelihood opportunities would manifest over time and that wealth could be built across generations (on longer time scales).

"We will get there – eventually" – Sufficient access to Marine resources/low disposable income

This scenario discussion (Figure 5.7) took place along the same lines like that for the first scenario space. This could be because, for some participants, this scenario closely resembled the present situation. Livelihood activities in this scenario space closely resembled those in the first scenario. Ultimately, the sentiments expressed echoed those by participants at the start of the workshop when they indicated that one needs money to make money by reiterating that insufficient disposable income and the inability to access a large amount of capital was the most significant barrier that exists for them. To earn a sustainable fishery derived income, fishers need not only to have enough capital for day-to-day running expenses but also need to access capital to buy equipment and training. As with the Bayesian network development process, participants highlighted the need for money to access skills training (such as skipper training).

Participants foresaw that the development trajectory for Melkhoutfontein would continue along the same lines in the first scenario space. Infrastructure development, managed by central government, would continue independently from community socio-economic circumstance. Importantly, fishers emphasised again that they would be able to accumulate personal wealth, albeit over a much more extended period. One of the participants pertinently noted that "if you have a vision, you can have wealth".

"The going is good" - Insufficient access to marine resources /high disposable income

Discussions around this scenario space (Figure 5.8) were much more optimistic, and after some initial hesitation, discussions were quite animated. To prompt the conversation and ensure even participation, each participant was asked to identify some livelihood activities they would choose to engage in if money was not a problem (bearing in mind that fishing activities were not an option). Activities identified were wide-ranging. Notably, all participants indicated they would own their own business while creating employment opportunities. Overall community upliftment was a common theme among participants. While all the participants identified service-oriented businesses far removed from any maritime related activity, a small number of participants also indicated they would capitalise current skillsets by engaging in fishing-related services industry such as selling tackle and repairing boats. Governmental housing projects would be ongoing. More disposable income means more opportunities for the town's inhabitants and with it, a general and accelerated improvement in socio-economic conditions for fishers and the wider community.

"The future is bright" - Sufficient access to marine resources /High disposable income

The discussion for this scenario space was the shortest when compared to the other scenario spaces (Figure 5.9). This was because there was a fair amount of repetition from the previous scenario spaces and participants were becoming fatigued. When considering livelihood activities in this scenario space, all but one of the participants indicated that they would revert to fishing as a principal livelihood activity. The ensuing discussion highlighted that sustaining a livelihood by harvesting marine resources was dependent on biophysical subsystem conditions. To guarantee livelihoods, many participants indicated that they would still choose to engage in the livelihood activities identified previously. This would be achieved by assuming an oversight role in the business that allowed them to go fishing without detriment to the business when they could do so. The development trajectory for Melkhoutfontein remained mostly unchanged from the previous scenario space.

5.5.2. Final Scenario Stories

Since it was not possible to build complete normative scenarios based solely of participants' input, it was necessary to synthesise research and expert knowledge together with participants' input to build holistic stories that speak to all the KDFs identified. This has been done by briefly examining the current system state, predictions (see Section 5.3) and other scenarios (Long-Term Adaptation Scenarios for South Africa (LTAS), the Indlulamithi South African scenarios[16] and the Vumalena land scenarios[17]) to create final scenario stories that can be somewhat useful to the small-scale fishers of the southern Cape as a product and learning tool.

5.5.2.1. The starting point

It is 2018, and the Small-Scale Fisheries Policy is slowly and systematically being implemented throughout coastal communities in South Africa. Fishers are optimistic about the possibilities that the successful implementation of the policy will mean for them and their communities. The opportunity to participate in a co-operative and directly benefit from the sale of the marine species and other livelihood activities managed by the co-operative pose an opportunity for the promotion and cultivation of more sustainable livelihoods enabling them to, not only grow personal wealth but also for the overall improvement of Melkhoutfontein.

The present-day situation finds fishers with limited access to marine resources and little to no disposable income. Most small-scale fishers act as crew on linefishery boats. The demand for 'a site' on a boat is high as the demand

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[16] The Indlulamithi South Africa Scenarios 2030 is a multi-stakeholder, research-driven initiative that seeks to re-invigorate our search, as a nation, for ways to create a society where all people experience a sense of belonging and solidarity. Three scenarios were developed as a tool to draw a wide range of stakeholders into a dialogue that will help them understand the country's options for building an inclusive society (http://sascenarios2030.co.za/)

[17] The Vumalena land reform scenarios are four scenarios for land reform in South Africa which outlines what could happen in South Africa what could take place in the context of South African land reform by 2030 (https://www.landreformfutures.org/)

for crew has steadily become less as skippers/commercial rights holders leave the fishery. The implementation of the small-scale fisheries policy has also created some conflict amongst skippers and crew with some small-scale fishers losing their 'site' on boats just because their names appear on the provisional list of verified small-scale fishers. Small-scale fishers in the community do not currently hold Interim Relief rights with access to fish in the river also blocked by regulation. Although fishers are optimistic about the policy and its implementation, there is also much uncertainty about the future. Most of this uncertainty is around the basket of species that will be allocated as part of the community right or co-operative. Implementation timelines are also uncertain, and many deadlines and implementation targets already being delayed. Conditions in the biophysical environment are also highly variable and not optimal. Fishers are only able to fish a couple of days a month as sea days have become scarce. Sea surface temperature, wind direction and strength as well as current direction and strength are not within the optimal ranges.

The present economic conditions mean that employment is scarce, and living is expensive. Fishing is lucrative when the fish bite – but even when fishers manage to fish, catches are not plentiful. It is not entirely clear why the kob has become so scarce although the activities of the Inshore Trawl sector are thought by many to play a vital role. In the meantime, fishers engage in a variety of alternative livelihood activities. They do not make much money, and although they struggle to make ends meet, they do manage to get by. Current livelihood activities are wide-ranging with fishers drawing on their current, often limited, skillsets. Activities include the gathering and selling of firewood, gardening, reed harvesting, housework and building labour. Figure 5.11 presents a schematic of these broad 'starting point' conditions.

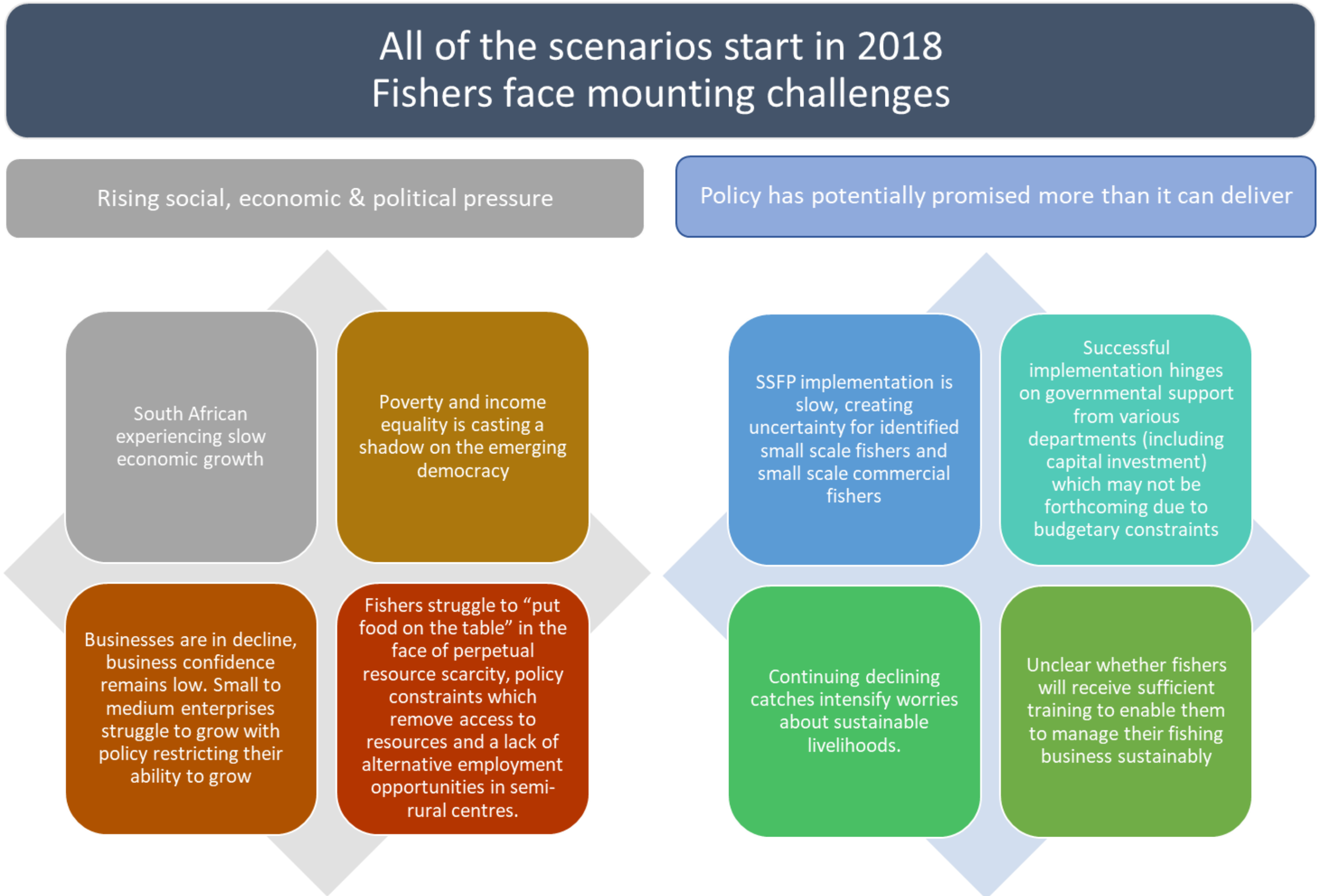


Figure 5.11. Starting point conditions (background) information for all the scenario stories. This background information is based on information of the macro system as it stands today from the Indlumamithi South African Scenarios (http://sascenarios2030.co.za/), the Vumelana land scenarios (https://www.landreformfutures.org/) and previous research into this fishery

5.5.2.2. Final integrated scenario stories

The final scenario stories produced to incorporate the crucial elements from the fishers' stories and the two additional KDFs that were included (Figure 5.3) and assumed the same starting point conditions per Figure 5.11. These stories are brief and were written specifically for inclusion in the feedback pamphlet and are written as an informal narration of the situation Melkhoutfontein will find itself in 30 years.

a. Scenario 1 - "Nothing much has changed"

This is a story about limited opportunities in a resource-constrained environment where a broad set of circumstances severely limits economic growth on micro - and macro-scales. The chaotic implementation of the Small-Scale Fisheries Policy has led to a situation where, 30 years later, small-scale fishers are left with little to no access to marine resources. Not much has changed since 2017, and it is unclear when these persisting issues will end or be addressed meaningfully. The government has been forced to repeatedly extend the interim relief policy of the 2000s to provide some access to marine resources. Obtaining Interim Relief permits is difficult, and many fishers active in 2017 have passed on or retired, with the few new entrants to the fishery borne out of necessity in the absence of other employment opportunities. The few remaining fishers from Melkhoutfontein still try to engage in interim livelihood activities where possible, although many do not have permits. They also continue to crew on linefish boats. However, more fishers require work as crew than there are available 'sites' and most fishers do 'odd' jobs where they can.

Linefish (specifically kob and silvers) catches have continued to decline slowly over the past 30 years, and no new commercially viable species have moved into the niche created by the decline of the primary target species. Fishers continue to target kob/silvers when they can, supplementing income with informal activities and employment outside the fishery to sustain basic livelihoods. The weather and climate are highly variable, with the Western Cape becoming increasingly drier over the past 30 years, and although the southern Cape is not impacted as severely as the rest of the province, an increase in population together with a highly variable local climate places an additional burden on agriculture and other water-intensive activities. The cost of mitigating the long-term impacts of these climate-driven impacts adds strain to the already struggling provincial and national fiscus, adding pressure to the already struggling economy.

The South African economy has continued to grow slowly, and disposable income is constrained due to low growth and limited local employment opportunities. Melkhoutfontein has continued to expand due to the government works programme (fulfilling housing demand by building RDP housing[18]). Due to the high demand for houses and

[18] RDP housing is a commonly used term for social housing, provided by the South Africa government to poor households.

as the population of the area has increased, this long-term project ensured that Melkhoutfontein had grown steadily over the last 30 years to become a fully-fledged town with necessary infrastructure and services associated to an established rural town. However, investments from residents and private companies remain low, thereby constraining development. The town struggles with the social ills associated with low socio-economic development levels such as substance abuse. It remains challenging to escape the poverty trap in which most people find themselves. Figures 5.12 and 5.13 are graphical depictions of critical elements and features of the scenario story.

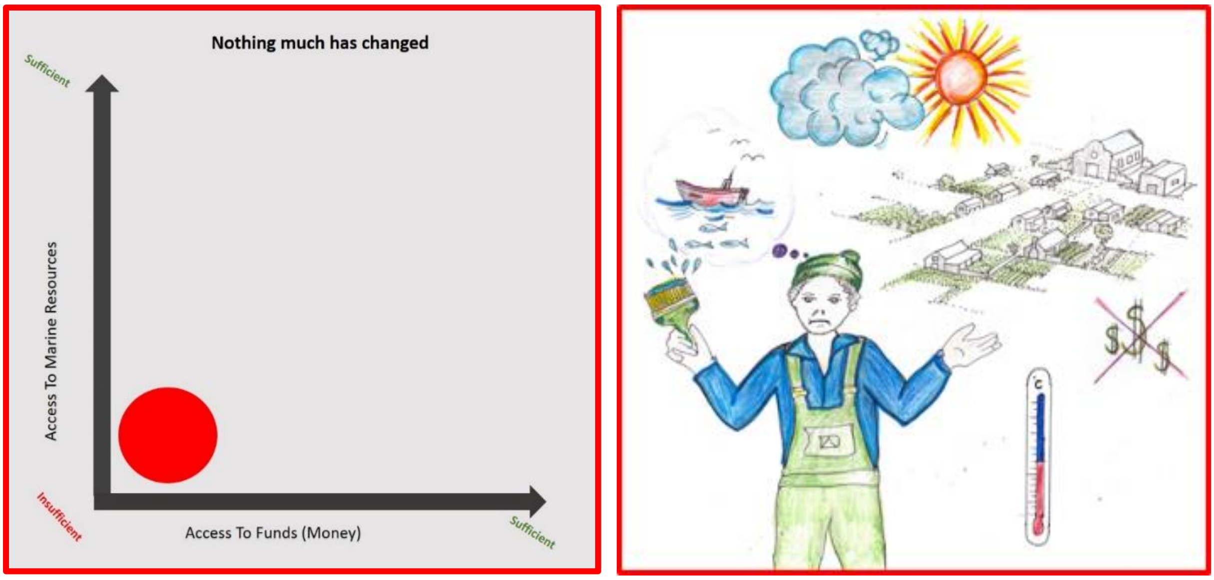
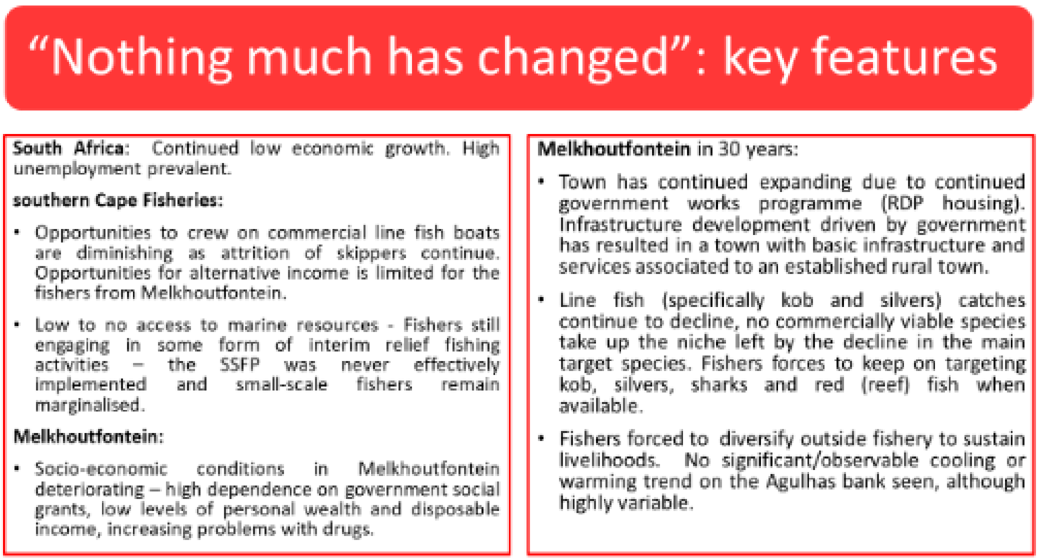


Figure 5.12. Conditions for the "Nothing much has changed" scenario story. The left panel schematically depicts the conditions under which the story plays out while the right panel draws the key elements of the story



"Nothing much has changed": key features

South Africa: Continued low economic growth. High unemployment prevalent.

southern Cape Fisheries:

- Opportunities to crew on commercial line fish boats are diminishing as attrition of skippers continue. Opportunities for alternative income is limited for the fishers from Melkhoutfontein.
- Low to no access to marine resources - Fishers still engaging in some form of interim relief fishing activities – the SSFP was never effectively implemented and small-scale fishers remain marginalised.

Melkhoutfontein:

- Socio-economic conditions in Melkhoutfontein deteriorating – high dependence on government social grants, low levels of personal wealth and disposable income, increasing problems with drugs.

Melkhoutfontein in 30 years:

- Town has continued expanding due to continued government works programme (RDP housing). Infrastructure development driven by government has resulted in a town with basic infrastructure and services associated to an established rural town.
- Line fish (specifically kob and silvers) catches continue to decline, no commercially viable species take up the niche left by the decline in the main target species. Fishers forces to keep on targeting kob, silvers, sharks and red (reef) fish when available.
- Fishers forced to diversify outside fishery to sustain livelihoods. No significant/observable cooling or warming trend on the Agulhas bank seen, although highly variable.

Figure 5.13. Bulleted list of the key features of the "Nothing much has changed" scenario story, as provided in the pamphlet

b. Scenario 2 - "We will get there –eventually"

This is a story about cautious optimism. Although fisher attrition rates have been high, the implementation of the small-scale fisheries policy in 2019 has resulted in the establishment of primary and secondary co-operative with new entrants steadily entering the co-operatives as needed. However, prevailing economic conditions at the time of policy implementation mean that fishers never received the initial capital injection needed to get the co-operatives up and running correctly; as a lack of access to fishing gear and funds to acquire and maintain gear being the biggest obstacle to successfully exploiting the community right. Fishers are thus forced to, in addition to limited, small-scale activities, continue crewing on commercial linefish boats, although employment opportunities on these boats remain limited as there is more available crew than required. The current situation in the southern Cape Linefishery continues as has been for the last 30 years - kob and silver catches are sporadic and are landed when available. Although catches remain relatively low, fishers catch enough fish to 'get by' and while they engage in outside livelihood activities to supplement income; the 'die-hard' fishers do not leave the fishery. Small-scale fishers are, however, able to harvest enough resources to feed the family (at the very least), which frees up some income for other activities.

The southern Cape weather and climate remain highly variable, with the Western Cape becoming increasing drier over time. Although the southern Cape is not impacted as severely as the rest of the province, an increase in population together with a highly variable local climate places an additional burden on agriculture and other water-intensive activities. The cost of mitigating the long-term impacts of these climate-driven impacts adds strain to the already struggling provincial and national fiscus, adding pressure to the already struggling economy. The South African economy has continued to grow slowly, and disposable income is constrained due to low growth and local employment opportunities.

Melkhoutfontein has continued to expand due to the government works programme (fulfilling housing demand by building RDP housing). Due to the high demand for houses and as the population of the area has increased, this long-term project ensured that Melkhoutfontein has steadily grown to become a fully-fledged town with necessary infrastructure and services associated to an established rural town. However, investments from residents and private companies remain low, thereby constraining development. Unemployment remains high, and the town struggles with the social ills associated with low socio-economic development levels such as substance abuse. It remains challenging to escape the poverty trap in which most people find themselves. Fishers' wealth has grown VERY slowly, and while this growth has not led to a sizeable disposable amount of capital, fishers have been able to make small improvements to their living condition. Figures 5.14 and 5.15 are graphical depictions of key elements and features of the scenario story.

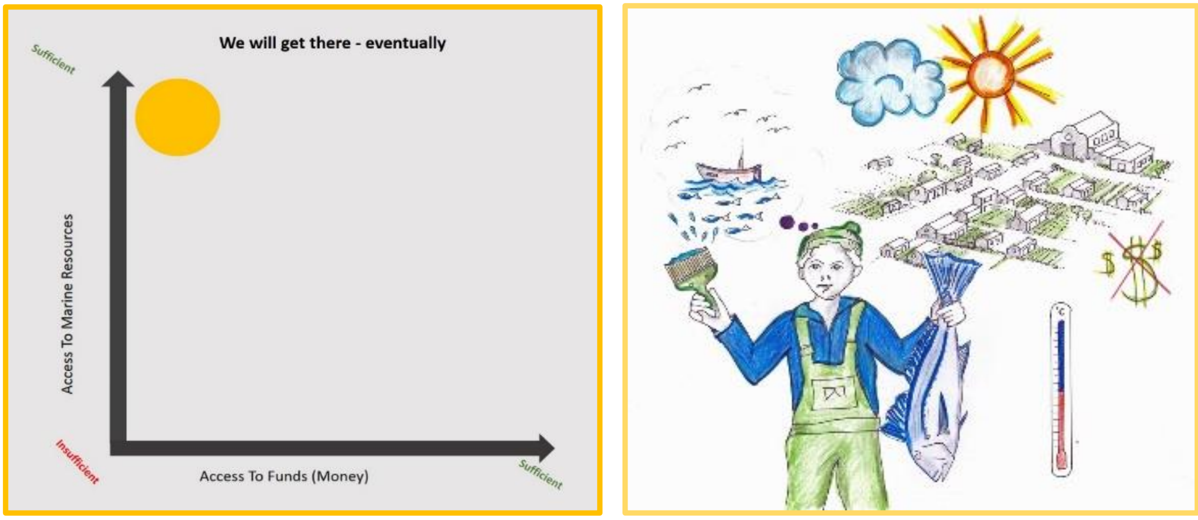


Figure 5.14. Conditions for the "We will get there - eventually" scenario story. The left panel schematically depicts the conditions under which the story plays out while the right panel draws the key elements of the story

"We will get there - eventually": key features

South Africa: Slow economic growth. High unemployment prevalent.

southern Cape fisheries:

- Adequate access to marine resources.
- Although fishers have access to resources, lack of access to capital means they are unable to invest in the required fishing gear (i.e .buy new boats to increase ranges etc). Fishers are however able to harvest enough linefish to establish a measure of food security.
- Fishers still have little personal wealth, but with food security improved, personal wealth can built up over long period of time.

Melkhoutfontein in 30 years:

- Town has continued expanding due to continued government works programme (RDP housing). Infrastructure development driven by government has resulted in a town with basic infrastructure and services associated to an established rural town.
- Current situation in the southern Cape linefishery continues as is - kob and silver catches are landed when available. Although catches remain relatively low, fishers catch enough fish to 'get by' and whilst they engage in outside livelihood activities to supplement income; the 'die-hard' fishers do not diversify out of the fishery. No significant/observable cooling or warming trend on the Agulhas bank seen. No significant/observable cooling or warming trend on the Agulhas, although highly variable.
- Fishers forced to diversify outside fishery to supplement fishery-derived income.

Figure 5.15. Bulleted list of the key features of the "We will get there- eventually" scenario story

c. Scenario 3 - "The going is good"

This is a story about growth and prosperity. Although the small-scale fisheries policy was successfully implemented in 2019, fishers are not able to exploit their rights' successfully at the scale required to sustain and improve livelihoods. Cooling on the Agulhas bank has increased upwelling resulting in traditional upwelling associated species such as Yellowtail becoming increasingly abundant. Although there are other linefish species available to target in the absence of kob and silver, catches are not big enough to sustain a fishery-derived income. Fishers who wish to continue engaging in fishery activities are forced to seek employment in the growing industrialised fishing sector in the area – either as crew on trawlers or in the fish processing plants.

The increase in availability of commercially exploitable fish was, however, gradual and fishers could get both their primary and secondary co-operatives up and running. These co-operatives were managed sustainably with the secondary co-operative also focussing not only on the direct marketing of fish but also engaging in alternative livelihood activities in times of fish scarcity. Fishers have thus over the last 30 years managed to accumulate capital. Coupled with this, a shift in macroeconomic policy after the 2019 elections have resulted in South Africa experiencing better growth which has also had a positive impact on the unemployment rate. The southern Cape weather and climate remain highly variable, with the western Cape becoming increasing drier over time. Pro-active planning from all levels of government means that although there are additional associated costs of mitigating long-term climate-driven impacts, the burgeoning economy means that the government can carry many of the mitigation costs. Better access to capital and funding has resulted in fishers being able to diversify outside the fishery, and most have been able to move away from engaging in grassroots livelihood activities to set up small business enterprises that are mostly concerned with service provision. Examples of such business include fixing boats, buying and selling fish (as middlemen), setting up a hair salon, selling tackle and other boating equipment, expanding a current mixed agriculture farm, care provision. Most of these businesses employ at least two-three local community members.

The government has continued with the provision of primary housing through the public works project initiated in the 2010s with all housing requirements being met. As there is more capital/funding available in the town, many community members have enough disposable income to improve their homes. As there are more businesses in the town, a formal business district has developed, and the town has increasingly urbanised as infrastructure expanded. Public facilities such as schools have been improved (specifically as higher school fees can be collected). The improvements to the town have led to the migration of people from other towns seeking new opportunities and tourism to the area has also increased. In general, Melkhoutfontein has seen a steady improvement in socio-economic conditions, resulting in better food security and well-being of not only fishers but also the town in general. Figures 5.16 and 5.17 are graphical depictions of key elements and features of the scenario story.

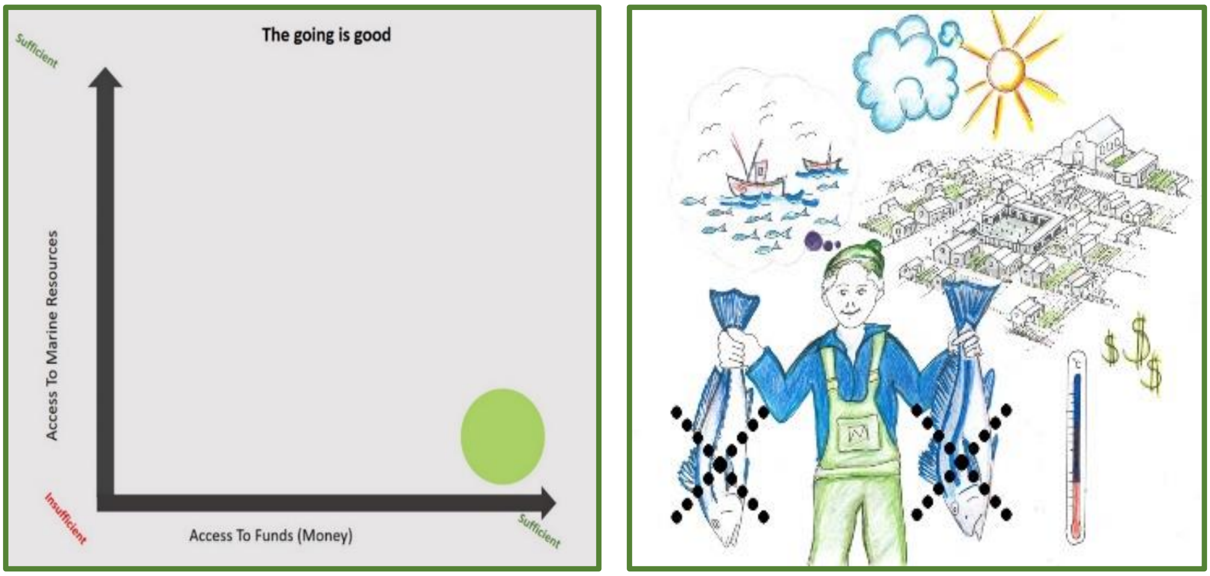


Figure 5.16. Conditions for the "The going is good" scenario story. The left panel schematically depicts the conditions under which the story plays out while the right panel draws the key elements of the story

"The going is good": key features

South Africa: Economic growth steadily improving. unemployment rate shows steady decline.

Southern Cape Fisheries:

- Low to no access to marine resources. Fishers have access to sufficient capital to engage in alternative livelihood activities.
- Socio-economic conditions in Melkhoutfontein show a marked improvement – fishers establish and manage small businesses which allow them to employ other community members which leads to an overall positive effect on the town's development.

Melkhoutfontein in 30 years:

- Town has continued expanding due to continued government works programme (RDP housing). Fishers who now have more access to capital are able to improve houses allocated to them. A formal business district develops in Melkhoutfontein. The town is increasingly urbanised are infrastructure expansion continues.

- Cooling on the Agulhas bank with increased upwelling sees an south (east) ward species distribution shift already observed continuing.
- Cold temperate species traditionally found between Cape Point and Cape Infanta such as Yellow Tail become increasingly abundant.
- Although offshore pelagic and demersal fishers are also more abundant, fishers are unable target these species, and if a sustainable linefish derived income is not possible (due to low linefish abundance), fishers who wish to continue in the fishing industry engage with the offshore fisheries by seeking employment as crew on trawlers or employment in processing plants.
- Alternatively, fishers forced to diversify outside fishery to sustain livelihoods, but employment opportunities are available due improved economy.

Figure 5.17. Bulleted list of the key features of the "The going is good" scenario story

d. Scenario 4 – "The future is bright"

This is a story about growth, prosperity and personal satisfaction. Warming in the Agulhas bank has triggered south (west) ward migration of warm temperate fish species. Line fishers easily changed their target species without significant shifts in strategy and fishery structure. The government was proactive in creating an enabling environment to encourage the continued participation of these fishers. Supported by the successful implementation of the small-scale fisheries policy; fishers have been able to sustain and advance livelihoods with their fishery derived as their only and most significant sources of income. Fishers have thus over the last 30 years managed to accumulate enough wealth to be able to engage with various economic activities proactively. Coupled with this, a significant shift in macroeconomic policy after the 2019 elections has resulted in South Africa experiencing significant long-term economic growth resulting in record low unemployment rates.

The southern Cape weather and climate remain highly variable, with the Western Cape province as a whole becoming increasingly drier. Although the southern Cape is not impacted as severely as the rest of the province, an increase in population together with a highly variable local climate places an additional burden on agriculture and other water-intensive activities. Pro-active planning together with the booming economy means that the government easily bears mitigation and risk aversion costs with projects creating an opportunity for innovation and employment.

Better access to capital and funding has resulted in fishers being able to diversify inside and outside the fishery and most have been able to move away from engaging in grassroots livelihood activities to set up small business enterprises. Many generational fishers have chosen to remain engaged with fishing-related activities or businesses by choosing to centre their livelihood activities around deriving a fishing-related income. For those who opted to keep on fishing, the presence of disposable capital means that they can afford skipper training, boats and related equipment and thus they both catch and market their fish while employing crew from the community.

The government has continued with the provision of primary housing through the public works project initiated in the 2010s with all housing requirements being met. As there is more capital/funding available in the town, many community members have enough disposable income to improve the houses allocated to them. As there are more businesses in the town, a formal business district has developed, and the town has increasingly urbanised as infrastructure expanded. Public facilities such as schools have been improved (specifically as more school fees can be collected). The improvements to the towns have led to the migration of people from other towns seeking new opportunities, tourism to the area has also increased. In general, Melkhoutfontein has seen a steady improvement in socio-economic conditions, resulting in better food security and well-being of not only fishers but also the town in general. Figures 5.18 and 5.19 are graphical depictions of key elements and features of the scenario story.

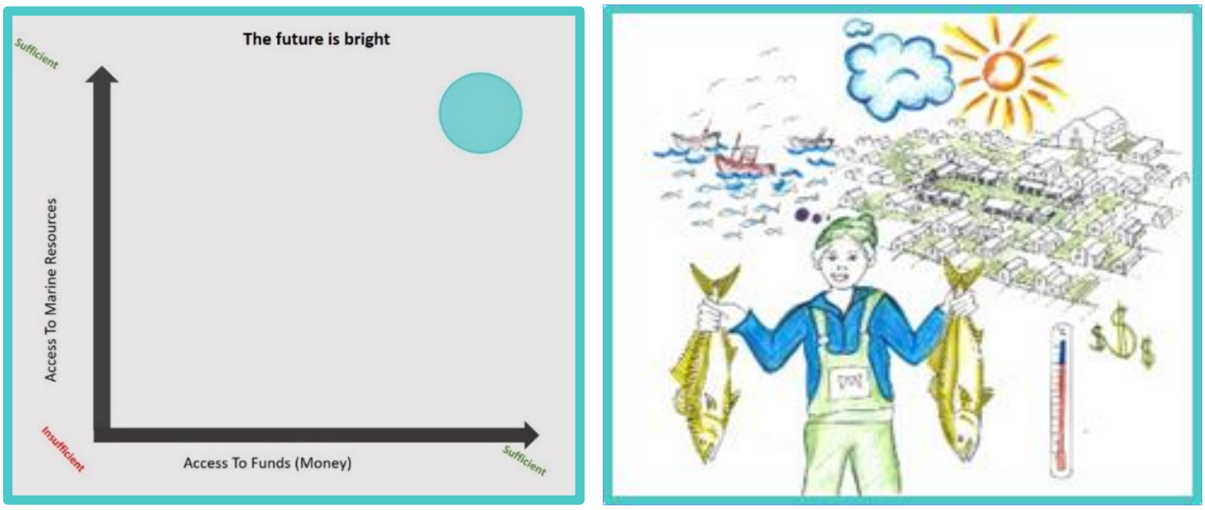


Figure 5.18. Conditions for the "The future is bright" scenario story. The left panel schematically depicts the conditions under which the story plays out while the right panel draws the key elements of the story

"The future is bright": key features

South Africa: Sustained long term economic growth. Unemployment at record low.

southern Cape Fisheries:

- Fishers have all the required access to marine resources and have more than enough financial capital and personal wealth at their disposal to invest in businesses and fishery if required.
- Socio-economic conditions in Melkhoutfontein show a marked improvement – fishers establish and manage small businesses which allow them to employ other community members which leads to an overall positive effect on the towns development.

Melkhoutfontein in 30 years:

- Town has continued expanding due to continued government works programme (RDP housing). Infrastructure development driven by government has resulted in a town with basic infrastructure and services associated to an established rural town.
- Warming in the Agulhas bank triggers an south (west)ward migration of warm temperate fish species such as Cape Salmon. Line fishers are able to easily change their target species without major shifts in strategy and fishery structure. Government is proactive in creating an enabling environment to encourage continued participation of these fishers.

Figure 5.19. Bulleted list of the key features of the "The future is bright" scenario story

5.6. Reflections on the scenario process and products

The motivation to use scenarios in this fishery was borne out of the realisation that fishers in the region are generally not well equipped to proactively deal with future change, based on previous research that found fishers' responses to change to bemostly reactive (see Gammage 2015 & Gammage et al. 2017b). Proactively responding to change is necessary if future livelihoods and wellbeing of fishers and their communities are to be secured (e.g. Hjerpe & Glaas, 2012). This is not only crucial for fishers, but also for long -term ecosystem sustainability. Interconnected challenges of poverty alleviation and ecosystem sustainability span across multiple scales and are arguably rooted in how societies understand their world and their interactions with natural systems (Folke et al., 2011). To achieve sustainability, it is increasingly clear that transformation of systems at various scales is required (Olsson et al., 2014; Pelling et al., 2015a; Galafassi et al., 2018). In this context, transformations are "understood as fundamental changes in and across various domains spanning from individuals' mindsets, attitudes, and belief to social norms and practices, to institutions and political systems" (Galafassi et al. 2018:1). To this end, not only are scenarios in a tool that assists fishers in dealing with system uncertainty but engagement with the process can be the catalyst for the change in mindset, attitudes and belief at the personal and household scale that is required for system transformation (Folke et al., 2010; Pelling & Manuel-Navarrete, 2011; Béné et al., 2012; Pelling et al., 2015a; Armitage et al., 2017). The aim of applying the tool in this context was thus multi-faceted – whilst aiming to produce a narrative that fishers, representing crew on southern Cape linefish boats, would find useful in developing their understanding of possible futures that may play out in their marine SES - the scenario development process also aimed to facilitate and prompt the type of learning and capacity building that is required to create small initial shifts in mindsets and attitude required for transformation.

For the analysis of the scenario as a tool, the validity of applying scenario techniques as a decision-making tool in the context of a small-scale fishery (as outlined in this chapter), has been evaluated. Specifically, this chapter has seeked to address Aim 4 (Section 1.9) through addressing the research questions (Section 1.10) that seek to identify the possible pathways for future development of Melkhoutfontein and evaluate the contribution the process makes to adaptive capacity through learning. As such, Section 5.6.1 presents a reflection on the process used to derive the scenario stories while Section 5.6.2 presents a reflection on the product (scenarios stories and feedback). The role of the scenario planning tool in the context of the entire scenario planning process across the thesis is discussed in Chapter Six.

5.6.1 Scenarios as a process

This scenario planning process was a prototyping exercise to establish if the process was applicable and useful in the context of this fishery system. Previous research has established how difficult it is for fishers to respond to changes in their system, with almost no-one proactively anticipating and adapting to change (Gammage et al. 2017b, Gammage 2015). Variations in the responses to change, together with the uncertainty that exists within this highly variable marine SES suggests that scenario planning may be more appropriate starting point for responding to change more proactively (e.g. Jarre et al., 2018). The prototyping exercise outlined in this thesis does not only seek to ascertain whether the tool is suitable for use in such participatory approaches at the small-scale with disenfranchised fishers but also to refine the methods and approaches for possible larger scale implementation in fishery systems.

One of the values of the process is the associated learning that can occur throughout such a participatory research process. This benefit is outlined extensively by various authors including van der Belt (2004); Gregory et al. (2012) and Tuler et al. (2017) who use perspectives from social learning and participatory modelling contexts. Facilitated learning can create a situation/space where knowledge, values, action and competencies can be developed in harmony to increase the capacity to build resilience to change. Learning amongst peers is believed to facilitate faster and deeper learning when compared to that received by top-down dissemination of information (Pelling et al., 2015b). For the fishers of Melkhoutfontein, the process created the space to reflect on processes not usually reflected on while forcing fishers to confront and consider more diverse issues at stake. This encouraged fishers to take a system view by seeing how different drivers interact and the consequences of these interactions (see Chapter Four) while considering how they may impact the future. While it is not possible to measure the learning that has taken place throughout the iterative process, it can safely be assumed that taking part in the process would have prompted learning for some, if not all the fishers. Importantly, this learning should also be viewed as a mechanism to start the process of building and fostering agency on a personal or household level. Important for this group of fishers, being able to engage with each other in a relaxed group setting offered the opportunity to exchange ideas and thoughts with each other in ways they are generally not able to do.

Scenarios are more robust when convened at a bigger scale (such as the scale of a fishery) with a stakeholder group that is heterogeneous with many diverse and opposing views which allow for common ground to be identified and expanded (Kahane, 2012). A conscious decision was made to convene this scenario at a small scale, with a homogenous group of fishers. Convening the scenario at the smaller scale was useful and necessary in that it created a safe space for a group of disenfranchised fishers to discuss and grapple with concepts they were unfamiliar with. As with the BBNs, the fishers at times struggled to engage with the more abstract nature of the exercises and thinking about Melkhoutfontein 30 years in the future was, for some, a challenging task. Should the scenario have been convened at the scale of the linefishery of the southern Cape, with a more diverse stakeholder group, this group of fishers may not have had the confidence to voice their opinions on contentious issues as they hold less power than other stakeholders in the fishery. In South Africa, small-scale fisheries have long remained marginalised with the balance of power favouring the more industrialised sectors (e.g. Sunde, 2004; Isaacs 2006; Sowman et al., 2011; 2014; Jarre et al., 2018). The marginalisation of small-scale fisheries and the role played by such fisheries in poverty alleviation and food security are well recognised (e.g. FAO 2012, 2016b & 2018). The publication of the 'voluntary guidelines for securing sustainable small-scale fisheries in the context of food security and poverty eradication' remains the first internationally agreed instrument dedicated entirely to small-scale fisheries to elevate the importance of this neglected and marginalised sector (FAO, 2015). For this research, the hypothesis is that by engaging in small-scale exercises such as these, fishers will be able to build capacity and knowledge required to confidently engage in a more extensive and likely more acrimonious larger scale scenario planning process. The process reveals a need to have more 'on the ground' interventions that can help facilitate learning and build capacity before engaging in any fully fledged (classic, multi-stakeholder) scenario planning process.

The difficulty with engaging with the future in the manner required has been compounded by the fact that participants did not want to engage with techniques/methods designed for thinking creatively about the future (such as the Lego building and newspaper headline exercises). An example of a TSP where these techniques have been successfully used is the Adaptation at Scale in Semi-Arid regions (ASSAR) project (http://www.assar.uct.ac.za). For the scenarios described in this thesis, adding predictions and research knowledge to the stories have mitigated the short-comings arising from the fact that the fishers' stories were lacking in detail. To build more vibrant and more complete scenarios, it became necessary to find ways to get around the unwillingness to engage on this level. A trained facilitator may have had more success in dealing with this problem and using one for an extensive, complicated scenario planning process may be an option to consider for future processes. The need for flexibility in the planning and execution of exercises and workshop programmes was reiterated throughout the research process as it remained necessary to structure and execute the programme in a manner with which fishers were always comfortable with. This is not only in keeping with the principles of inductive research (Cresswell & Plano Clark, 2011), but also because it is crucial for fishers to have the opportunity to influence the participatory research process (no matter how small) in a learning setting or process (Muro & Jeffrey, 2008).

5.6.2. Scenarios as a product

The final scenario stories are not all-encompassing – the Melkhoutfontein fishers tended to talk about the same topics they usually talk about with the solution for the future very much coupled to the problem experienced in the present. This led to fisher scenario stories which, while crucial to the process and the construction of the final stories, lacked the level of detail required to construct useful, normative system scenarios. This is consistent when comparing the weighted hierarchy and the BBN analysis in Chapter Four, which revealed that although 'top of mind' drivers discussed were regarded as the most important drivers in the weighted hierarchy, these drivers were ranked to be less critical when the questions posed were reframed through the BBN. The scale of the possibilities and their stories are also small, and apart from policy and governance issues, fishers did not consider interactions on the macroeconomic scale. However, as with the BBN, this result serves to highlight what fishers regard as necessary at the scale of the individual, household and community and provides insight to the values and knowledge they hold about the fishery system.

The creation of the scenario stories as a product creates the space to synthesise system knowledge and predictions into a narration of probable futures. This allows users to take the proverbial step back and take a wider system-view through the facilitation of systems-thinking which ultimately promotes complexity thinking (Biggs et al., 2015) as opposed to linear thought processes. Scenario stories highlight both opportunities and barriers created by change (SPACES, 2017; Galafassi et al., 2018). The current narratives of change in the southern Cape linefishers mostly highlight the negative aspects and impacts of these changes. It is, however, necessary to remember and highlight the opportunities that can be created by change. The 'future is bright' scenario where subtropical fish species fill the niche left by the migration of temperate species is an example of opportunities that could be created by substantial changes in the marine ecosystem. This highlights the need to make opportunities created by change to be more explicit in future scenario development processes while keeping an eye on potential barriers.

The final scenario stories provide some more insights into the scale, impacts of the uncertainty and associated risks that exist in the marine SES. Being able to see consequences of drivers and interactions between drivers weaved into an understandable reality may prompt fishers to consider different (less popular) drivers in their system view and eventually, decision-making. It remains crucial to bear in mind that the value of the scenario does not only lie in the knowledge co-creation and system view development (Peterson et al., 2003a; Oteros-Rozas et al., 2015), but also in the contribution that can ultimately be made to inform policy and management (Carpenter et al., 2006; Oteros-Rozas et al., 2015). To be able to inform policy and management, a sizeable full-scale scenario planning process will need to be convened at the scale of the linefishery in the southern Cape. These regional scenarios will not deal with fine-scale interactions in the same way that the final scenario stories have been able to (i.e. the town scale) and may result in scenarios which do not resonate with fishers at their scale of operation. Importantly, convening scenario planning exercises at various scales of operation and with overlapping stakeholders may provide an exciting opportunity to address the scale challenges experienced when dealing with change in marine SESs. There should be a more significant chance of success in addressing scale challenges when research/interventions are carried out at various scales of operation at the same time. This is not a new insight – authors such as Biggs et al. (2007) provide an extensive overview of methodology that could in principle be implemented to deal with multi-scale scenario planning. One would then be able to establish where the common ground (points of contact) are between the various scales, which can in turn, form the baseline from which interventions and further research can be carried out. It is important to note that, as discussed in Chapter Four, the scale does not necessarily have to relate only to spatial scales and it may in the future, instead be more useful to consider contextual scales, such as a community of fishers (see Gibson et al., 2000). Although not always ideal, the scenario planning process outlined in this chapter has shown that techniques and methods developed for large scales can successfully be adapted and adopted at the smallest of scales.

The scenarios also provide an important opportunity for fishers to be provided with research feedback and interact more directly with research results. Providing feedback in the context of such participatory approaches is crucial considering the nature of the research. The provision of feedback is also an essential contribution to learning for both fishers and researchers, a fact which is highlighted by authors such as Oteros-Rozas et al. (2015) in their review of 23 PSP papers (see Chapter Two, Section 2.5). The value of the feedback also lies in the trust building that has taken place as fishers were appreciative that the effort was made to produce a pamphlet and provide feedback. Producing the pamphlet also allowed the researcher to provide indirect feedback to fishers who were not available at the time. Considering that fishers often find it challenging to attend formal feedback sessions due to work and other commitments, producing resources which fishers can engage within their own time proved a more effective way to communicate these research results. Additional feedback session planned in the near future will provide an opportunity to further assess learning, capacity building and trust.

5.6.3. Across product and process: the value of the scenario-planning process so far

The fishers of Melkhoutfontein displayed a willingness to engage with the overall process by attending the workshops (especially those who attended all three workshops). As seen in the causal mapping and BBN development process, fishers sometimes struggle to engage with day-to-day challenges which threaten their livelihoods such as climate variability and change. It was expected that the same reticence would be seen when engaging with the scenario planning process. However, the process seems to have been less daunting than expected for fishers and it seems that considering problems that may or may not occur 30 -35 years into the future is less intimidating than dealing with immediate challenges. Fishers were hence more willing to engage with the overall process. As with the BBN development process, it was not always easy to facilitate the scenario planning process. Fishers are not used to being compelled to think about these problematic (sometimes emotive) issues in a formal setting such as a workshop. The concepts that were dealt with were unfamiliar and moving through the programme was painstaking at the best of times. This, together with the fact that fishers often did not want to engage in the more creative workshopping exercises, resulted in some of the programme not being completed as planned.

Notwithstanding the necessary changes to the workshopping programme and the resulting deficiencies in the participant stories, the planning exercise was not futile, and the sense is that fishers did find the engagements useful and more comfortable to deal with as time progressed. This demonstrates the small, incremental shifts that happen during such interactions which can foster learning (Muro & Jeffrey, 2008; Cundill & Rodela, 2012). Fishers such as the Melkhoutfontein fishers would, without some prior engagements, struggle to meaningfully engage in larger scale processes due to pre-existing unequal power relations amongst various stakeholders. Engaging in such processes at the small-scale and in settings where they do not feel intimidated can help such fishers to build capacity and confidence to allow them to meaningfully engage with larger scenario planning processes in future.

The feedback session, discussed in Section 5.6.2, provided fishers with insights into how their system could change over the next 30 years. This does not in any way imply that fishers are locked into any one of these futures. Hopefully, engaging with the scenario planning process and the ensuing product (pamphlet), will have created enough of a shift in mindset to prompt fishers to start proactively considering those aspects of the future that they can change at the personal and household level. Although fishers were not very engaged with the scenario stories when providing feedback - opting to instead engage with other, more pressing issues such as the delays in the implementation of the SSFP – providing pamphlets created the space for fishers to reflect on the scenario stories in their own time with the pamphlet remaining a resource they can refer to at any time. Providing feedback to participants is often difficult due to practical challenges, by diversifying how feedback is provided and by making use of the opportunities presented by social media and other media formats, the communication of research findings to participants and other relevant stakeholders can be improved upon in future.

The scenario-planning process outlined in this chapter strived to identify pathways in the form of future stories for the potential development of Melkhoutfontein by using an iterative and participatory research approach. These stories not only incorporate scenarios on key driving forces identified by participants, but also incorporate scenarios from key driving forces identified through the BBN process. This demonstrated the value of incorporating tools such as BBNs in a scenario planning process. Promoting learning and capacity building is not only important to individuals' adaptive capacity, but also to eventually build capacity to be able to meaningfully engage in larger scale scenario planning processes. It was exceedingly difficult to evaluate if learning has indeed taken place. However, considering the engagements with the participants throughout the workshopping process, there was evidence of some learning and/or skills development having taken place. Providing more in-depth feedback in the near-future will present an opportunity to evaluate not only the amount and value of the learning that has taken place, but also for participants to reflect on their experience of the process. Importantly, developing the scenarios in this iterative and interactive process has presented the small-scale fishers of Melkhoutfontein with a unique opportunity to not only engage with challenging (and often emotive) concepts related to the future of the town, but also their and their families' possible future pathways.

In summary, this chapter has addressed the development of a scenario stories for the town of Melkhoutfontein using an iterative scenario planning exercise to identify possible pathways for future developments of Melkhoutfontein within the context of key driving forces identified by fishers and the BBN. The contribution made towards building capacity through learning and the possibility of implementing larger scale processes have also been explored through a discussion which provides reflections on insights gained from the product (final stories) and the process. Notably, overarching themes emerging from this chapter and discussed in Chapter Six, are related to the use the overarching scenario-based approach to address issues of scale within marine SES and the contribution the development of these tools can make towards EAF implementation in South Africa.

Chapter Six

Synthesis and Conclusion

The increased recognition of the complexity of marine fisheries systems has given rise to research that aims to expand the knowledge base to incorporate more holistic approaches to management (Schnute & Richards, 2001; Garcia et al., 2003; Garcia & Charles, 2007; Ommer & Team, 2007; Haapasaari et al., 2012b). This has led to the development of approaches that strive to cross disciplinary lines, perceptions, forms of knowledge and scales (Degnbol & McCay, 2007; Garcia & Charles, 2007, 2008; Ommer & Team, 2007). Furthermore, the adoption of SES perspectives offers the opportunity for placing aspects of the natural and human subsystems into conversation with each other with an eye to move towards more sustainable systems. For fisheries, the implementation of an Ecosystem Approach to fisheries management (EAF) (see Chapter One) is the preferred approach to deal with the complexity in marine SES to achieve such sustainability.

Building on my own research (Gammage, 2015; Gammage et al., 2017a, b) and recent work in connection with the Global Learning for Local Solutions (GULLS) project (Hobday et al., 2016), this thesis has examined the iterative and interactive development and use of structured decision-making tools (SDMTs) in a scenario-based approach. The approach, specifically focussed on the linefishery system of South African's southern Cape, strives to build local adaptive capacity and improve decision-making in support of the implementation of an EAF. This has been done by firstly defining the stressors that drive change in the southern Cape linefishery from the perspective of the small-scale fishers who act as crew in the commercial linefishery (Chapter Three). The results, perceptions from a user group underrepresented in previous similar research (Gammage, 2015; Gammage et al., 2017a), show that the perceptions of drivers of change in the fishery system are the same as those described by other user groups. In Chapter Four, causal maps have been used to examine hidden interrelationships, feedback loops, and the multi-scalar interactions of stressors that lead to change in the selected fishery. The use of the causal maps is not only a means of problem framing but also provided research participants and researchers with a system view of the interactions between the drivers. A prototype Bayesian belief network (BBN), co-designed with research participants, provided insights into where the uncertainty lies within the stressors that drive change. The BBN also, to a certain extent, provided insights into the relative importance fishers attach to drivers of change. Chapter Five presented scenario stories as a product of the scenario-planning approach and insights into the use of tools developed in the context of multiple-criteria decision support, in a scenario-based approach to change management. Importantly, the approach has been iterative and participatory throughout, with an inductive approach being followed in keeping with the principles of participant-led research.

This concluding chapter seeks to address Aims 5 and 6 as outlined in Chapter One, Section 1.9 and is directly related to the over-arching research question (Section 1.10). Aim 5, seeking to evaluate the contextual suitability of the application of the tools used throughout the research process has been achieved as planned and is specifically addressed in Section 6.1 below. Aim 6 relates to a reflection on the opportunity presented to fishers to engage in a process that could enhance their understanding of change response strategies through capacity building at the small scale. The contribution made by the process to the practical implementation of an EAF in South Africa has also been addressed within the context of Aim 6. In addressing these aims, some key themes have emerged (Table 6.1).

Table 6.1. Themes emerging in addressing Aims Five and Six.

Themes	Sub-themes & Topics	Section in Chapter Six
Semi-quantitative modelling for decision-support	• Knowledge of system at the local scale • Capacity building and agency at small scale • Practical implementation of EAF in South Africa	6.1, 6.2, 6.4
Scale	• Role of scale in implementing an EAF in South Africa • Spatial approaches to address scale challenges in EAF implementation	6.3
EAF implementation	• Exploration of linkages between social, economic and ecological systems in support of EAF implementation • Scope for future work	6.2, 6.4

Consequently, and considering the overall research process, this chapter presents a reflection on the contextual suitability of the application of the various tools as a whole, the appropriateness of the approach as a solution-based EAF implementation tool, the implications for dealing with scale problems in managing human activities in SESs and the contribution made towards promoting the EAF implementation in South Africa, together with recommendations for future research.

6.1. The southern Cape linefishery system

The broad aim of Chapters Three and Four was to first expand our knowledge of the marine SES in the southern Cape linefishery. Previous research (Gammage, 2015; Gammage et al., 2017a) provided qualitative system analyses from the perspectives of a diverse range of stakeholders. In the sample of stakeholders, the skippers were over-represented, and crew were under-represented. The research presented in Chapter Three, which focussed on crew perceptions, found that the perceptions of stressors that drive change matched across all groups of participants interviewed. The causal maps (Chapter Four), revealed the similarities of stressors that drive change to those described previously. Although fishers report that weather conditions and economic factors are the biggest determinants for proceeding to sea on a day-to-day basis, the causal maps highlight the complexity of the drivers of change and show how many indirect drivers of change are present in the system. Many of these drivers were often not immediately apparent and unaccounted for in fishers' decision-making as they were not 'top of mind'. An example of this is the indirect link between the risk of injury and kob catches and the resulting impact on achieving a sustainable livelihood (see Chapter Four, Figure 4.3).

Importantly, insight gained regarding drivers of change in the fishery system do not speak so much to the specificity of the drivers of change in the natural system, but to change itself. This change specifically relates to drivers of sea state over the long-term. Fishers rely on patterns in the natural system to aid their decision-making to proceed to sea or not. Fishers base this decision on whether it will be a good 'sea day' or not with subtle changes in well-established patterns making it harder to make well-informed decisions. Although seen in the causal maps, it became more evident in the BBN process where fishers defined optimal states for SST, wind and current. The impact of shifts in the natural environment, where day-to-day conditions fall outside optimal ranges, are exacerbated in a resource-constrained environment (both in ecological and economic terms), and fishers are forced to proceed to sea on days that are a 'sure bet' with regards to catching enough fish to make a profit. Changes in weather (Gammage et al., 2017a; Ward, 2018) result in unreliable patterns leaving fishers struggling to make informed decisions in both the short- and longer term. This means that if long-term patterns (that the fishers are used to) are increasingly less reliable, the risk of not making a profit on fishing trips increases as fishers may not always make the 'right' decision in the short term. One way to reduce this uncertainty would involve technological advances such as internet-based weather applications which are increasingly offering up-to-date and accurate weather information at the small scale. However, these applications only provide short-term forecasts of wind direction and speed while fishers would ideally require information on currents and other oceanographic features, such as stability of thermoclines. Weather forecasts are also often only reliable on the short-term (two- to three days), and fishers would prefer seven to 10-day forecasts. Longer-term reliability of information via applications is not necessarily a technology failure as the natural variability in weather in the southern Cape (Ward, 2018) make accurate predictions difficult. As technology and modelling techniques advance in terms of providing more accurate long-term weather predictions, the fishers' ability to make decisions based on changing weather and sea conditions should improve, providing they have low-cost access to such technologies.

The finding that stressors that drive change within this marine SES are consistent throughout the research area presents the opportunity to address issues of scaling drivers of change and suggests that one can safely 'upscale' drivers where the system context is similar or the same. This system context could refer not only to place but also to other contextual scales in the SES. When considering the drivers of change in the ecosystem, the exact impact at each town is not as important as the broad impact of the drivers. However, the same is not true when considering how fishers respond to change. Gammage (2015) and Gammage et al. (2017b) found that responses to change varied across the research area where fishers were either coping, reacting or adapting based on the capital (financial, educational, social) held by the different user groups. Many of the fishers (including research participants) are not able to respond to change proactively (whether by adapting, transforming or any other response which is appropriate to the driver of change). The reasons for this are multi-faceted, but a lack of knowledge of system interactions, policy and regulatory challenges and a lack of access to capital and financing is prominent. Some of these challenges also become 'top of mind' issues as they are the more immediate threat, with less threatening issues (or issues that appear 'further away') shifting to the background. Fishers may also be choosing to discount issues over which they feel they cannot exercise any power, such as changing weather conditions, even if 'climate change' was one of the top three drivers of change as revealed by the BBN sensitivity analysis. Acknowledging the extent of the problems in understanding the natural environment and their inability to exercise any power over those changes, may lead to acknowledging that their futures as fishers may well be in jeopardy (Gammage, 2015). This creates even more uncertainty regarding future livelihood options, and although fishers might admit the problem to themselves in private, they were less willing to openly confront this issue in group conversations. One of the achievements of the scenario planning workshops was that the BBN approach moved the participants' past this barrier (see Section 6.2 below).

The considerable variation in change responses across a relatively small geographic area pose distinct management challenges, demonstrating how difficult it is to achieve best-fit decisions from a governance perspective when confronted with diverse change response strategies (see Gammage, 2015; Gammage et al., 2017b). The imminent implementation of the Small-Scale Fisheries Policy (SSFP) in South Africa could significantly change the outlook for small-scale fishers (who are mostly the current crew in the commercial linefishery) and presents an opportunity to deal with many of the regulatory challenges experienced by these fishers since the promulgation of the Marine Living Resources Act (MLRA) in 1998. The successful implementation of the SSFP is a massive undertaking which requires extensive resources and the collaboration of DAFF with other government departments. Implementation has been slow and fraught with challenges, specifically concerning implementation capacity. What is clear is that the landscape of policy and regulatory challenges experienced by the small-scale fishers in the southern Cape will shift significantly as they gain direct access to marine resources in the area. The extent to which the implementation of the policy will address the challenges brought on by the lack of access to capital remains to be seen. Small-scale fishers in the southern Cape do not have the capital required to purchase boats and equipment and the adage that 'to make money, you have to have money' seems applicable in this context. Fishers could also find investors, but the choice of investor must be made very carefully to ensure that current monopolies (elites) within the fishing landscape in the southern Cape do not indirectly gain control of the co-operatives as often happens within the context of 'wealth based' approaches to resource management (Béné et al., 2010; Isaacs, 2011; Sowman et al., 2014; Visser, 2015; Duggan, 2018). Should this happen it may result in a situation where the money inadvertently flows back to the 'larger players' in the sector with the actual benefit to the small-scale fishers remaining small.

While the successful implementation of the policy will remove a large policy barrier to achieve a sustainable fishery-derived income, the challenges presented by economic factors and changes in the biophysical system will remain. If provided with adequate support to build their business acumen and management skills within the context of the fishing cooperatives, the small-scale fishers in the southern Cape should be able to build enough adaptive capacity to enable them to diversify to livelihood activities that are outside the fishery (within the context of the cooperative). Such shifts will not only build some local resilience towards changes in the biophysical system that they hold no power over but will also allow them to transform their local fishery system over the long-term. This transformation will not mean that they do not engage in any fishing activities at all, but rather that they become able to engage with a variety of livelihood activities such as boat repairs, barber shops, fish shops, farming (to name a few), which can over the long term lead to the creation of personal wealth and the development of the town community, as illustrated by the scenario stories "The going is good" and "The future is bright" (see Chapter Five). In short, the successful implementation of the policy could create the enabling environment required for these small-scale fishers to build their agency to not only affect change in their immediate environment but also to proactively start responding to short- and long-term change. With more proactive and careful planning than what is presently done, such change could lead to improved sustainability in the longer-term.

6.2. Reflections on the scenario planning approach as a tool for the implementation of an ecosystem approach to fisheries management: moving from problems towards solutions

For any realistic future planning to take place, one first needs to understand the driving forces of change. As seen in the development of the BBNs, the issues that were 'top of mind' for fishers – those stressors identified in the weighting (Chapter Five) - are different to the weighting revealed by the BBN sensitivity analysis. As discussed above, it seems that fishers may not be factoring some of the more important stressors within the system into their cognitive decision-making. Furthermore, fishers of the southern Cape all respond to change in diverse ways and with varying success (Gammage, 2015; Gammage et al., 2017b). A possible short-coming in most of the strategies employed by fishers across the research area may be a lack of foresight required to plan on the longer-term. Even those who have successfully diversified within the fishery such as the Mossel Bay commercial line fishers (Gammage, 2015; Gammage et al., 2017b) have had to base decision-making on current conditions within the fishery, as uncertainty and complexity make it extremely difficult to anticipate how change will pan out in the long-term. Added to this, the desire to stay engaged in fishery activities makes it hard for fishers to consider alternative principal livelihood options which may be necessary should the linefishery as a livelihood not survive in the longer term.

To consider sustainable futures, fishers need to be aware of the effects of multiple drivers of change in their decision-making. Using causal maps and BBNs in this research has allowed the participants to engage in a process which can, over the long term and at the correct scale, assist fishers to move towards a more solution-driven decision-making space. In this solution-driven space, fishers are then able to proactively consider the future and how to approach it by using techniques such as scenario planning. For small-scale fishers, who currently remain marginalised in terms of resources (education, capital), it may remain difficult to bring about the required shift in thinking without outside support through capacity building. Structured planning exercises such as the one developed in this thesis, can provide fishers with opportunities to enhance their system understanding, which allows them to consider how drivers of change interact within the system. The iterative nature of the planning process has created the conditions required for fishers to contextualise drivers of change not normally 'top of mind' regarding those, often equally important drivers that directly affect day-to-day fishing operations. This was evident in the way the conversations evolved throughout the three workshops, and in the results of the BBN sensitivity analyses.

The tools used throughout this thesis firstly aimed to highlight complexity, uncertainty and indirect drivers and feedback loops. Such understanding is are necessary to be able to engage in formal problem structuring. This phase of problem structuring is not only required for fishers to be able to improve their responses to change, but also creates a more holistic knowledge base which can lead to more informed decision-making at the various levels of governance. Problem framing and structuring are integral to structured decision-making support processes (Belton & Stewart, 2002; 2010). The causal map developed for the small-scale and commercial line fisheries of the southern Cape has achieved all these broad aims and helped participants to identify and define the variables for the BBN. The maps were also a useful tool in the workshopping process where fishers could consult the maps when they felt unsure.

The development of the weighted hierarchy and the BBN provided valuable information about how this group of fishermen perceived drivers of change in their fishery system. While the results must not be viewed in isolation, they do provide a vital stakeholder perspective. The development of the BBN also served as an essential problem restructuring tool. Asking the same question (what are the three most important things that affect your ability to earn a fishery derived livelihood?) in a different, less direct way, resulted in a different answer where the sensitivity analysis showed a different influence weighting to that of the weighted hierarchy. Reframing questions in this manner can move the conversation past 'top of mind' issues by foregrounding those drivers revealed to have the most influence on the central question. The diversity of participants' inputs into the BBN where three distinct response groupings could be identified by the sensitivity analysis (Section 4.3.3.2) is a function of the high uncertainty in the system. This diversity for such a small group was surprising and it is unclear whether the same diversity will come to the fore in a bigger group of participants. The BBN as a tool is, however, well suited and equipped to deal with such diverse inputs and opinions.

Untangling the drivers of change in this manner helped move the group towards a space where they could start considering how the future may play out, based on what is known about today's systems. Naturally, the perspective portrayed by such a BBN (driven by stakeholder input), is most reliable from the vantage point of that given stakeholder group. Importantly, researching future policy and developing positive future scenarios require the incorporation of often unexplored, but critical, human (social) variables (Tiller et al., 2013). Combining systems thinking (such as the weighted hierarchy) with Bayesian network development provided valuable insights and inputs which can inform such policies and future scenarios, with the principal characteristic of being co-designed by stakeholders. The conditional probability tables (CPTs) provided important insights into how participants see the fishery system. Although the scale of the BBN developed in this research is not appropriate for the assessment of future management options (see Postma & Liebl, 2005; Tiller et al., 2013), the ability to implement and use the tool together with stakeholders show that there is potential to use the tool at larger scales in management and decision-making contexts.

For this scenario prototyping exercise, the highest value may not lie within the final scenario stories themselves, but in the capacity building that has been initiated through the research process. This may be most evident in the fact that fishers were able to actively engage with the BBN development process at the end of the workshopping process, while they struggled with the same exercises in the first workshop. Through the process of deriving the BBN, a certain amount of individual and group learning would have taken place (e.g. van den Belt, 2004; Gaddis et al., 2010; Tuler et al., 2017). However, whether the participants adopted a new technique or mastered a new skill, is unclear and difficult to evaluate (Tuler et al., 2017). Notwithstanding, the fact that fishers were able to engage with the processes such as the BBN development process towards the end of the field research does indicate that some learning or shift in thinking must have happened in the workshopping process (see Chapter Five, Section 4.3.3.1). This process so far has been more useful on the personal level than for management decisions. However, this prototyping exercise has provided valuable insights into how one could go about conducting a fully-fledged scenario-planning exercise in a marine SES such as the one in the southern Cape, discussed in Section 6.4 below.

Previous research by Duggan (2012; 2018) has documented a high amount of distrust between fishers, and the distrust fishers hold of outsiders, specifically scientists and government officials. These elevated levels of mistrust can hamper collaborative processes which are an integral part of any scenario planning (and EAF implementation) process. The approach followed by this scenario planning prototyping exercise can help to create the spaces required for incremental trust building. However, participants also attended the workshops because they recognised the value of the process within the context of the implementation of the SSFP. Specifically, participants were interested in any information they could get regarding the SSFP implementation while, at the same time, recognising the use of the process in exploring ideas for livelihood activities that could be undertaken in the context of the co-operatives.

When considering the possible pathways developed for responding to future change, it is necessary to consider the role of capacity building and agency in the practical implementation of such strategies. To develop adaptive capacity and build agency within disenfranchised (South African) communities, other parallel - often policy-driven - processes need to take place. An example of this is the SSFP – while the implementation of the SSFP removes a significant barrier regarding access to resources, without added support from both DAFF and other government departments and NGOs, these small-scale fishers will struggle to capitalise on the opportunities presented by the SSFP. The communities in the southern Cape where the current crew reside lack the resources to bring about change themselves. This is demonstrated by the responses to change within the community as documented by Gammage (2015) and Gammage et al (2017a). This lack of agency, partly associated with the socio-economic conditions the community find themselves, is aggravated by low formal education (e.g. Duggan, 2018). For any grassroots 'social movement' to succeed, a sufficient base of motivation, human resources, solidarity networks and (often) external agitators are required (Ballard et al., 2005). Considering the current lack of adaptive capacity and agency within the southern Cape linefishery, strategic future planning may only become viable if external agitators (which include champions within the State and key NGOs who have networks and resources to draw on) are willing and able to actively move the processes of capacity building and planning along.

Scenario development processes such as the one initiated here can play a vital role in the development of agency in communities. As the start of the scenario workshop, participants initially did not 'dare to dream', since they did not believe that they had the agency to bring about changes. It was apparent that there was a disconnect between what fishers believe they can do. However, as the process advanced, the participants became more engaged with the concept of future casting, and there was enthusiastic engagement with future business ideas and possibilities. To foster agency, community developers/facilitators who work with communities over the long term are required to plant the seeds and guide them towards making real, substantive changes in their communities (Pereira et al., 2018a,b). Examples of such interactions are already evident in Melkhoutfontein where a small-scale fishing NGO has been integral in assisting fishers in getting themselves organised to apply for their Community Right under the auspices of the SSFP. The NGO continues to provide support to the fishers although it is unclear whether any strategic future planning is done. The fishing community of Bitouville has also benefitted from their association with the same NGO, specifically from the improved communication of information relative to the implementation of the SSFP and the networking opportunities for community leaders facilitated by the NGO. While this case refers to an NGO, the collaboration between various partners within other settings, for example, 'Abalobi'[19], could in future assist in creating an enabling environment required to foster agency with diverse and multiple stakeholders (including, amongst other fishers from multiple sectors and various decision-makers).

Lastly, for diverse stakeholders to get to the point where they are willing to engage in a transformative scenario planning (TSP) process calls for a significant amount of groundwork to be completed before the actual workshopping takes place. Although not within the context of scenario planning, Paterson & Petersen (2010) and

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[19] Abalobi; a registered NPO; is a mobile app suite for small-scale fisheries governance. The app suite, co-designed with fishers, consists of five modules – Abalobi -fisher, -monitor, - manager, - co-op and market-place and will be used in the management of the co-operatives established as part of the SSFP implementation (http://abalobi.info/) .

McGregor et al. (2016) emphasise the importance of carrying out the proper groundwork in a multi-stakeholder processes in the context of Benguela fisheries. This groundwork, called the co-initiating phase in the TSP process (see Figure 2.9), involves articulating the problem (or theme), mapping the system stakeholders and enrolling a diverse and representative team of people from across the systems who want to, and can, influence the future of the system (Kahane & Van Der Heijden, 2012). In the context of this prototyping exercise much of this groundwork was done in the context of other research studies (such as Gammage, 2015), and due to the homogenous group of stakeholders, the co-initiating phase was significantly reduced. Should the approach be implemented across the expanse of, for example, small-scale fisheries in the Western Cape (an appropriate scale for a TSP), a significant amount of time and resources will have to be spent on the co-initiating phase. To successfully implement such an approach, getting buy-in from decision-makers who are willing and able to influence the system, will be the most challenging aspect. This is especially true for government, where political will is key to bring about change through the creation of a favourable governance and management environment which favours the implementation and use of approaches such as scenario planning. Only then will such approaches be able to *directly* influence decision-making at the scale where policy and regulatory decisions are made.

6.3. Complexity, uncertainty and the role of scale in managing human activities in social-ecological systems

The challenge presented by issues of scale is a key characteristic of the complexity of the human-environmental system, more especially where multi-level decision-making is required. The term scale (Gibson et al., 2000) refers to space, time and jurisdictional scales while 'level' can refer to a specific point along a scale. Governance issues in the Anthropocene are often multilevel and cut across jurisdictional scales while linking decision-makers both horizontally and vertically (Berkes, 2017). In the South African fisheries context, multi-level and cross-scale governance would require that information and knowledge flow not only 'top-down' but also 'bottom-up' between national and local levels in a system of co-management (see Figure 6.1), as mandated by the SSFP and promoted by the EAF. Considering the scale of the ecosystem, this would also infer a need for more cross-scale flows of information and interaction between different fishery sectors at the various levels of decision-making.

For the southern Cape, this would imply that there is an uptake of fishers' knowledge at the policy-making scale together with more meaningful sharing of information and interactions between the small-scale, small-scale commercial line -and inshore trawl fisheries which operate in the same area. There are competing interests at various levels of decision-making, for example, local perspectives on biodiversity may focus on livelihoods, the national level may focus on tourism development and the international level on global biodiversity conservation. Importantly, these competing interests also exist between different fishery sectors. All these perspectives are both unique and valid and need to be incorporated into overarching governance and decision-making structures. Figure 6.1 shows current management paradigms in the South African context. Although bottom-up management practices may be espoused in legislation such as the MLRA, the mechanism to affect practices from the bottom up is not defined nor effective (shown by the broken line); management remains top-down with local scale interaction not being considered at the policy decision-making scale (Sowman, 2011). Importantly, the SSFP makes explicit provision for the co-management of small-scale fisheries (Chapter One, Section 1.3), although the same is not true for other fishing sectors. When considering the interaction between national and multinational (Figure 6.1b), the bottom-up interaction is more effective as South Africa is afforded the opportunity to give input as participants in and signatories of multi-national/international fora and agreements, such as the EAF (see Chapter One, Section 1.2 and 1.3).

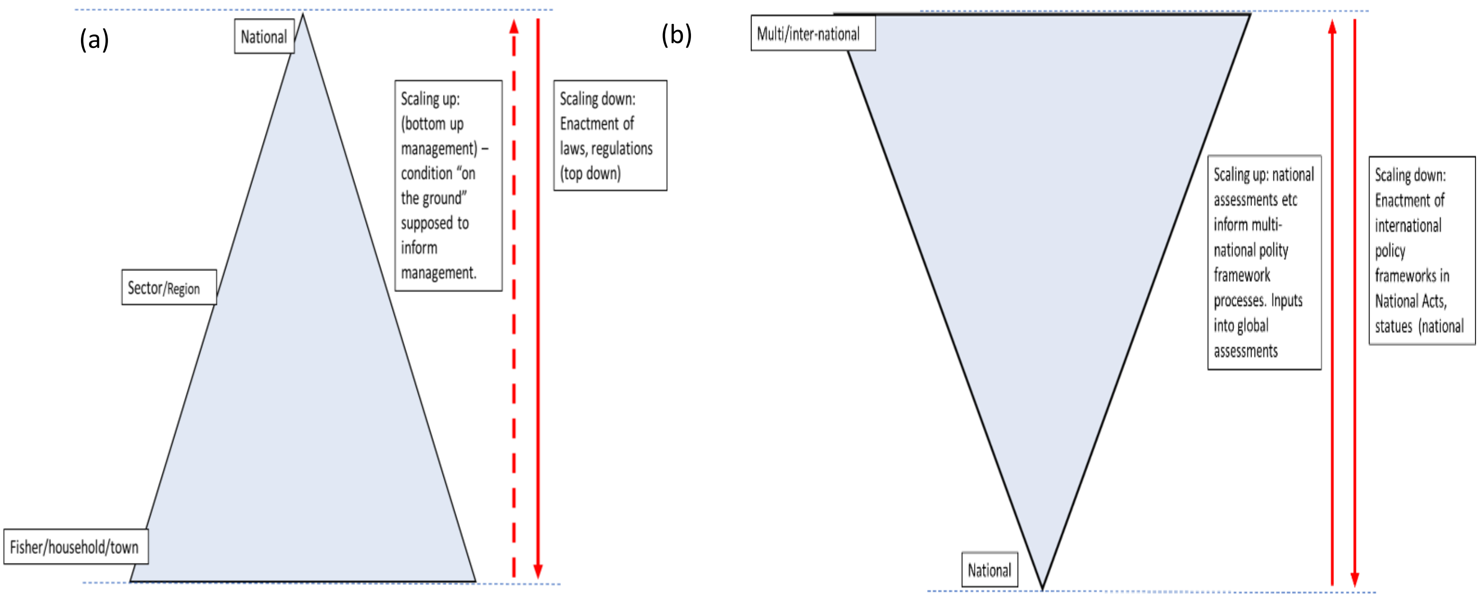

Figure 6.1. Pathways for scaling processes in the South African fisheries policy landscape. Fisheries management in South Africa is typically 'top-down' (a) with local scale interactions often not considered in policy-making decisions (indicated by broken line). Inter-, multinational policy frameworks and commitments (b) are enacted in the government's national policies/acts. Conversely; national assessments, concerns are integrated into the inter-multinational policy frameworks and assessments by engagement in a process which formulate such frameworks and assessments (such as IPCC, IPBES, SDGs).

It is thus vital, in considering the implementation of an EAF, to see approaches such as scenario planning as an integral part of an overarching governance approach. Scenarios remain an appropriate method for dealing with uncertainty within the entire SES, and at small scales of the individual town of group, scenario planning is a useful tool for capacity building and social learning (Quay, 2010). Additionally, applied in the approach pursued in this thesis, the tool presents a means to engage more directly with problems of scale by facilitating dialogue at various levels of the decision-making structure. This thesis shows how such an approach, even when carried out at the small scale, is not only useful for capacity building at the smallest scale of interaction but also provide valuable insights which are valuable at larger scales. Figure 6.2 shows how a multi-scalar decision-making process using scenario approaches could work in the South African context.

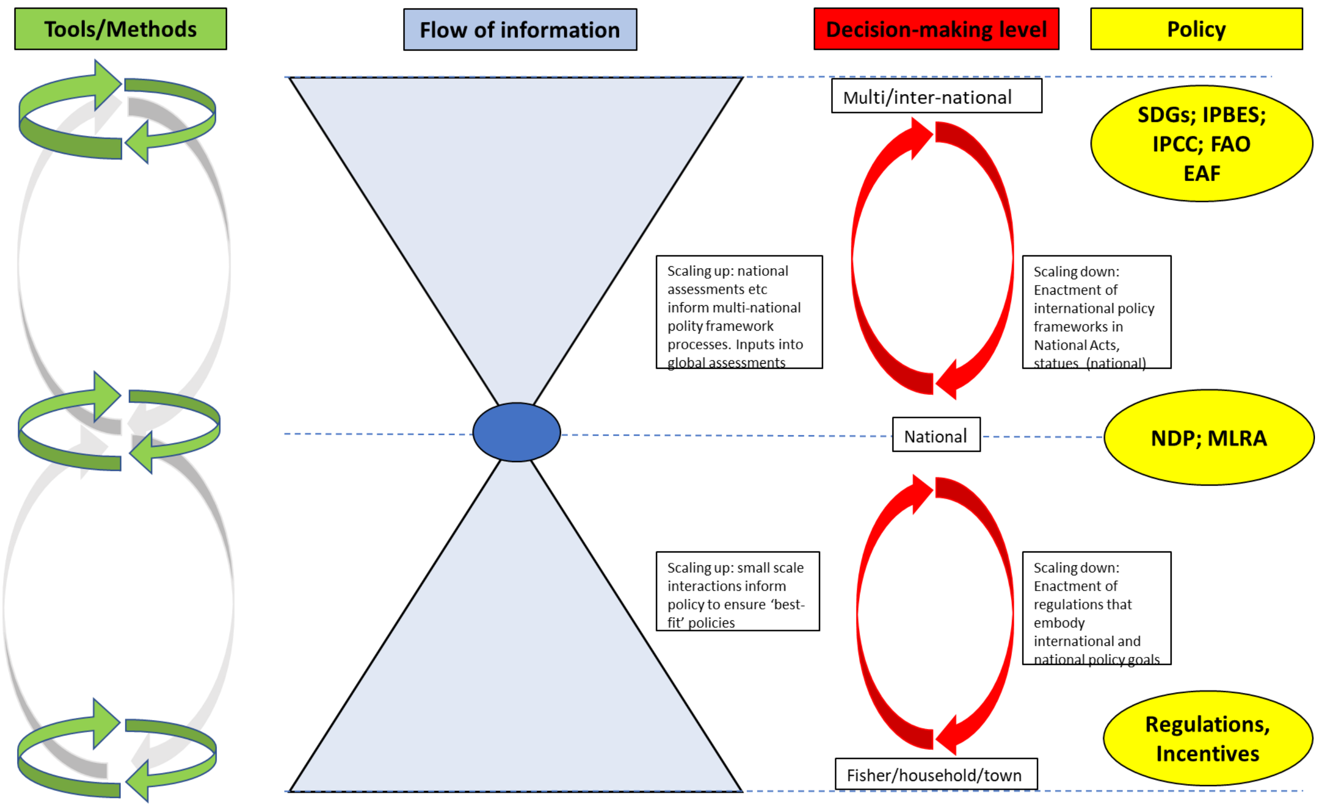

Figure 6.2. Pathways for scaling within the decision-making context. Policy positions and international undertakings need to be enacted in national policy and legislation. Actions at the small-scale must inform legislation at the national level, which in turn informs inputs made to multi-national and international evaluations, policy positions. There is a need for simultaneous 'top-down' and 'bottom-up' governance processes. Policy processes are thus not seen as linear, but iterative. Scenario processes and the use of structured decision-making tools will be more effective if used in a governance approach which considers and integrates processes at various scales – both within and between different scales.

Any governance approach will be more effective when the scale of ecological processes is well matched within the human social institutions that are charged with managing in the human-environmental interactions (Leslie et al., 2015). In the case of South African fisheries, the sectoral nature of the management approach enforces a mismatch between the scales of the ecosystem and that of the management structures. This is demonstrated in the South African linefishery when considering the management zone delineation (DAFF, 2013) and the linefish stock composition on the western Agulhas bank in the Benguela (Blamey et al., 2015). To better ensure better alignment between management and ecological scales, Blamey et al. (2015) proposed how management zone delineation could be adjusted to better suit the fish assemblages (ecological) units of scale. For South Africa, would mean moving away from current management scales (national- sector-management zone) to a scale which better reflects the biogeographical regions documented in the ecosystem of the southern Benguela namely, southern Benguela, Agulhas bank, central Agulhas bank, coastal fisheries.

For the southern Cape line fishers, a better alignment between ecological and management scales would benefit both the ecosystem and the fishers operating in the revised regions (although it must be borne in mind that it would result in a better alignment which will not necessarily be perfect as challenges related to migratory species will remain unresolved). Such a shift in approach should result in a reduction of competition for resources that currently exists between fishing sectors such as the commercial line- and inshore trawl fisheries of the southern Cape through the implementation of catch limits and restrictions that are area-specific. An example that could be considered in the southern Cape would be to review how areas of operation for the various fishing sectors that target kob are delineated with the aim to decrease areas of overlap and reduce fishing pressure. It must be said that, at present, this is an unlikely scenario as such this could have negative impacts on other Rights holders. This again demonstrates the complexity of the fishery governance system, further highlighting the need for dialogue which, importnatly can both be facilitated and supported by inclusive scenario planning.

For the southern Cape, it could be argued that what matters is not how fishers respond (adapt, react, cope), but instead that they need the capacity to respond to changes and drivers of change in proactive ways that are appropriate (in time and scale) for the situation. The research has highlighted the realistic (and attainable) ambitions participants hold for developments over the next generation. Notably, one of the highlights was that they did not consider the individual/household response as such, but also the community (town) as a whole – which is in keeping with the findings of previous research where change response strategies were identified per town (Gammage 2015; Gammage et al., 2017b). The Coasts Under Stress project (Ommer & Team, 2007) had similar findings in Canada. The importance of the community and its well-being recognised by fishers in this study for the ability to achieve sustainable livelihoods and well-being has important implications for management and suggests that impact on the community and overall community well-being should explicitly be included in decision-making processes throughout.

6.4 Implications for the implementation of an ecosystem approach to fisheries management in South Africa and scope for future work

While rooted in the human dimensions of SES and keeping a focus on participant engagement, this thesis has explored tools to achieve a balance between social, economic and ecological objectives, as needed for the implementation of EAF in South Africa, by using a case study in the context of the linefishery of the southern Cape. The research, which is reproducible, transparent and adhering to principles of democracy and ecosystem justice[20] (Brunk & Dunham, 2000), opens a new view on the human dimensions of the southern Cape linefishery and describes a methodology which can be applied across fishery sectors in South Africa. This is done by presenting an approach that has explored the linkages within the SES with an eye on improving the practical implementation of an EAF.

For any EAF implementation to succeed, various perspectives need to be integrated into the decision-making process at various scales. Paterson et al. (2010) highlight the need for a transdisciplinary approach where real-world problems are used to develop solutions in partnerships with multiple stakeholders. They identify a common vision, exemplified by the development of an EAF together with the means to facilitate useful interactions using SDMTs as the two most important requirements for the development of sustainable research partnerships. SDMTs do not only help stakeholders make sense of their SES, but it also guides managers in uncertain and complex systems. Through participating in processes where such tools are developed in support of an EAF, the common focus, which is required from all stakeholders can be fostered.

Considering these requirements, the scenario-based approach developed in this thesis provides a means to conduct the type of transdisciplinary research required in the development and implementation of an EAF in South Africa. This research has shown that SDMTs can work in communities where participants/fishers have little formal education. By using iterative and participatory processes, even the most disenfranchised and powerless stakeholders can be meaningfully engaged in a structured process. This shows that to engage stakeholders there is no need to lose structure altogether. This in itself, would be a statement of power. With structure crucial to the practical aspects of fisheries management in order to ensure repeatability and transparency, this finding shows that by using SDMTs in processes where the required groundwork, capacity building and resourcing take place, it is possible to integrate vulnerable, marginalised stakeholders into formal decision-making processes directly, effectively as required by the EAF (Garcia et al., 2003).

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[20] Ecosystem justice is "the ethically acceptable relationship among all competing and complementary interests of an ecosystem 'community'" (Brunk & Dunham, 2000:294).

This thesis presents a prototype which will need to be developed more widely and comprehensively to make a meaningful decision-making contribution. As a start, and in keeping with the general guidelines for a TSP process, this would entail scaling up to cover a larger geographical scale. For the southern Cape linefishery, and in keeping with the fish assemblage delineation suggested by Blamey et al. (2015), this would entail engaging with all fishery sectors who target linefish in the area between Cape Infanta and Cape St Francis. Crucial to the success of such a process is the painstaking work of laying the appropriate basis to ensure that all stakeholders are engaged in a co-initiating (or convening phase). Kahane (2012a,b) describes the requirements of this first phase of the process in detail while also highlighting the importance of the phase for the overall success of the process, as is done here.

The co-initiating phase will be challenging given the South African fisheries management context. Although the State is central to management, it is considered weak (e.g. Norton, 2014; Jarre et al., 2018). To convene a process that can have meaningful inputs at various decision-making scales, it will be important to at least have a champion within the State who would be willing to, participate in such a process. Institutions such as NGOs who have close links to the target communities will also be crucial to the co-initiating phase, as discussed above. Importantly, much time and effort will have to be spent by the research and facilitation team to identify and approach key individuals from the State and other institutions who will be willing to learn from each other, remain engaged in a long-term project and who can facilitate collaboration with various communities of fishers.

Given the inductive nature of the research, it remains important that some flexibility is built into the research design. Although the prototype process has been based on the principles of a TSP, there is space to integrate other types of scenarios (e.g. predictive, see Chapter Two, Section 2.4) into the process if the need arises. There is also a need to ensure that the tools used for structured decision-support are appropriate, bearing in mind that there are more tools that can be developed. While the tools were mostly used successfully in this research, these tools may not be suitable for all contexts and would require testing (prototyping) in different contexts to ensure wide applicability. As the robustness of the process depends on diverse stakeholders giving diverse opinions on often sensitive matters, an experienced facilitator (or facilitation team) remains key to the eventual success of the planning process. Importantly, the need to implement the process in a slow manner which ensures that all participants are prepared to actively engage with the process, together with the time and resources to ensure a properly facilitated process with diverse stakeholders, remains key to the successful implementation of the approach.

For line fishers such as those from the southern Cape, programmes and interventions which create conditions where they are able to make informed decisions based on both macro- and micro system interactions, together with the tools and power to implement these decisions, is what would move them towards futures that can be regarded as more sustainable - especially in terms of their livelihoods and well-being. The creation of enabling conditions, where policy and decision-makers (which include fishers as direct resource users) at various levels actively engage on issues affecting the marine SES, is key to effectively implementing an EAF, moving fisheries and dependent coastal communities closer to attaining sustainable futures. Specifically, this research shows that by engaging in capacity building on the ground, disadvantaged communities can actively be empowered to participate in more complex, multi-stakeholder planning processes. Their inputs could thus inform policy processes in a bottom-up approach, as opposed to the current top-down approach where they are 'told what to do'. While 'bottom-up' management mechanisms do not currently function well in South Africa, the approach demonstrates the potential to facilitate a two-directional flow of information between various scales of the system. Establishing more effective flows of information across scales, although only the first step in a complicated process of re-imagining decision-making processes, is the first step in moving fisheries and fishing communities towards improved sustainability.

6.5. Conclusion

The benefit of oceans to people is undeniable and well described. Complexity and uncertainty in marine SES require a paradigm shift in how we perceive, study, manage and govern. Considering that the earth system seems to be nearing critical tipping points faster than previously expected, it becomes evident that this paradigm shift cannot take the traditional 'slow and steady' trajectory generally favoured by researchers and decision-makers alike. Importantly, this change in thinking calls for research that moves beyond the traditional framings and discourses that places the focus on what we know, towards approaches where there is a focus on increasing the capacity of stakeholders to make sustainable decisions within rapidly changing complex adaptive systems with an eye on actively planning for the future.

The research presented in this thesis has shown that modelling approaches such as SDMTs can be done with stakeholders, even those who have not previously been exposed to such methods. Specifically, through the use of the BBN, fishers have been able to move past 'top of mind' issues in a problem reframing process. Considering that participants tended to downplay the effect of climate change on their environment, this is important as the BBN results show that climate drivers are as important as other drivers. This result highlights the ecological – human linkage and the importance of such interactions. Through the implementation of an interactive and iterative process, the process has resulted in the promotion of capacity building at the scale of the individual, household and community of fishers. Importantly, meaningful scenarios have been developed for the small-scale fishers in Melkhoutfontein. Reflecting on the development and implementation process has allowed for the discussion of multiple stakeholder settings and the value of the approach in addressing issues across multiple scales in SESs.

Complexity and uncertainty in marine SES hamper effective decision-making at all scales. This thesis shows that scenario-based approaches present a practical, scalable methodology that is able to facilitate learning, capacity building and decision-making with the ultimate aim of improving the implementation of an EAF. Importantly, through the use of SDMTs crucial local system insights have been documented, enhancing our understanding of local system interactions. By building on this essential knowledge of the local SES, the next implementation step will be to scale up the scenario-planning process to an appropriate ecological scale. To facilitate the necessary learning and capacity building required for valuable interactions, the research shows that it is crucial to lay the appropriate basis for multiple stakeholder meetings, with all the effort that needs to go into it. Only then is it meaningful to embark on a full-blown, multiple stakeholder planning process. Through the implementation of the tools and approach used here, it will become possible to improve decision-making at all scales, promoting adaptive capacity of the person, household and community while enabling improved governance at the larger scale. Ultimately, better decision-making does not only promote social justice for fishers, but also ecosystem justice, both of which are crucial not only for the implementation of an EAF, but more generally, for long-term system sustainability.

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Appendix A. Ethics Approval for research

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25 January 2016

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The development of a scenario-based approach to adaptation to change in fishery systems. A case study in the small scale fisheries of the Southern Cape

Dear Louise Gammage

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

- Implement the measures described in your application to ensure that the process of your research is ethically sound; 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 03 – 2016**

I wish you success in your research.

Yours sincerely

Prof Timm Hoffman
Chair: Faculty of Science Research Ethics Committee

Cc: Supervisor – Prof Astrid Jarre

Appendix B. The modelling process and its application to this research

Models can be used to assist in expanding the understanding of the likely effectiveness of alternative management decisions (Barton et al., 2012). The implementation of an EAF will benefit from close collaboration between various researchers and stakeholders working together in interdisciplinary teams to build system models (Starfield & Jarre, 2011). Varying contexts, objectives, priorities, knowledge, influence and stakeholders require that models be adaptable and thus flexible to include evolving bodies of knowledge as well as to incorporate different bodies of knowledge, especially in systems models (Starfield & Jarre, 2011). In order to do this and to be able to operate on multiple scales and levels of resolution (with the eventual aim to facilitate of wise decisions and promote social learning), there is a requirement for various models which can address different questions and suit different purposes (Jarre & Moloney, 1996; Barton et al., 2012).

The 'real world' is complex with all variables being potentially important. The first step of any modelling process is to design a simplified model 'world' which may distort, simplify or ignore some of what is found in the real world. The objectives of the modelling exercise determine model inputs and the process of model design be the process of focussing attention on important system aspects. Research knowledge or data is then used to build and code the model. Once the model is coded, data from the 'real world' are required for parameterisation and calibration. Important to note that if data is missing best estimates or guesses can be used as the design of the model world (and model) is determined by objectives and data availability. The model is exercised, and the results produced. The results relate to the model world and must be interpreted back to the 'real world'. This interpretation needs to take the assumptions of the model and data quality into consideration (Starfield & Jarre, 2011) and will typically build on extensive sensitivity and assumption analyses (e.g. Cooper, 2015; Watermeyer, 2015). Figure B1 below is a visual representation of this process.

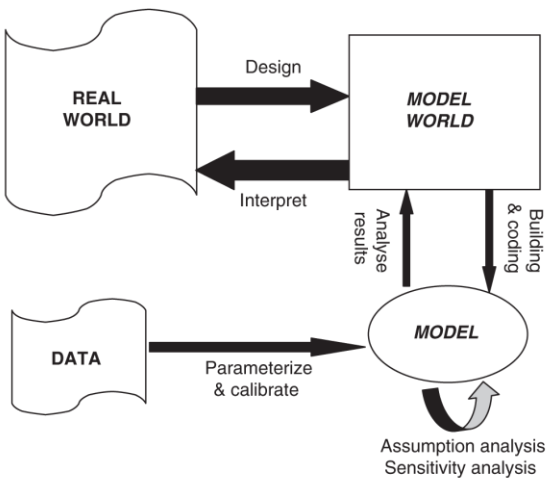

Figure B1. The modelling process (adopted from Starfield & Jarre, 2011)

The causal diagrams in the research are the conceptual models of the system which define the terms of the debate. Bayesian belief networks (BBNs) are a modelling tool that can be used to quantify these conceptual models (or in this case causal diagrams) by defining states in order to describe model variables and use probabilities for the occurrence of these states using Bayesian statistics (Kjærulff & Madsen, 2008). The modelling philosophy applied in this thesis follows that of a rapid prototyping approach (Starfield & Jarre, 2011).

Modelling with Stakeholders

SDMTs assist with the synthesis of information, thereby making the method and process both transparent and communicable to stakeholders. While these strengths are emphasised, in practice effective communication is often neglected (Grey & Weideman, 1999; Chess et al., 2005; Potts, 2006). Through the process of designing and implementing SDMTs together with the interactions of stakeholders and users with these tools, 'buy-in' may facilitate. This also offers ways to improve communication among stakeholders around the problem or decision (McGregor, 2015). The development of models with increased visibility of input data and calculation, assist in making the modelling methodology understandable and more acceptable to stakeholders (Belton & Stewart, 2002).

Broader stakeholder buy-in to decisions made can be facilitated by making sure that model outputs are communicated understandably and transparently amongst stakeholders which facilitates broader stakeholder buy-in to the decisions (e.g. Garcia, 2000; Starfield & Jarre, 2011). One way to communicate model results is to include stakeholders in the modelling process. However, should stakeholders only be included at the end, their acceptance of decisions could be limited (van den Belt, 2004). Through the meaningful involvement of stakeholders in all the stages of a modelling process, a sense of ownership and buy-in will be instilled in stakeholders which increases the likelihood that the tools will be included in decision-making processes (Garcia, 2000; Belton & Stewart, 2002; Voinov & Bousquet, 2010; Duggan, 2012; Gray et al., 2017). A structured way to include stakeholders in modelling processes is provided by participatory or mediated modelling which can be defined as the "use of modelling in support of decision-making processes that involve stakeholders" (van den Belt, 2004: 14). Participatory or mediated modelling includes stakeholders directly in the modelling process and can assist with the integration of aspects of complex environmental problems, drawing in ecological, social and economic components of a problem while effectively facilitating stakeholder participation (van den Belt, 2004; Robinson & Fuller, 2017). Access to data is improved through this process and available data, quality checked (van den Belt, 2004). The synthesis provided by van der Belt (2004) provides examples of the resolution of conflict, building trust between stakeholders, and the facilitation of interactive group learning process. A more recent synthesis from Gray et al. (2017) focusses on environmental modelling with stakeholders and present an comprehensive overview of considerations for modelling with stakeholders together with specific application and products of methods by examining case studies.

Appendix C. Appendix for Chapter Three

Table C1. Comparison of survey question asked in GULLS survey vs Questions used in this analysis[21]

Question in SA Gulls Survey	Question included in the Thematic framework	Indicator (original survey)	Rationale for omission
1.1	1.1	Fishing main Occupation	
1.2	1.2	Average number of days spent fishing per week	
1.3	1.3	Average time spent fishing per trip	
1.4	x	Highest daily catch	Badly answered. Mostly crew
1.5	x	Best catch of the year	Badly answered. Mostly crew
1.6	1.6	Average distance from the coast where fishing takes place	
1.7	1.7	The directionality of any change in the distance from the coast where fishing takes place now compared to when began fishing	
1.10	1.10	Three most commercially important species	
1.11	1.11	The observed change in main target fish species in the past five years	
2.1	2.1	Monthly income	
2.2	2.2	Monthly income	
3.1	3.1	Possession of own fishing business	
3.2	x	People provided work to in the last 12 months	Not business owners (crew)
3.3	x	Business income over the year	Not business owners (crew)
4.1	x	Source of food purchases	Information integrated into the qualitative analysis.
4.2	x	Percentage of food by volume (how obtained)	Not relevant ito framework
5.1	x	Level of interaction and dependence on other people and institutions	Not relevant ito framework
5.2	x	Level of interaction and dependence on other people and institutions	Not relevant ito framework
6.1	x	Number of nights per week that household consumes seafood	Not relevant ito framework
6.2	x	Source of seafood consumed	Not relevant ito framework
6.3	x	Typical species are eaten by household	Not relevant ito framework
7.1	x	Days per week fresh vegetables consumed	Not relevant ito framework
7.2	x	Days per week fresh meat consumed	Not relevant ito framework
7.3	7.3	The relative importance of the household's food source	Not relevant ito framework
7.4	x	How to pay for goods not grown or caught	Not relevant ito framework
7.5	x	Possession of garden/plantation	Not relevant ito framework
7.6	x	Reason for growing food	Not relevant ito framework

[21] The main reason for omitting questions was irrelevancy to the thematic framework. It should also be borne in mind that some of the original survey questions, developed in a comparative context, were ill-suited to the specific research sites and thus were not answered well. Such questions were also omitted

Question in SA Gulls Survey	Question included in the Thematic framework	Indicator (original survey)	Rationale for omission
7.7	x	How much of crops are grown for commercial purposes	Not relevant ito framework
7.8	x	Where do you plant	Not relevant ito framework
7.9	x	List crops are grown	Not relevant ito framework
7.10	x	Livestock (yes/no)	Not relevant ito framework
7.11	x	Livestock activity	Not relevant ito framework
7.12	x	Type of livestock and numbers	Not relevant ito framework
8.1	8.1	Length of time as a fisher	
8.2	8.2	Age of the fishery	
8.3	8.3	The extent of ancestral involvement in fishing	
8.4	x	The extent of ancestral involvement in fishing	Information integrated into the qualitative analysis.
8.5	8.5	Perception of a "fishing" family identity	
9.1	9.1	Difference in occupation from parents	
9.2	9,2 (a)	Level of schooling of parents (father)	
	9,2 (b)	Level of schooling of parents (Mother)	
9.3	9.3 (a)	Level of schooling of parents (father)	
	9.3 (b)	Level of schooling of parents (Mother)	
9.4	9.4	Homeownership of parent's vs interviewee	
9.5	9.5	Boat ownership of parent's vs interviewee	
9.6	x	Level of financial well-being compared to parents	Question poorly answered.
10.1	10.1	Level of interest in changing employment	
10.2	10.2	Perception of finding work in an alternative sector	
10.3	10.3	Number of options for alternative work	
10.4	10.4	Have courses been taken to improve employability	
10.5	10.5	Which courses were completed	
10.6	10.6 (a)	Level of interest in working for someone else	
11.1	11.1	Number of employment changes in the past five years	
11.2	11.2	If yes in 11,1, what work (work available to fishers/work fishers willing to engage in)	
11.3	x	Preference of different livelihoods	Information integrated into the qualitative analysis.
11.4	11.4	Level of interest in working in the non-fishing sector	
11.5	x	Factors and types of work sought in a different livelihood activity	Not relevant ito framework
11.6	11.6	Factors and types of work sought in a different livelihood activity	
	11.7	Factors affecting fishing livelihoods	
12.1	x	Number of markets to buy fish in the community	Question poorly answered.
12.2	12.2	Number and type of avenue to sell fish	
12.3	12.3	Nature of relations between members of the market chain	
12.4	x	Nature of relations between members of the market chain	Question poorly answered.
12.5	x	The possibility of selling fish outside the community	Question poorly answered.
12.6	12.6	The possibility of selling fish outside the community	

Question in SA Gulls Survey	Question included in the Thematic framework	Indicator (original survey)	Rationale for omission
12.7	x	Distance to markets outside the community	Question poorly answered.
12.8	x	Stability and factors controlling the local fish price	Question poorly answered.
12.9	12.9	Stability and factors controlling the local fish price	
12.10	12.10	Stability and factors controlling the local fish price	
12.11	x	Number of markets to sell meat and vegetables	Information integrated into the qualitative analysis.
13.1	13.1	Presence of natural resource management institutions in community	
13.2	x	Type of management system	Question poorly answered.
13.3	13.3	Level to which rules have changed due to environmental changes	
13.4	x	Level to which rules have changed due to environmental changes	Question poorly answered.
13.5	x	The degree of recording/reporting of catches required	Question poorly answered.
13.6	x	The degree of recording/reporting of catches required	Question poorly answered.
13.7	x	Types of community organisations active in the community	Not relevant ito framework
14.1	14.1	The feeling of belonging to the community (4-point scale)	
14.4	14.4	Importance of friendships in the community	
15.2	x	The regularity of recreational fishing	Not relevant ito framework
16.4	16.4	The degree of pride in telling others one is a fisher (4-point scale)	
16.6	16.6	Level of interest in one's children becoming fishers (4-point scale)	
17.2	17.2	Possibility to feed the family without fishing	
18.1	x	Perception of whether too many or too few fishers operate in the community (4-point scale)	Information integrated into the qualitative analysis.
18.2	x	Perception of whether too many or too few fishers operate in the community (4-point scale)	Information integrated into the qualitative analysis.
18.3	18.3	The degree of concern about illegal fishing levels locally (4-point scale)	
19.1	x	Inclusivity of local ecological knowledge within marine resource management planning	Question poorly answered.
19.2	19.2	Concern regarding the continuation of fishing as a livelihood among the next generation	
20.1	20.1	Level of knowledge about the marine environment	
20.2	20.2	Importance to ensure LEK is passed on to younger generations	
20.3	20.3	Relative maintenance of LEK between generations	
21.1	21.1	Level of habituation to changes in everyday life (4-point scale)	
21.2	21.2	Perception of which user groups are most at risk to future changes (4-point scale)	
22.1	22.1	Level of financial planning (4-point scale)	

Question in SA Gulls Survey	Question included in the Thematic framework	Indicator (original survey)	Rationale for omission
22.2	22.2	Level of interest to learn new skills outside of fishing (4-point scale)	
22.4	22.4	Perception of the possibility to personally improve the marine environment (4-point scale)	
23.1	23.1	Level of confidence that events will work out well regardless of everything else (4-point scale)	
24.1	24.1	Perception of responsibility to protect the marine environment (4-point scale)	
25.2	x	Perception of ability to adapt to change compared to others locally (4-point scale)	Information integrated into the qualitative analysis.
26.1	26.1	Perception of the utility of own skills to set up a business outside of fishing (4-point scale)	
27.1	x	The relative importance of tourism to the community and natural resources to tourism (4-point scale)	Not relevant ito framework
27.2	x	The health of the marine resources locally (4-point scale)	Not relevant ito framework
27.3	27.3	The relative importance of fishing as economic activity locally (4-point scale)	
28.1	28.1	Level of occupational diversity throughout the year (4-point scale)	
28.2	28.2	Willingness to relocate for livelihood purposes (4-point scale)	
29.4	29.4	Possibility to predict money made each month by your business (4-point scale)	
29.5	x	Level of detail of the business plan for the following year (4-point scale)	Not relevant ito framework
30.1	30.1	Relative occurrence of illegal fishing locally (4-point scale)	
30.4	x	Number of people who know those who break the rules (4-point scale)	Not relevant ito framework
30.5	x	Level of enforcement of fishing rules (4-point scale)	Not relevant ito framework
30.6	30.6	Relative occurrence of conflict among fishers (4-point scale)	
31.2	31.2	The strength of links between fishers and institutions or government	
32.1	32.1	Perceived level of risk to the community from environmental change (4-point scale)	
32.3	32.3	The degree of anxiety felt about environmental changes observed locally	
33.1	33.1	Perceived level of danger to fishing from weather changes	
33.2	33.2	The degree of difficulty in finding/catching fish compared to the past	
33.3	33.3	Number of changes in marine species observed locally	
34.3	34.3	Number of ideas held to ensure the sustainability of the target fish species locally	
34.4	x	Amount of knowledge good fishers possess about target fish biology	Not relevant ito framework

Question in SA Gulls Survey	Question included in the Thematic framework	Indicator (original survey)	Rationale for omission
35.1	35.1	The primary source of assistance when having financial, food or basic needs	
36.1	x	Number of women in leadership roles in the community and positions	Not relevant ito framework
36.2	x	Number of women in leadership roles in the community and positions	Not relevant ito framework
37.1	x	Sources of fishing, weather and sea conditions information	Not relevant ito framework
38.1	x	Presence of infirm or unwell person in the household in the last year	Not relevant ito framework
38.2	x	Presence of a chronically ill person in the household	Not relevant ito framework
39.1	39.1	The highest level of formal education attained	
41.1	x	Possession of basic knowledge in environmental, marine, fishing or business knowledge	Not relevant ito framework
42.1	42.1	The degree of difficulty in finding alternative work if known as a fisher	
42.2	x	Types of community organisations actively participated in	Not relevant ito framework
43.1	43.1	The contribution of each household members' income to household expenses	
43.2	43.2	Possibility to obtain cash for an emergency today	
44.1	44.1	Presence of savings for emergencies	
45.1	45.1	Mortgage repayments	
45.2	x	Mortgage repayments amount	Not relevant ito framework
45.3	45.3	Money owed excluding mortgage	
46.1	46.1	The main source of credit	
46.2	46.2	Loan provision for others in past year	
47.1	x	Types of insurance policies held	Not relevant ito framework
48.1	48.1	Tenant or owner of the house	
48.2	x	Age of building	Not relevant ito framework
48.3	x	Number of rooms in the house	Not relevant ito framework
48.4	x	The estimated value of the house	Not relevant ito framework
48.5	x	Need for maintenance or renovations	Not relevant ito framework
48.6	x	The primary construction material of the house	Not relevant ito framework
49.1	49.1	Possession of a boat	
49.2	x	Type, number and size of the boat owned	Not relevant ito framework
49.3	x	Type, number and size of the boat owned	Not relevant ito framework
50.1	x	Possession of freshwater tank	Not relevant ito framework
50.2	x	The primary source of drinking water	Not relevant ito framework
51.1	x	The main source of energy	Not relevant ito framework
51.2	x	The primary source of water heating	Not relevant ito framework
52.1	x	The primary source of cooking fuel	Not relevant ito framework
53.1	x	Possession of own toilet	Not relevant ito framework
53.2	x	Type of toilet	Not relevant ito framework
53.3	x	Route of waste water	Not relevant ito framework
53.4	x	Disposal of rubbish	Not relevant ito framework

Question in SA Gulls Survey	Question included in the Thematic framework	Indicator (original survey)	Rationale for omission
54.1	54.1	Observed changes in communities' marine resources during a lifetime	
54.2	x	Main causes of these changes	Not relevant ito framework
54.3	54.3	Perception of changes in the local sea habitat	
54.4	x	Factors cause fish number declines locally	Not relevant ito framework
54.5	x	Methods to help increase fish numbers locally	Not relevant ito framework
54.6	54.6	Perception of overharvesting of marine resources locally	
54.7	54.7	Observed changes to livelihood due to changes in marine environment locally	
55.1	x	Relative confidence in calling on someone for help financially (4-point scale)	Not relevant ito framework
56.1	56.1	The degree of involvement in community decision making (4-point scale)	
56.3	56.3	The degree of involvement in MPA management/decision making (4-point scale)	
57.1	x	The strength of community leadership	Not relevant ito framework
57.4	x	Accessibility of community leadership	Not relevant ito framework
58.1	x	Equality of access and control over livelihoods and resources between men and women	Not relevant ito framework
58.2	x	The degree of vulnerability to future harm among different community members	Question poorly answered.
59.1	59.1	Perception of the relationship of the role of technology and skill of fishers (4-point scale)	
59.2	59.2	Confidence in own skills resulting in success in the fishing industry (4-point scale)	
60.1	60.1	Ability to endure some income shocks (4-point scale)	
60.2	60.2	Possibility to access financial reserves during periods without work	
61.1	x	Amount of money owed on main assets	Not relevant ito framework
61.2	x	Number of possessions/assets in good condition	Not relevant ito framework
62.1	62.1	Relative diversity of marine habitat locally (4-point scale)	
62.2	62.2	Perception of change in fish numbers in the past five years (4-point scale)	
62.3	62.3	Perception of change in the marine environment in the past five years (4-point scale)	
64.1	64.1	Sea level (Increase/ Decrease/ Same)	
64.2	64.2	Rain (Increase/ Decrease/ Same)	
64.3	64.3	Wind (Increase/ Decrease/ Same)	
64.4	64.4	Air temperature (Increase/ Decrease/ Same)	
64.5	64.5	Wave height (Increase/ Decrease/ Same)	
64.6	64.6	Current strength (Increase/ Decrease/ Same)	
64.7	64.7	Rough seas (Increase/ Decrease/ Same)	
64.8	64.8	Sea temperature (Increase/ Decrease/ Same)	
64.9	64.9	Bottom temperature (Increase/ Decrease/ Same)	

Question in SA Gulls Survey	Question included in the Thematic framework	Indicator (original survey)	Rationale for omission
65.2	65.2	Perception of safety in current livelihood despite environmental/climatic exposure	
66.1	66.1	The occurrence of large storms in past five years (moment –adverse; longtime – advantageous)	
66.2	66.2	Personally, directly impacted by storm	
66.3	66.3	The degree of damage to household	
66.4	x	Action taken to prevent future large storm damage	
66.5	x	Action taken to prevent future large storm damage	
66.6	66.6	Number fishing days lost to large storms in past year	
67.1	x	Household in area prone to flooding	
67.2	67.2	The occurrence of floods in the past five years	
67.3	67.3	Personally, directly impacted by flood	
67.4	x	The degree of damage to household	
67.5	x	Action taken to prevent future flood damage	
67.6	x	Action taken to prevent future flood damage	
67.7	67.7	Number fishing days lost to floods in past year	
68.1	68.1	The occurrence of drought in the past five years	
68.2	68.2	Personally, directly impacted by drought	
68.3	x	The degree of damage to household	
68.4	x	Action taken to prevent future drought damage	
68.5	x	Action taken to prevent future drought damage	
68.6	68.6	Number fishing days lost to droughts in past year	
69.1	69.1	The occurrence of shoreline changes in the past five years	
69.2	69.2	Observation of shoreline erosion by the sea locally	
69.3	69.3	Degree of beach erosion over the last five years	
69.4	x	Impact of shoreline erosion on livelihood (Increase/ Decrease/ Same)	
70.1	70.1	Response to possible change in primary livelihood (fishing) - what will you do if weather conditions continue to worsen or change?	
70.2	70.2	Response to possible change in primary livelihood (fishing) - what will you do if it becomes too difficult to find fish?	
70.3	70.3	Response to hypothetical change in primary livelihood (fishing) - what will you do if catches decline with 50%	
70.4	70.4	Response to possible change in primary livelihood (fishing) - what will you do if market prices drop by 50% and remain there?	
71.1	71.1	Presence of climate change centred institutions or government departments in the area/community	
71.2	x	Types of institutions working with the community on climate change issues	
72.1	72.1	Attitude/Perception of climate change	
72.2	72.2	Do you think the climate has changed over time?	
72.3	x		Not relevant ito framework

Question in SA Gulls Survey	Question included in the Thematic framework	Indicator (original survey)	Rationale for omission
72.4	x		Not relevant ito framework
73.1 - 73.7	73.1 - 73.7	Household expenses	
74.1 – 74.16	74.1 – 74.16	Number of assets owned from the list of 16 items	

Table C2. Rationale table and scoring for GULLS household survey questions included in the present analysis of stressors from a crew perspective and revised.

Broad theme	Sub Theme	Q No	Survey Question	Indicator	Rating/scoring method	Notes
		Detailed household data		Age of participant	1=20-29; 2=30-39; 3=40-49; 4=50-59; 5 =	
				Town	1=Bitouville 2=Melkhoutfontein 3=Mossel Bay; 4=Slangrivier; 5=Vermaaklikheid	
Fishing Business (FB)		1.1	Is fishing your main	Fishing main Occupation	yes = 4, no = 1, N/A=0	
		3.1	Do you own your own fishing business (the licenses to go fishing)	Possession of own fishing business	yes = 4, no = 1, N/A=0	
		1.6	What is the average distance from the coast that you fish at now?	Average distance from the coast where fishing takes place	1= 0-5km; 2= 6-15km; 3=16-25km; 4=26-35km; 5= more than 35km; 6 = species dependent; 7 = unsure; 0= not applicable	Categories kept intact to increase resolution of data.
		1.7	Has this average distance increased, decreased or not changed in the time you have been fishing?	The directionality of any change in the distance from the coast where fishing takes place now compared	Changed = 4 or not changed = 1; Not applicable = 0	No of participants did not answer question categorised as N/A
		1.2	How many days per week do you go fishing?	Average number of days spent fishing per week	Every day=1; 2 - 3 days a week=3; 3 - 5 days a week=2; 1 to 2 days a week (deck boat trawlers (trips exceeding 24 hours) =4; weather dependent=5; N/A=0	Categories kept intact to increase the resolution of data.
		1.3	What is the average (typical) length of a fishing trip?	Average time spent fishing per trip	1 -6 hours =1; 7 - 12 hours=2; 12 - 24 hours=3; 1-7 days = 4; more than one week=5; Not applicable=0	Categories kept intact to increase resolution of data.

Broad theme	Sub Theme	Q No	Survey Question	Indicator	Rating/scoring method	Notes
Education/skill/ knowledge (EDU)		39.1	What is the highest level of education reached by you	The highest level of formal education attained	7-point scale: 0= NA/No answer; 1=None, 2=started primary, 3= finished primary, 4= started secondary, 5=finished secondary, 6= technical/artisanal training, 7= tertiary degree;	Used GULLS scoring
Education/skill/ knowledge (EDU)		10.4	Have you done any courses to improve your employability?	Have courses been taken to improve employability	yes = 4, no = 1, N/A=0	
		10.5	If yes, what courses were they?	Which courses were completed	1=Agriculture/Gardening; 2=courses directly linked to fishing business (e.g. skipper, radio, maritime safety); 3= Artisan (incl carpentry, chainsaw operator, welding etc.); 4 =Maritime related (diving etc.); 5 = building/engineering etc.; 6=Other (incl financial management); 7=NA-Retired 0=N/A	Categorised per industry in which the courses reside.
		22.2	How interested are you in learning new skills outside of your area of expertise?	Level of interest to learn new skills outside of fishing (4-point scale)	1= Very interested, 2= interested; 3= Slightly Interested; 4= Not interested; 0 = N/A (no response recorded)	ack of interests in learning new skills = reduced AC
		40.1	Do you have basic skill in any of the following fields?	Possession of skill sets outside of fishing related activities	1= Gardening; 2= Electronics; 3 = First Aid; 4 = Mechanics; 5 = Welding, Building, masonry; 6=other (including wood cutting & thatching); 0= none/NA	More skills = increased AC
		59.1	Would you say that, with the technology available to the industry now, that anyone or only certain people can be a skilful fisher?	Perception of the relationship of the role of technology and skill of fishers (4-point scale)	1=Everyone; 2=Many people; 3=Some people; 4= Very few People; 0 = No Answer	

Broad theme	Sub Theme	Q No	Survey Question	Indicator	Rating/scoring method	Notes
		59.2	How confident are you that your skills will mean that you are successful in the	Confidence in own skills resulting in success in fishing industry (4-point	1= very confident; 2=confident; 3= Slightly confident; 4=not at all confident;0=NA/No answer	
A biophysical system component (B)	**Fishing (FISH)**	1.8	List the three most important fish species you target for commercial purposes?	Three most commercially important species	1= Kob, 2=Silvers; 3= Sharks; 4= Red Fish; 5= Grunter; 6=Hake;7=Sole;8=Kingklip; 9=Maasbunker;10=Kolstert; 11=Snapper; 12=Dassie; 13=Geelbek; 14=Geelstert; 15=Leervis; 0=NA/No answer	
The biophysical system component (B)	**Marine Env (MEnv)**	1.9	Have these top three species changed in the past five years?	Observed change in main target fish species in past 5 years	1 = yes; 4= no; 0 = no answer	
		33.1	Have these top three species changed in the past five years?	Perceived level of danger to fishing from weather changes	Very dangerous=1, Dangerous=2; Slightly dangerous = 3; Not at all = 4; NA/No answer=0	
		33.2	How difficult has it become to catch fish in the area's you fish?	Degree of difficulty in finding/catching fish compared to the past	Very difficult=1, difficult=2; Slightly difficult = 3; Not difficult at all = 4; NA/No	
		34.3	How many ideas would you say you have about how to ensure the sustainability of the main species you catch?	Number of ideas held to ensure the sustainability of the target fish species locally	Many ideas=1; Some ideas=2; Few ideas=3; No ideas=4; NA/No answer = 0	
		62.2	How diverse (number of species) is the marine habitat of your community?	Perception of change in fish numbers in the past five years (4-point scale)	Big increase in diversity=1; Increase in diversity=2; Decrease in diversity =3; Big decrease in diversity=4; NA/No answer =0	fewer fish = reduced adaptive capacity, increased vulnerability. Some fishers' responses were outside scale (same) = scored as N/A
		20.1	How much do you think you know about the environment in which you fish?	Level of knowledge about the marine environment	A lot of knowledge = 1; Quite a lot of knowledge=2; A little knowledge= 3; Nothing =4; NA/No answer = 0	

Broad theme	Sub Theme	Q No	Survey Question	Indicator	Rating/scoring method	Notes
		22.4	How possible is it for you to make a personal difference in improving the health of the marine environment in this area?	Perception of possibility to personally improve the marine environment (4-point scale)	Very possible=1; Possible, 2; Slightly possible=3; Impossible=4; No answer/NA=0	lack of motivation/ positivity (?) = reduced AC
		24.1	How responsible do you feel to protect the marine environment?	Perception of responsibility to protect the marine environment (4-point scale)	Very responsible=1; responsible= 2; Slightly responsible=3; Not at all responsible=4; No answer/NA=5	lack of responsibility = reduced AC
		33.3	How many changes would you say you have noticed in the marine species you see?	Number of changes in marine species observed locally	Many changes=1; changes= 2; Few changes=3; No changes=4; No answer/NA=0	
The biophysical system component (B)	**Access to resources (ACC)**	54.1	Have you noticed changes in your communities' marine resources during your lifetime?	Observed changes in communities' marine resources during a lifetime	yes=1, no=4; NA/No answer = 0	
		54.3	Do you think that the sea habitat in your area is	Perception of changes in the local sea habitat	The same as it always was =1; slightly damaged = 2; badly damaged = 3; irrecoverably damaged =4; improved since you were a child=5; Don't know/Not answered=0	
		54.6	Do you think your local marine resources are being over-harvested now?	Perception of overharvesting of marine resources locally	yes=1, no=4; NA/No answer = 0	
		62.1	How diverse (number of species) is the marine habitat of your community?	Relative diversity of marine habitat locally (4-point scale)	Very high=1; high=2; low=3; very low=4, Same/NA=0	less biodiversity = reduced adaptive capacity
		62.3	Has the marine environment worsened or improved over the past five years?	Perception of change in the marine environment in the past five years (4-point scale)	Improved a lot=1; Improved=2; worsened =3; Worsened a lot=4; Same/NA=0	more damage = reduced adaptive capacity, increased vulnerability

Broad theme	Sub Theme	Q No	Survey Question	Indicator	Rating/scoring method	Notes
		18.1 & 18.2	Would you say there are too many or too few fishers in the fishing industry in this community? Would you say there are too many or too few fishers working in the area's you fish?	Perception of whether too many or too few fishers operate in the community (4-point scale)	Too many=1; Slightly too many=2; Slightly too few=3; Too few=4; NA/Not answered=5	fewer fishers = reduced competition and reduced sensitivity/vulnerability
	Climate change/ climate exposure (CC)	72.1	Have you ever heard of climate change?	Have you ever heard of climate change?	yes=4, no=1; NA/No answer = 3	
		72.2	Do you think the climate has changed over time?	Do you think the climate has changed over time?	yes=4, no=1; NA/No answer = 4	
		65.2	How safe do you feel you are in your main occupation in the context of climatic exposure?	Perception of safety in current livelihood despite environmental/climatic exposure		
The biophysical system component (B)	**Climate change/ climate exposure (CC)**	64.1	Increase or decrease past 5 years	Perception of changes in sea level	same = 1, change = 4; not answered = 0	
		64.2	Increase or decrease past 5 years	Perception of changes in Rainfall patterns	same = 1, change = 4; not answered = 0	
		64.3	Increase or decrease past 5 years	Perception of changes in wind speed	same = 1, change = 4; not answered = 0	
		64.4	Increase or decrease past 5 years	Perception of changes in air temperature	same = 1, change = 4; not answered = 0	
		64.5	Increase or decrease past 5 years	Perception of changes in wave height	same = 1, change = 4; not answered = 0	
		64.6	Increase or decrease past 5 years	Perception of changes in current strength	same = 1, change = 4; not answered = 0	

Broad theme	Sub Theme	Q No	Survey Question	Indicator	Rating/scoring method	Notes
		64.7	Increase or decrease past 5 years	Perception of changes in sea state	same = 1, change = 4; not answered = 0	
		64.8	Increase or decrease past 5 years	Perception of changes in sea surface temperature	same = 1, change = 4; not answered = 0	
		64.9	Increase or decrease past 5 years	Perception of changes in bottom temperature	same = 1, change = 4; not answered = 0	
		66.1	Has there been a large storm in the last five years in your area?	Occurrence of large storm in past 5 years (moment – adverse; long time –	same = 1, change = 4; not answered = 0	
		66.2	Were you directly impacted by the large storm?	Personally, directly impacted by storm	same = 1, change = 4; not answered = 0	
		66.3		The degree of damage to household		
The biophysical system component (B)	**Climate change/ climate exposure (CC)**	66.6	How many fishing days did you lose due to the large storms in the past year?	Number fishing days lost to large storms in past year		
		67.2	Has there been a Flood in the last five years in your area?	Occurrence of floods in past 5 years	yes=1, no=4; NA/No answer = 0	
		67.3	Were you directly impacted by the Flood?	Personally, directly impacted by flood	yes=1, no=4; NA/No answer = 0	
		67.7	How many fishing days did you lose due to the Flood in the past year?	Number fishing days lost to floods in past year		

Broad theme	Sub Theme	Q No	Survey Question	Indicator	Rating/scoring method	Notes
		68.1	Has there been a Drought in the last five years in your area?	Occurrence of drought in past 5 years	yes=1, no=4; NA/No answer = 0	
		68.2	Were you directly impacted by the Drought?	Personally, directly impacted by drought	yes=1, no=4; NA/No answer =0	
		68.6	How many fishing days did you lose due to the Drought in the past year?	Number fishing days lost to droughts in past year	1-5, positive, x/5*4	
		69.1	Has the shoreline in your village/area changed over the years?	Occurrence of shoreline changes in past 5 years	yes = 4, no = 1; NA/No answer =0	
		69.2	Have you noticed places in your area where the shoreline has been eroded by the sea?	Observation of shoreline erosion by the sea locally	yes = 4, no = 1; NA/No answer =0	
		69.3	How much of the beach has eroded in the last five years?	The degree of beach erosion over the last five years	1-5, positive, x/5*4; NA/No answer =0	
Social and economic system component (SE)	**Income (household finances) (Inc)**	2.1	Is there much variation in your household income between the summer and the	Monthly income	yes = 4, no = 1, N/A=0	
		2.2	What is your average household income per month before tax and from all sources?	Monthly income	<R1000=1; R1000 - R2500=2; R2500-R5000=3; R5000-R7500=4; R7500-R10000=5; >R10000=6; No answer=0	Rating based on rating in the survey. Some responded with individual incomes, some with household (many time respondents did not disclose how much other household members were earning).

Broad theme	Sub Theme	Q No	Survey Question	Indicator	Rating/scoring method	Notes
		7.3	What is the most important food source for your family's household?	Relative importance of household's food source	grow in garden =1; buy local shops=2; fish for food/small portion from catch=3; collect food from the bush/sea=4; other=5	
		22.1	How well have you planned for your financial security?	Level of financial planning (4-point scale)	Very well planned =1; Well Planned=2; Planned a little=3; No plan at all =4, No	lack of planning = reduced AC
		29.4	How possible is it to guess how much money your business will make each month?	Possibility to predict money made each month by your business (4-point scale)	Very possible=1; Possible=2; Slightly possible=3; Impossible =4, No answer/NA=0	less predictable income = decreased AC
		43.1	Does each working household member contribute to basic household expenses (electricity, food, water etc.)?	Contribution of each household members' income to household expenses	yes = 4, no = 1; No Answer/NA/Not sure = 0	
		43.2	If you needed cash today for an emergency – would you be able to get that cash?	Possibility to obtain cash for an emergency today	yes = 4, no = 1; No Answer/NA/Not sure = 0	
		44.1	Do you have any savings or money put aside for emergencies?	Presence of savings for emergencies	yes = 4, no = 1; No Answer/NA/Not sure = 0	
	Income (household finances) (Inc)	45.1	Do you have a mortgage on your house?	Mortgage repayments	yes = 4, no = 1; No Answer/NA/Not sure = 0	
Social and economic system component (SE)	**Income (household finances) (Inc)**	45.3	Do you owe money to anyone (aside from a mortgage on your house)?	Money owed excluding mortgage	yes = 4, no = 1; No Answer/NA/Not sure = 0	

Broad theme	Sub Theme	Q No	Survey Question	Indicator	Rating/scoring method	Notes
	Access to capital (Acc)	46.1	Who/where do you normally borrow money from?	Main source of credit	Family & Friends=1; Large companies=2; Small money lender=3; Banks=4; Other =5; No Answer/NA=0	Access to formal lending institutions will score higher. (5 =Other incl 'skipper', 'employer ' & "no-one" response; (most
		46.2	Have you loaned money to anyone in the last year?	Loan provision for others in past year	yes = 4, no = 1; No Answer/NA/Not sure = 0	lending money = disposal income, increased adaptive capacity
		60.1	How possible is it for you to endure some income shocks if it should occur?	Ability to endure some income shocks (4-point scale)	Very possible=1; Possible, 2; Slightly possible=3; Impossible=4; No answer/NA=0	inability to survive income shocks = decreased adaptive capacity
		60.2	How possible is it for you to access financial reserves if you end up without work for a while?	Possibility to access financial reserves during periods without work	Very possible=1; Possible, 2; Slightly possible=3; Impossible=4; No answer/NA=0	inability to access funds = decreased adaptive capacity
	Employment and livelihood (Emp)	27.3	How important is fishing as an economic activity in this community?	Relative importance of fishing as economic activity locally (4-point scale)	Very important =1; Important=2; Important=3; Not at all Important =4, No answer/NA=0	
		10.1	Right now, if you had a chance would you: Change your job/Stay doing what you are doing	Level of interest in changing employment	change = 4; stay = 1; 0= no answer/NA	
		10.2	At this time, do you feel you could find work in a different sector?	Perception of finding work in alternative sector	yes = 4, no = 1; 0=no answer/NA = 0	
The social and economic system component (SE)	Employment and livelihood (Emp)	10.3	How many options for a different type of job/work would you say you have?	Number of options for alternative work	Many options=1; Some options=2; Few Option=3; No options =4; NO answer/NA=0	

Broad theme	Sub Theme	Q No	Survey Question	Indicator	Rating/scoring method	Notes
		10.6	Would you be happy working for someone else? If so, why?	Level of interest in working for someone else	yes- 4, no = 1, N/A = 0	
		26.1	How useful would your skills be in setting up a business other than in fishing?	Perception of the utility of own skills to set up a business outside of fishing (4-point scale)	Very useful =1; Useful=2; Slightly useful=3; Not at all useful =4, No answer/NA=0	more useful skills = greater adaptive capacity
		28.1	How often are you employed in more than one job per year?	Level of occupational diversity throughout the year	Very often=1; often=2; Rarely=3; Never=4, No answer/NA=0	more jobs = higher AC; less jobs = higher sensitivity
		28.2	How willing are you to move to a bigger town or community for work if necessary?	Willingness to relocate for livelihood purposes (4-point scale)	Very willing =4, Willing=3, Slightly willing =3, Not willing at all=4 No answer/NA=0	willingness to move = increased AC
		42.1	Is it easy to find work outside of fishing if you are known to be a fisher?	The degree of difficulty in finding alternative work if known as a fisher	yes = 4, no = 1; No Answer/NA/Not sure = 0	
		11.1	Have you had a change in employment in the past five years?	Number of employment changes in the past five years	Cannot be scored.	Do not see how occupations can be ranked in a way that would be comparative.

Broad theme	Sub Theme	Q No	Survey Question	Indicator	Rating/scoring method	Notes
The social and economic system component (SE)	Employment and livelihood (Emp)	11.2	If so, what was your previous occupation?	If yes in 11,1, what work (work available to fishers/work fishers willing to engage in)	Tourism=1, Aquaculture=2; Office work=3; Masonry/Carpentry/Daily wage labour=4; Service industry =5; Different fishing sector =6; Mining=7; Other (including retired) =8	Use the same categories as for 11.6, Most responses, gardening and building work
		11.6	List the alternative employment sectors that you would consider taking another job in	Factors and types of work sought in a different livelihood activity	Tourism=1, Aquaculture=2; Office work=3; Masonry/Carpentry/Daily wage labour=4; Service industry =5; Different fishing sector =6; Mining=7; Other (including	8= included respondents that were not sure had retired or were recorded as NA in this category.
		11.7	What do you see as the biggest risk to the fishing livelihoods in this community?	Factors affecting fishing livelihoods	The market=1; Environmental change=2; Reduced fish abundance=3; Injury/Health=4; Management Changes=5; Other=6	Other - payment and treatment by boat owners. Another participant answered "nothing", petrol, distance from the coast, fish prices
		17.2	How possible would it be to feed your family if you did not go fishing?	Possibility to feed family without fishing	Highly possible=1; Possible=2; Slightly possible=3; Not at all possible=4, No answer/NA=0	
		35.1	When I need help financially or regarding food or basic needs, I ask for assistance from:	The main source of assistance when having financial, food or basic needs	Family=1; Friends;2; Loans=3; Neighbours=4; local organisation=5; Other=6; No Answer/NA=0	

Broad theme	Sub Theme	Q No	Survey Question	Indicator	Rating/scoring method	Notes
		54.7	Have you noticed any changes to your livelihood because of changes to the marine habitat?	Observed changes to livelihood due to changes in marine environment locally	yes = 4, no = 1; No Answer/NA/Not sure = 5	
The social and economic system component (SE)	Markets and fishing (MRK)	12.2	By which avenue do you sell your fish?	Number and type of avenue to sell fish	local individual fish buyer=1; Directly off boat (direct to public) =2; Large processor (large company) =3; Middlemen=4; Other/NA=5	Often intermediaries selling to big companies; Some fishers indicated catches sold to skippers and then big companies - this has been rated as selling to middleman as skipper becomes middleman).
		12.3	If you sell through intermediaries, how would you describe your relationship with intermediaries in this community?	Nature of relations between members of the market chain	acrimonious/ bad =1, fair=2, good=3, excellent=4; Not involved in process, NA, not sure =0	Better relationship = increased AC
		12.6	Do you ever sell fish to a fish market outside your community?	Possibility of selling fish outside the community	yes = 4, no = 1; NA, not sure =0	
		12.9	Have fish prices been relatively stable over the past three years?	Stability and factors controlling the local fish price	Increase=1; Same= 2; Unstable=3; Decrease=4; No answer/NA=0	Price instability and decreases will have a negative impact on AC, but an increase will be positive.
		12.10	What do you think dictates the price of fish most in the local market?	Stability and factors controlling the local fish price	Power of middleman=1; Price fisher demands=2; Quantity of fish available on day=3; Other=4; Don't know/NA=0	"Other includes the price of petrol and price demanded by companies.
	Physical capital (PHY)	48.1	Do you own or rent the house you live in?	Tenant or owner of house	own = 4, not own/not rent =2; rent = 1; NA/No answer=0	House ownership increases capital, increases adaptive

Broad theme	Sub Theme	Q No	Survey Question	Indicator	Rating/scoring method	Notes
		49.1	Do you own a boat?	Possession of a boat	boat ownership: yes = 4, no=1; No answer/NA=0	Boat material can be included qualitative information.
		74.1 – 74.16	Number of assets owned from the list of 16 items	Number of assets owned from the list of 16 items		
Culture (historical dependence on fishing) (CUL)		8.1	How long have you been a fisher?	Length of time as a fisher	8-point scale: 0-5=1, 6-15=2, 16-25=3, 26-35=4, 36-45=5, 46-55=6, 56-65=7,	
		8.2	When did the fishery, you are involved with begin in this area?	Age of the fishery	Purely descriptive information was not relevant for comparative usage. Excl from the main datasheet.	Age of industry may suggest historical dependence but only if respondents have long personal and family history of involvement with the fishery.
		8.3	Were previous generations of your family/ancestors' fishers?	Extent of ancestral involvement in fishing	yes = 4, no = 1; No Answer/NA/Not sure = 0	
		8.5	Would you describe your family as having a fishing identity/culture?	Perception of a "fishing" family identity	yes = 4, no = 1; No Answer/NA/Not sure = 0	
		11.4	Would you be interested in doing a job other than fishing if you could earn as much as you do fishing?	Level of interest in working in non- fishing sector	yes = 4, no = 1; No Answer/NA/Not sure = 0	

Broad theme	Sub Theme	Q No	Survey Question	Indicator	Rating/scoring method	Notes
		9.1	What is/was the main occupation of your parents? (Mother/Father)	The difference in occupation from parents		Descriptive information. Not included in the main spreadsheet.
		9,2 (a)	Did your parents attend school? (father)	Level of schooling of parents (father)	Education Father = yes=1, No=4; No Answer/NA/Not sure = 0	
Culture (historical dependence on fishing) (CUL)		9,2 (b)	Did your parents attend school? (Mother)	Level of schooling of parents (Mother)	Education Mother = yes=1, No=4; No Answer/NA/Not sure = 0	
		9.3 (a)	To what level did your parents attend school? (father)	Level of schooling of parents (father)	7 -point scale: 0= NA/No Answer 1=None, 2=started primary, 3= finished primary, 4= started secondary, 5=finished secondary, 6= technical/artisanal training, 7= tertiary degree;	Used GULLS scoring
		9.3 (b)	To what level did your parents attend school? (mother)	Level of schooling of parents (Mother)	7-point scale. 0= NA/No Answer 1=None, 2=started primary, 3= finished primary, 4= started secondary, 5=finished secondary, 6= technical/artisanal training, 7= tertiary degree;	Used GULLS scoring
		9.4	Did your parents own their own house?	Home ownership of parents' vs interviewee	yes = 4, no = 1; No Answer/NA/Not sure = 0	
		9.5	Did your parents own their boat?	Boat ownership of parents' vs interviewee	yes = 4, no = 1; No Answer/NA/Not sure = 0	

Broad theme	Sub Theme	Q No	Survey Question	Indicator	Rating/scoring method	Notes
		14.1	Would you say you feel like you belong or do not belong to this community/town?	The feeling of belonging to the community (4-point scale)	Strongly belong=1; Belong=2; Slightly belong=3; Not at all belong=4, No answer/NA=0	
		14.4	How important are the friendships/relationships you have in this town?	Importance of friendships in the community	Very important =1; Important=2; Important=3; Not at all Important =4, No answer/NA=0	
		16.4	How proud are you to tell people that you are a fisher?	The degree of pride in telling others one is a fisher (4-point scale)	Very Proud=1; Proud=2; Slightly proud=3; Not proud at all=4; NA/not important =0	lack of pride indicates lower attachment to a fishing
Culture (historical dependence on fishing) (CUL)		16.6	Would you like your children to continue in the fishing profession?	Level of interest in one's children becoming fishers (4-point scale)	Like very much=1; Like=2; Not like=3; Not like at all=4; NA/not important =0	not wanting children to stay in industry indicates low attachment
		19.2	How concerned are you by the lack of young people entering the fishing industry in your area?	Concern regarding the continuation of fishing as a livelihood among the next generation	Very concerned=1; Concerned=2; Slightly concerned=3; Not concerned at all=4; NA/not important=0	greater concern = less sensitivity
		20.2	How important do you think it is to pass on local knowledge about fishing to younger generations?	Importance to ensure LEK is passed on to younger generations	Very important =1; Important=2; Important=3; Not at all Important =4, No answer/NA=0	
		20.3	Would you say local knowledge about fishing is being lost or maintained in this community?	Relative maintenance of LEK between generations	Well maintained =1; Maintained=2; Partly lost=3; Almost all lost =4, No answer/NA=0	
Management/governance (MNG)		13.1	Does your community have any type of marine resource management?	Presence of natural resource management institutions in	yes = 4, no = 1; No Answer/NA/Not sure = 0	

Broad theme	**Sub Theme**	**Q No**	**Survey Question**	**Indicator**	**Rating/scoring method**	**Notes**
		13.3	Have rules; practices changed in the past in response to environmental changes?	Level to which rules have changed due to environmental changes	yes = 4, no = 1; No Answer/NA/Not sure = 1	
		18.3	How concerned are you about the level of illegal fishing that is occurring?	Degree of concern about illegal fishing levels locally (4-point scale)	Very concerned=1; Concerned=2; Slightly concerned=3; Not concerned at all=4; No answer/NA=0	greater concern = possible higher incidence of illegal fishing, greater sensitivity/vulnerability
Management/governance (MNG)		30.1	Would you say that illegal fishing does not occur or does occur in the community in which you fish?	Relative occurrence of illegal fishing locally (4-point scale)	Occurs a lot=1; Occurs=2; Occurs a little=3; Does not occur at all =4; No answer/NA=0	
		30.6	How common are conflicts between fishers in this area?	Relative occurrence of conflict among fishers (4-point scale)	Very common=1; Common=2; Not very common=3; Not common at all=4; No answer/NA=0	
		31.2	How well linked is this community to government departments and/or academic institutions, so you receive up to date information about fishing?	The strength of links between fishers and institutions or government	Very well linked =1; Well linked=2; Linked slightly=3; Not at all linked =4, No answer/NA=0	poor linkages = reduced adaptive capacity
		56.1	How involved are you in community decision making?	The degree of involvement in community decision making (4-point scale)	Very involved =1; Involved=2; Slightly involved =3; Not at all Involved=4, No answer/NA=0	

Broad theme	Sub Theme	Q No	Survey Question	Indicator	Rating/scoring method	Notes
		56.3	How involved are you in marine protected area management?	The degree of involvement in MPA management/decision making (4-point scale)	Very involved =1; Involved=2; Slightly involved =3; Not at all Involved=4, No answer/NA=0	
Attitude to change (ATT)		21.1	How used would you say you are to the changes in everyday life?	Level of habituation to changes in everyday life (4-point scale)	Very used to it=1; Used to it=2; Not used to it=3; Not at all used to it =4, No answer/NA=0	ability to accommodate change = increased AC
		21.2	Would you say that only big companies or only small-scale fishers will survive future changes in the industry?	Perception of which user groups are most at risk to future changes (4-point scale)	Small-scale fishers=2; More small scale than big company=2; More big companies than small scale=3; Only big companies=4; NA/No answer=0	If only big players will survive, no room for smaller companies to adapt/ survive; lack of positivity = reduced AC
		23.1	How confident are you that things will turn out well regardless of the changes and challenges you confront?	Level of confidence that events will work out well regardless of everything else (4-point scale)	Very confident=1; Confident=2; Slightly confident=3; Not at all confident=4; No answer/NA=0	less confidence = decreased adaptive capacity
Attitude to change (ATT)		32.1	How much of a risk do you think environmental change poses to the community you live in?	Perceived level of risk to the community from environmental change (4-point scale)	Very well linked=1; Well linked=2; Linked slightly=3; Not at all linked=4; No answer/NA=0	
		32.3	How anxious/scared do you feel about the changes you see in the environment in your area?	The degree of anxiety felt about environmental changes observed locally	Very scared/anxious=1; Scared/anxious=2; Little scared/anxious=3; Not at all scared/anxious=4, No answer/NA =0	
Adaptation options (ADT)		70.1	What will you do if weather conditions continue to worsen or change?	Response to hypothetical change in primary livelihood (fishing) - what will you do if weather conditions continue to worsen or change?	Seek alt employment/alt income=1; Keep on fishing, carry on as per normal where possible=2; Relocate/target alt species=3; Stop fishing/Unsure=4; No answer NA=0	Pension and grants also alt source of income (one or two people revealed they would stop fishing and go on pension) - scored as =1

Broad theme	Sub Theme	Q No	Survey Question	Indicator	Rating/scoring method	Notes
		70.2	What will you do if it becomes too difficult to find enough fish?	Response to hypothetical change in primary livelihood (fishing) - what will you do if it becomes too difficult to find fish?	Seek alt employment/alt income=1; Keep on fishing, carry on as per normal where possible=2; Relocate/target alt species=3; Stop fishing/Unsure=4; No answer NA=0	
		70.3	What would you do in the event of a 50% decline in fish catches?	Response to hypothetical change in primary livelihood (fishing) - what will you do if catches decline with 50%	Seek alt employment/alt income=1; Keep on fishing, carry on as per normal where possible=2; Relocate/target alt species=3; Stop fishing/Unsure=4; No answer NA=0	
		70.4	What would you do in the event of market prices dropping by 50% and remaining there?	Response to hypothetical change in primary livelihood (fishing) - what will you do if market prices drop by 50% and remain there?	Seek alt employment/alt income=1; Keep on fishing, carry on as per normal where possible=2; Relocate/target alt species=3; Stop fishing/Unsure=4; No answer NA=0	Most =4 responses indicated they would stop fishing without qualifying what they would do instead.
		71.1	Are there institutions or government departments working on climate change or facilitating adaptation to change in the community?	Presence of climate change centred institutions or government departments in the area/community	yes = 4, no = 1, No answer/NA=0	

Appendix D. Appendices for Chapter Four

Appendix D1. Second Iteration Maps and adjustments per town - Mossel Bay

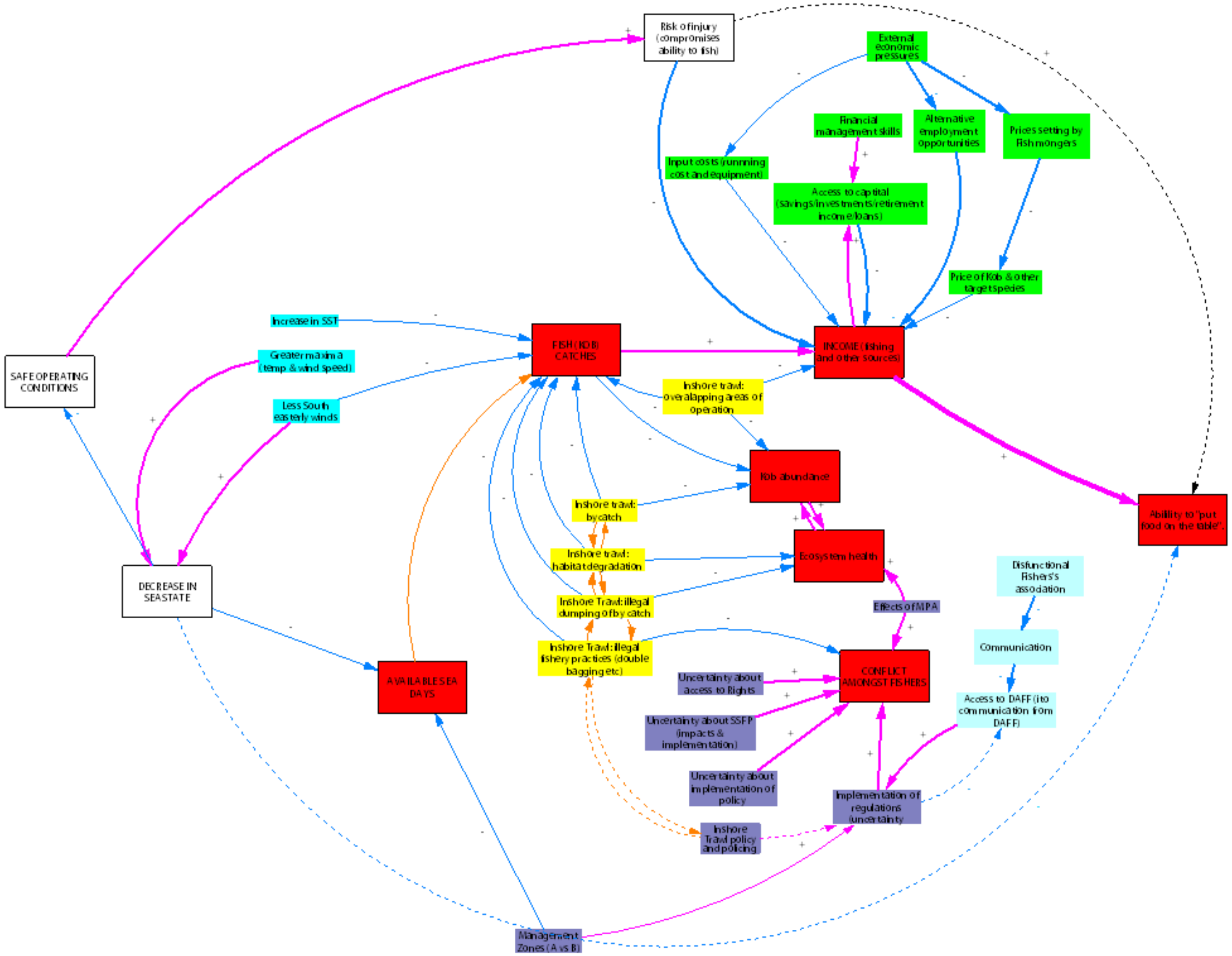

Figure D1. Mossel Bay Causal Map after the digitising of the results of the 2nd iteration. Tables 4.1, 4.2 & 4.3 show the colour coding of the additional links added in this iteration

Table D1. Key Adjustments made to Base map to make the second iteration for Mossel Bay

Action	Detail	Reason
Insertions	'Risk of injury' compromises 'ability to fish' and thus compromises the 'ability to put food on table'	Via direct input to 'income', 'indirect to the ability to put food on the table'
	Effect of external economic pressures on alternative employment opportunities	Dampening effect on 'fishery derived income'
	New variable 'inshore trawl regulation', 'policy & policing' (inserted as indirect feedback between illegal practices and policy & policing	Policies in place for inshore trawl not well policed. Lack of policing allows illegal practices to flourish
	Amplifying indirect input on 'uncertainty about the implementation of regulations'	Primarily centred around uncertainty regarding the implementation of the SSFP
	General 'communication'	Communication from DAFF and skippers is lacking. Creates uncertainty as crew do not feel that they are being informed. Mistrust also grows in information constrained environment.
	'Dysfunctional fishers' association' linked to communication".	Dampening effect on 'communication', dampening effect on 'access to DAFF'. Related to the communication issue above. Importantly, an association not dysfunctional, the crew are just not included.
Deletions	Dampening effect on 'increase in rainfall' on fish catches	Not applicable to Mossel Bay (no river mouth)
Adjustments	Variable 'kob catches' changed to 'fish catches'	More focus on the failure to catch any fish instead of just Kob
	Connect inshore trawl variables	Double arrow to indicate amplifying and dampening effects
	Linked illegal fishery practices in inshore trawl to a new variable 'inshore trawl regulation'	Ineffective regulation and policing reinforce illegal practices.
	'Access to DAFF' amended to 'Access to DAFF' (communication from DAFF).	Interaction amended to dampening and amplifying feedback loop. Poor communication from DAFF increases uncertainty. Better communication from DAFF is required as uncertainty increases.
	Linked 'decrease in sea state' with 'ability to put food on Table'	Indirect, dampening effect

Appendix D2. Second iteration Maps and adjustments per town - Bitouville

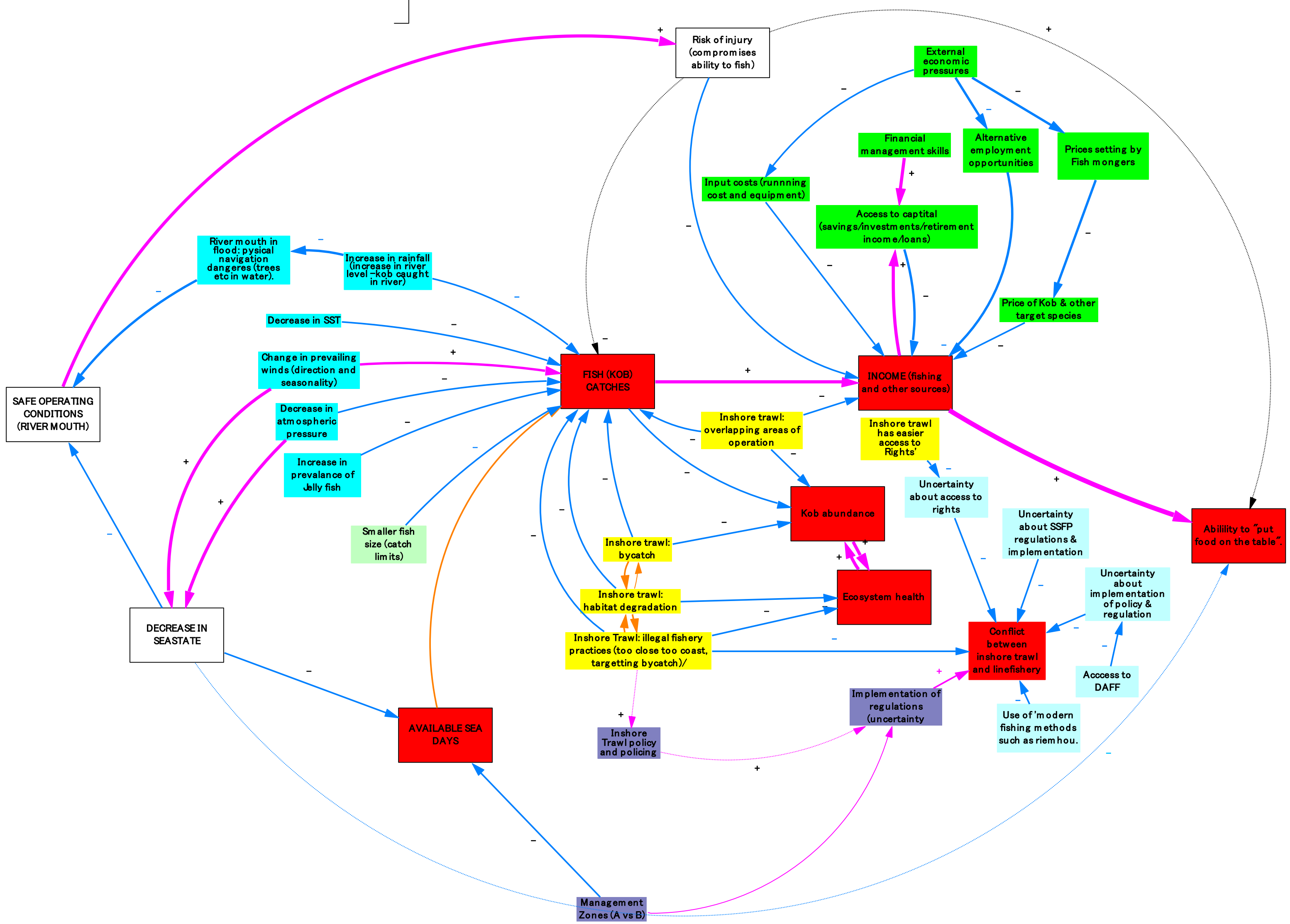

Figure D2. Bitouville Causal Map after the digitising of the results of the 2nd iteration. Tables 4.1, 4.2 & 4.3show the colour coding of the additional links added in this iteration

Table D2. Key Adjustments made to Base map to make the second iteration for Bitouville

Action	Detail	Reason
Insertions	'Effects of flood' (linked to river) – linked to an 'increase in rainfall' and 'safe operating conditions'	Boats launched in the river, exit to sea through river mouth.
	'Risk of injury' compromises 'ability to fish' and thus compromises the 'ability to put food on table'	Via direct input to 'income', indirect to the 'ability to put food on the table'
	'Increased prevalence of jellyfish in the area'	Regarded as a dampening effect on 'fish (kob) catches'
	'Use of modern fishing methods such as 'Riemhou'	Riemhou perceived to have a negative impact on fish catches (sound of the motors chases the fish away) and showed only be used if skippers have no choice. Also alluded to having "informal" rules in each town – fishers from outside (such as Mossel Bay), come into the area and uses techniques such as Riemhou which negatively impacts on the fishers from the area.
Deletions	'Dumping of by-catch'	Trawlers are targeting fish such as kob and landing it as allowable by-catch
Adjustments	'Safe operating conditions' to 'safe operating conditions in the river mouth'	River mouth conditions are seen as the most significant threat to the operation of boats – if they can proceed to sea via river mouth, the sea state on open water should be fine for fishing.
	'Change in prevailing winds' (direction and seasonality), linked as an amplifying effect to a 'deterioration of sea state'	Stronger winds will lead to a deterioration in sea state
	Link 'illegal practices' to 'better policing' (indirect link)	Better enforcement of policies ito the inshore trawl will lead to a cessation of illegal practices

Appendix D3. Second Iteration Maps and adjustments per town - Melkhoutfontein

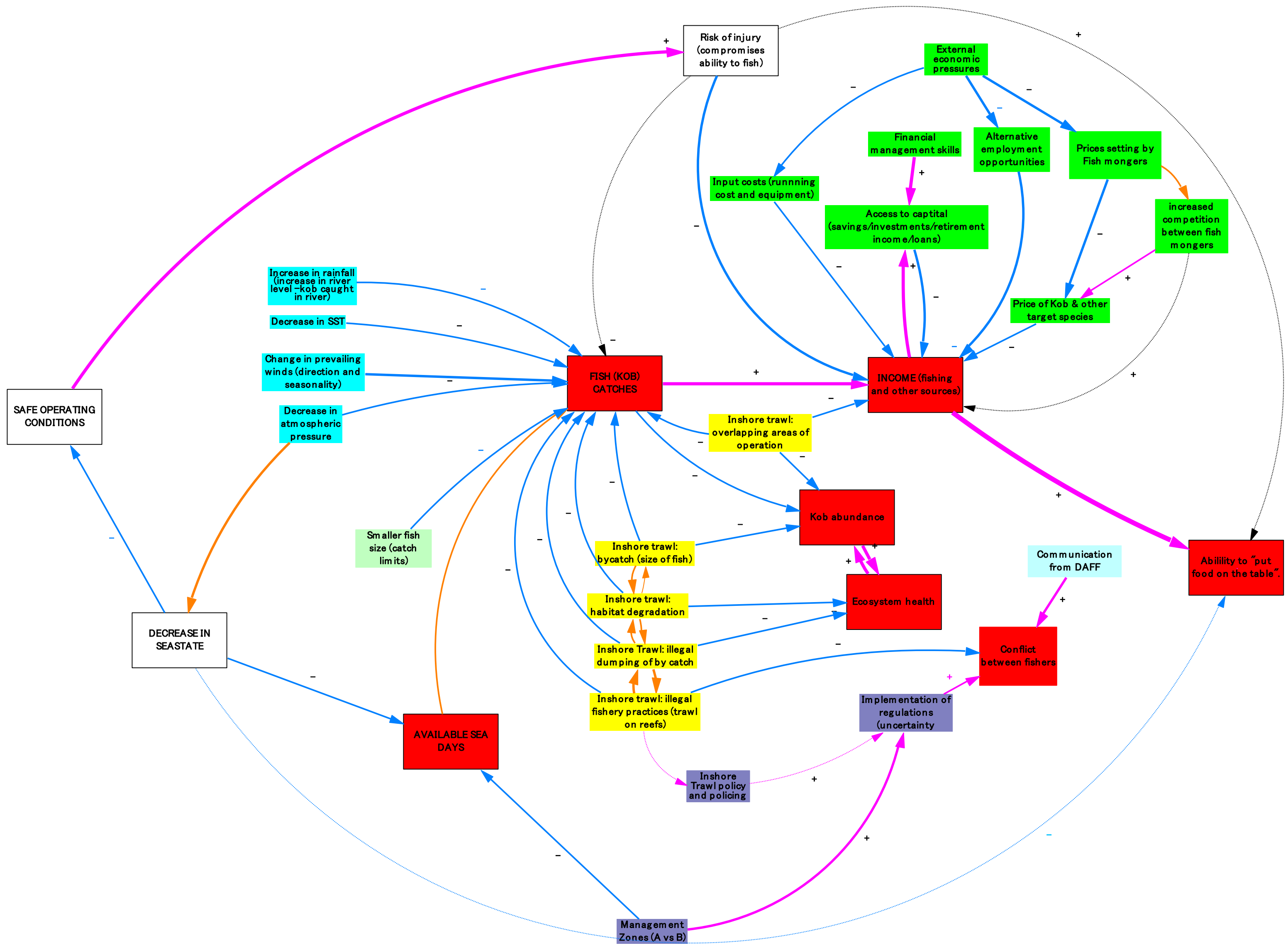

Figure D3. Melkhoutfontein Causal Map after digitising of the results of the 2nd iteration. Tables 4.1, 4.2 & 4.3 show the colour coding of the additional links added in this iteration

Table D3. Key Adjustments made to Base map to make the second iteration for Melkhoutfontein

Action	Detail	Reason
Insertions	'Risk of injury' compromises 'ability to fish' and thus compromises 'ability to put food on table'	Via direct input to 'income', indirect to 'the ability to put food on the table'
	'Increased risk of injury' on 'kob catches'	Indirect (dampening) effect
	'Decrease in atmospheric pressure' non-direction link to 'decrease in sea state'	Fishers did not indicate directionality of forcing. Fisher do however believe the lower air pressure at night had an adverse effect on kob catches (night)
	'Smaller fish size' (fish size limits)	Dampening effect on kob catches. If fishers could land smaller kob, overall kob catches landed would increase.
	'Inshore trawl – policy and policing'	Inshore trawl policies and regulations not enforced or policed effectively.
	'Communication from DAFF'	Amplifying influence on the conflict between fishers. Ineffective communication leads to more uncertainty which allows space for tensions between fishers to increase.
	'Increased competition between fishmongers'	Price setting between fish monger's influences competition. The arrival of an additional fish monger in the Still Bay area led to more competition between the mongers, which caused the fish price paid to fishers to increase. |
Deletions	'Greater maximum temperature'	Not applicable to the area.
	'Access to information'	Fishers are provided information from the Coastal Links NGO.
Adjustments	'Inshore trawl: bycatch' – add 'size of fish'	Inshore trawl can land small fish as part of by-catch.
	'Inshore trawl: illegal dumping fishing practices (double bagging etc.)' changed to 'Inshore trawl illegal fishing practices' (trawling on reefs, dumping of bycatch). Has influence on policy and regulation of the inshore trawl.	Bad policy and enforcement have an impact on illegal practices.

Appendix D4. Second Iteration Maps and adjustments per town - Slangrivier

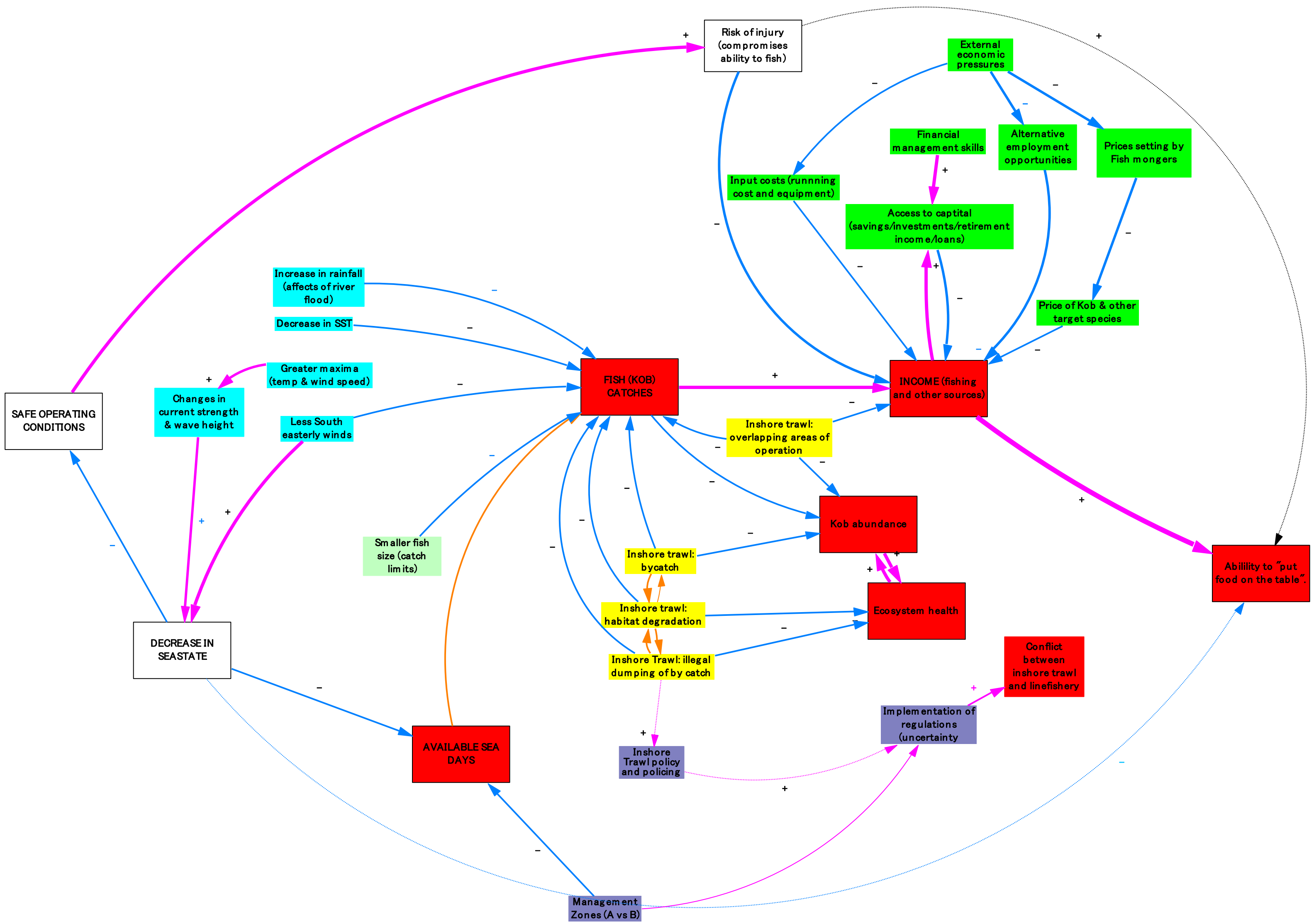

Figure D4. Slangrivier Causal Map after the digitising of the results of the 2nd iteration. Tables 4.1, 4.2 & 4.3 show the colour coding of the additional links added in this iteration

Table D4. Key Adjustments made to Base map to make the second iteration for Slangrivier

Action	Detail	Reason
Insertions	‘Risk of injury’ compromises ‘ability to fish’ and thus compromises ‘ability to put food on table’	Amplifying effect. Via direct ‘input to income’, indirect to the ‘ability to put food on the table’
	‘Decrease in SST’	Dampening effect on kob catches. Kob needs optimal SST range for them to bite.
	‘Current strength and wave height’	Amplifying effect on sea state.
	‘Small fish size ‘(Catch size limits)	Dampening effect on ‘Kob catches landed’. Kob size limits were increased to 600 mm in the last couple of year – many fish caught must now be released. Often just undersize
	‘Conflict between linefishery and inshore trawl fishery’ – moved to be the primary variable (stressor).	The conflict between linefishers is minimal; there is, however, the conflict between fisheries.
	‘Implementation of regulation (uncertainty)’	Amplifying effect on the conflict between inshore trawl and linefishery
Deletions	‘Conflict amongst fishers’	Conflict not amongst linefishers, but fisheries.
	‘MPA’	No MPA in area
	‘Access to DAFF’	Skipper provides all necessary information when required.
Adjustments	‘Uncertainty about access to Rights’ changed to ‘Implementation of regulations (uncertainty)’	Uncertainty regarding the implementation of the SSFP.
	Greater maxima (temperature and wind speed)	Amplifying effect on Current strength and wave height.

Appendix D5. Causal trees derived from the final regions map

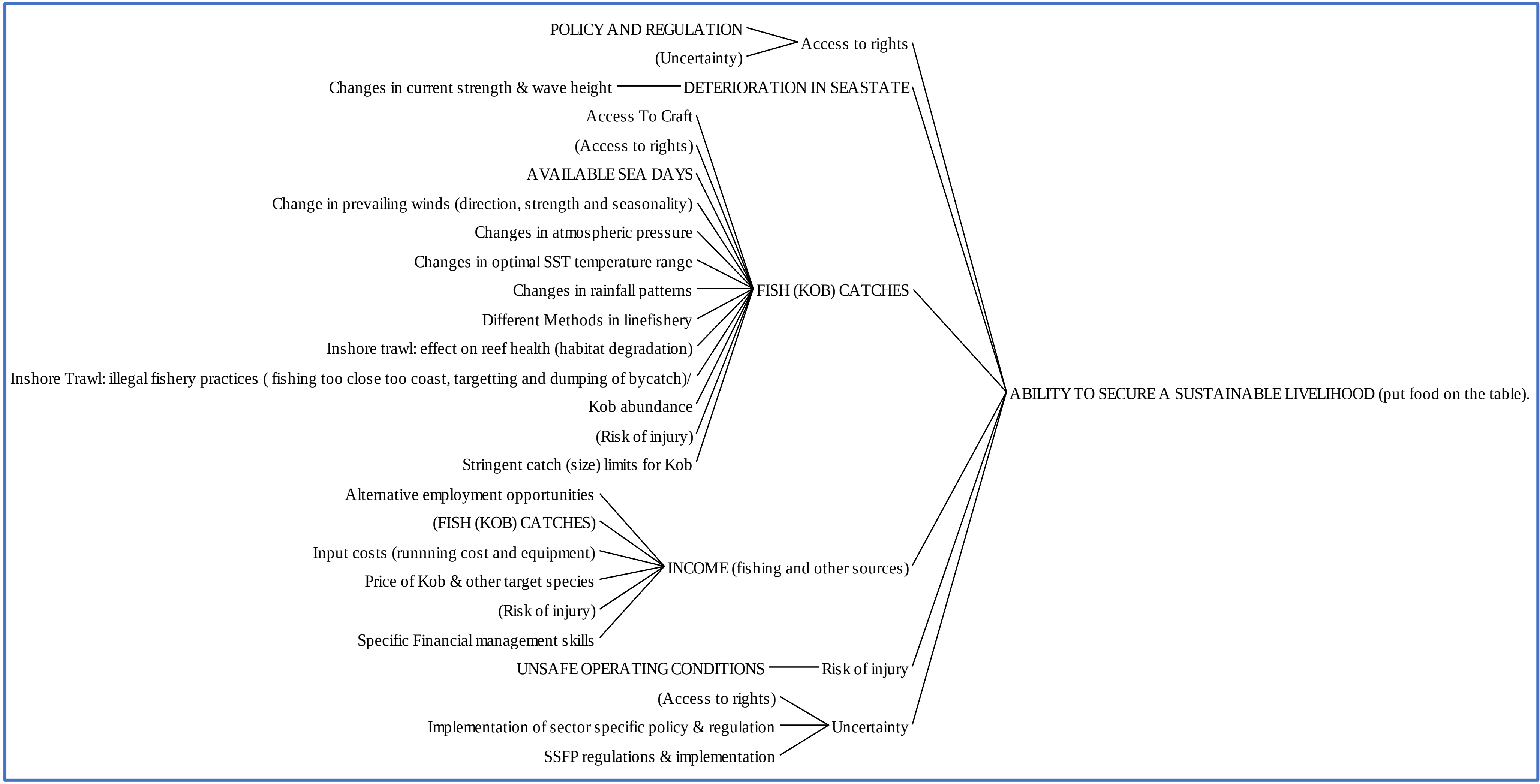

Figure D5.1. Causes tree derived from the final regional Causal map which shows the hierarchy of the stressor interactions within the diagram

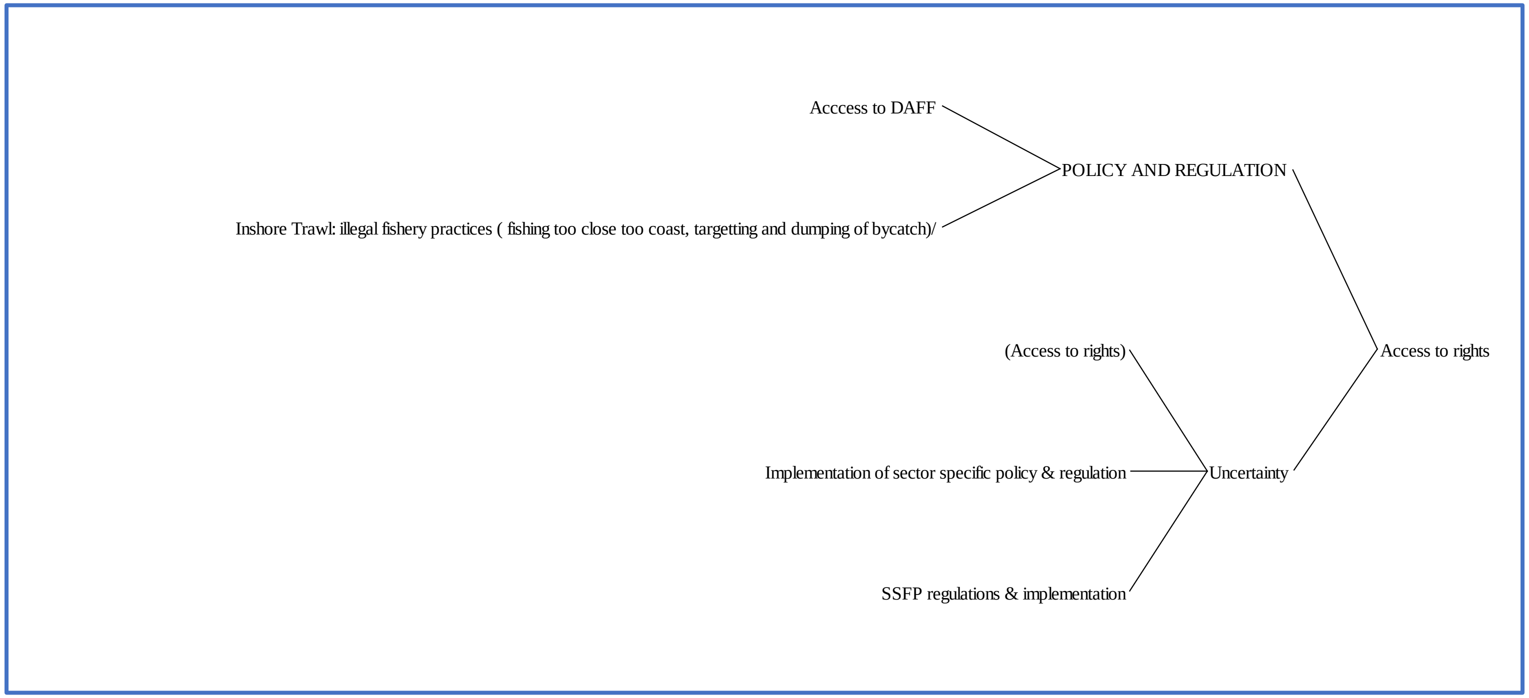

Figure D5.2. Causes tree for "Access to rights" driver

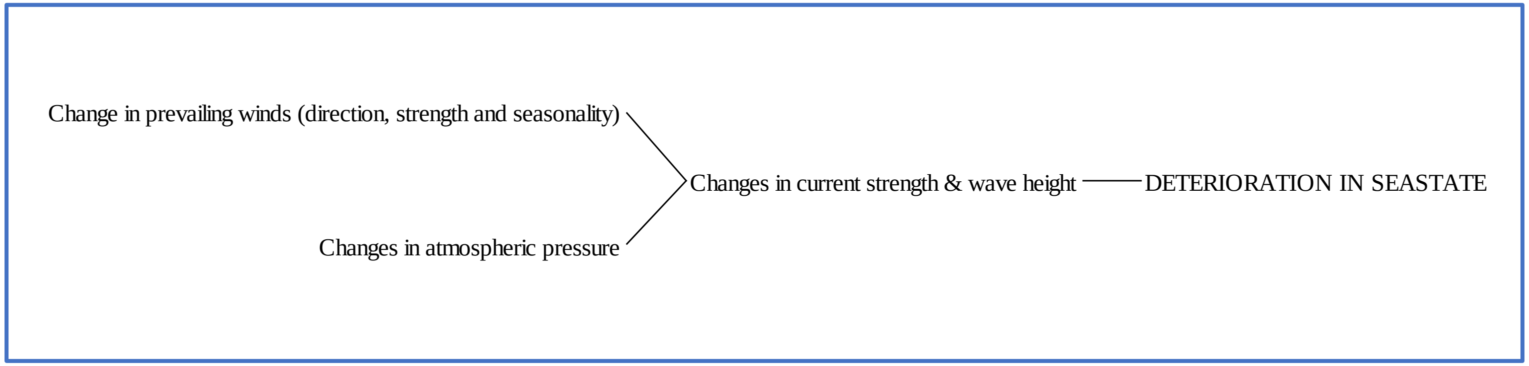

Figure D5.3. Causes tree for "Deterioration in sea state" driver

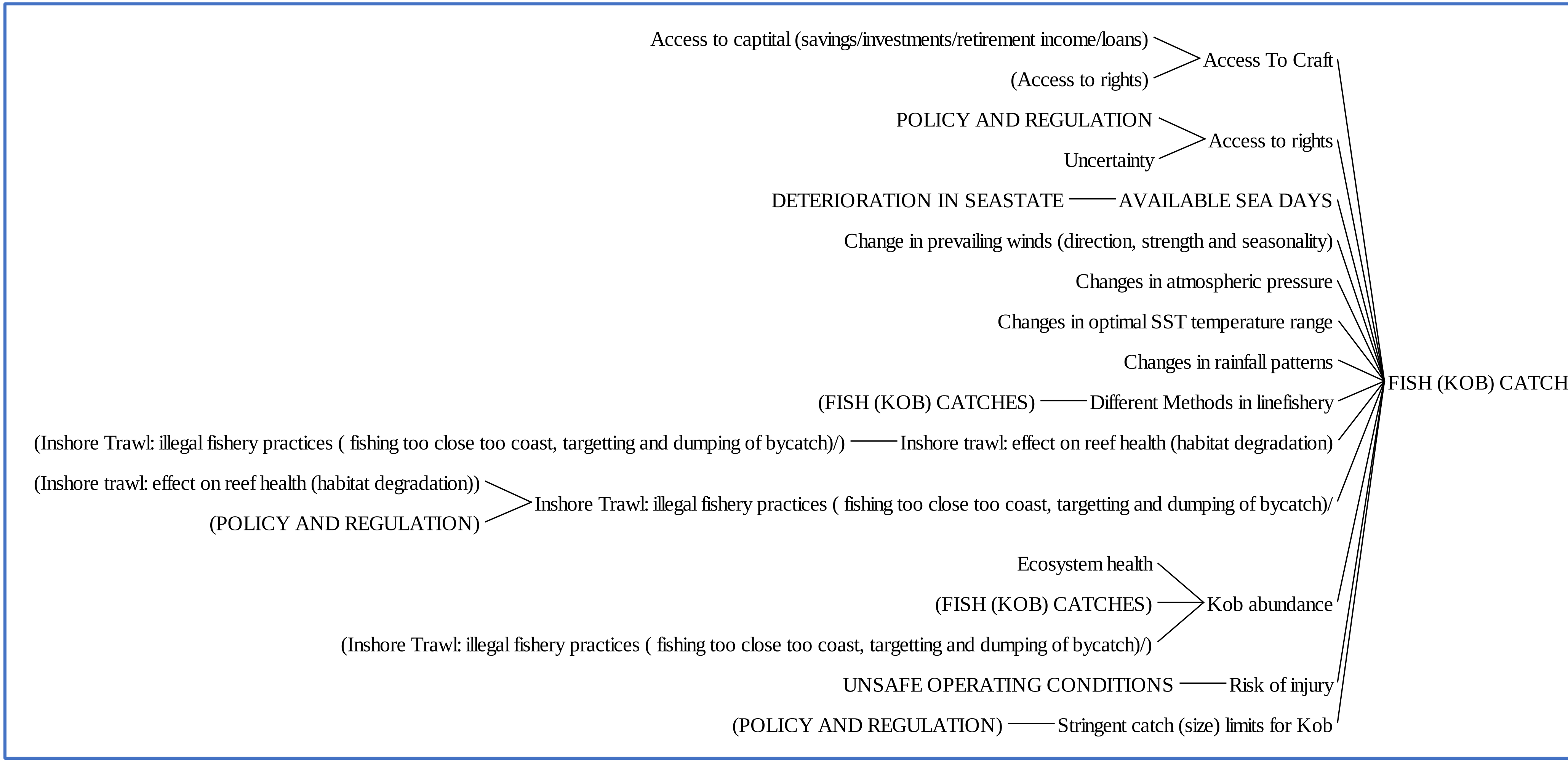

Figure D5.4. Causes tree for “Fish (kob) catches” driver

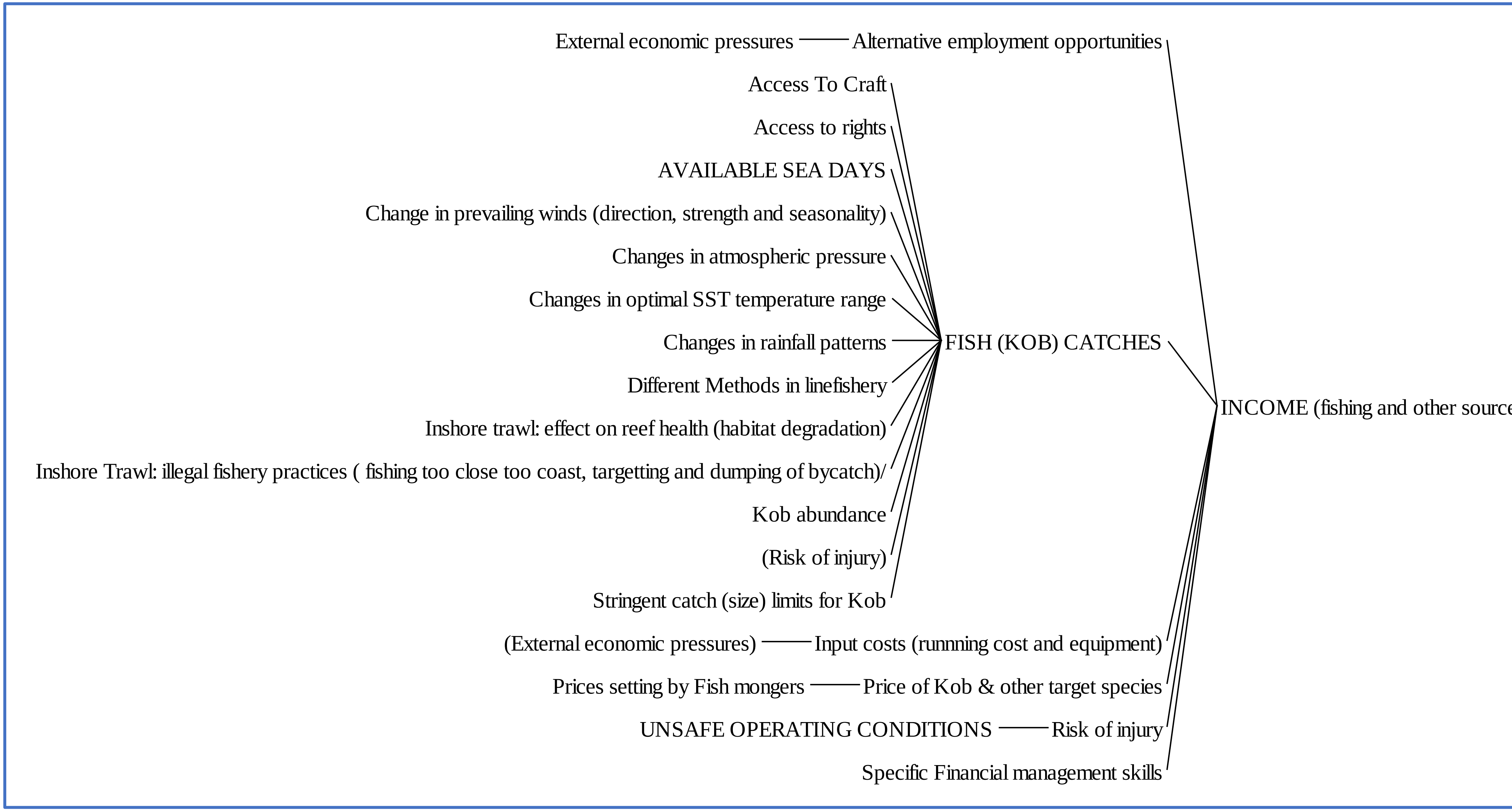

Figure D5.5. Causes tree for "Income" driver

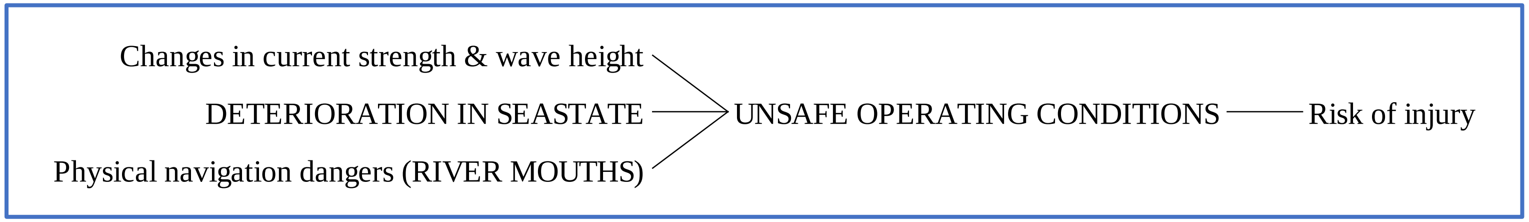

Figure D5.6. Causes tree for "Unsafe Operating Conditions" driver

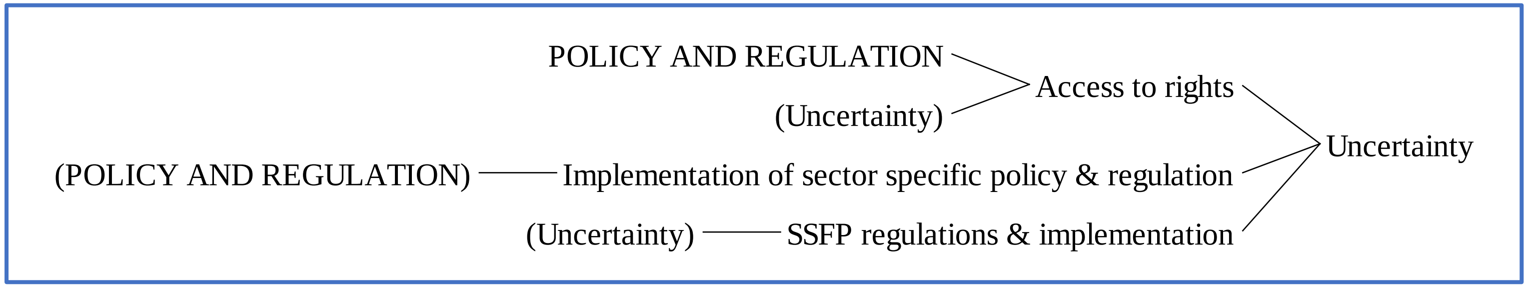

Figure D5.7. Causes tree for "Uncertainty" driver

Appendix D6. Final (regional map) showing feedback loops and indirect drivers of changes

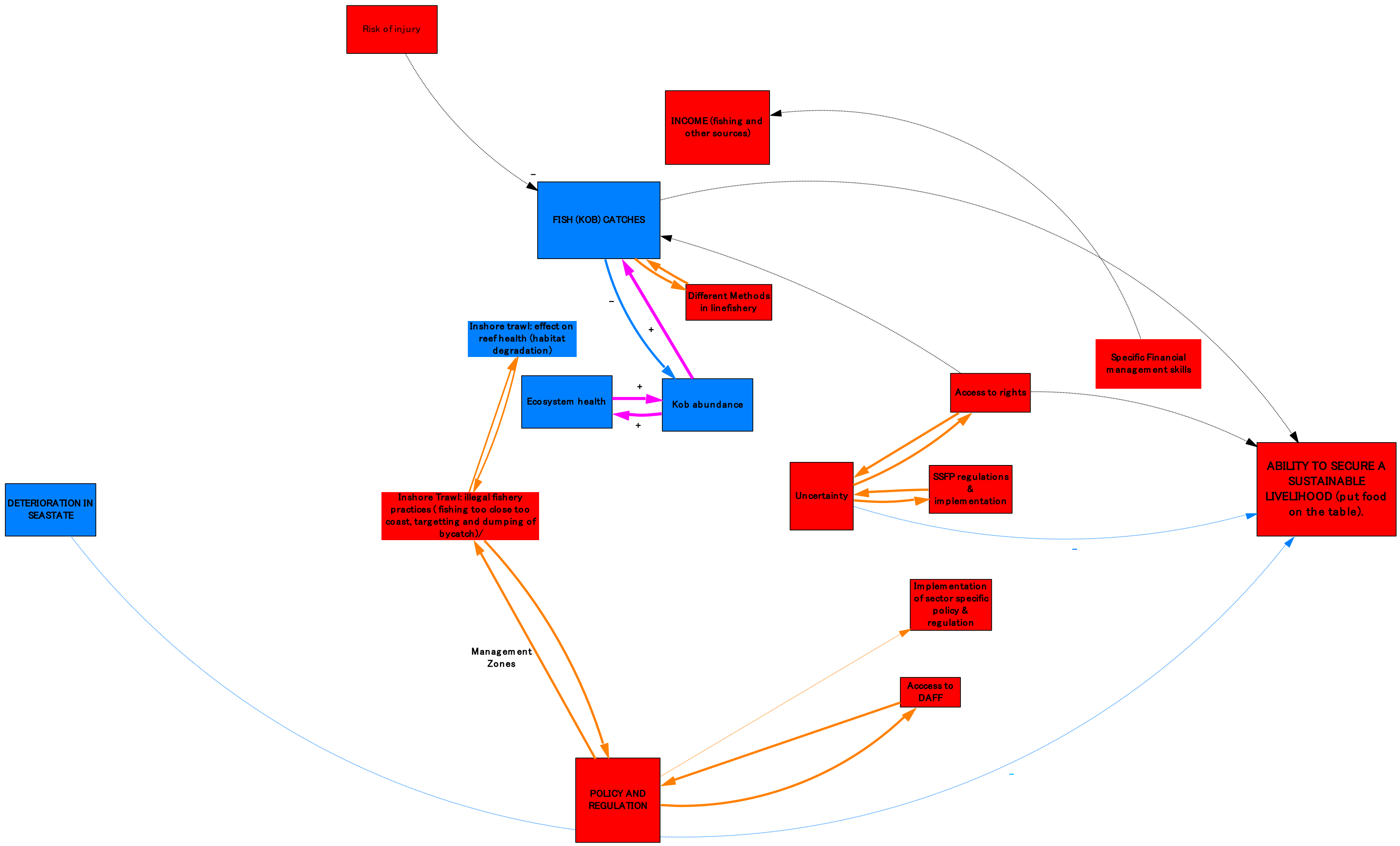

Figure D6. Final (regional map) showing feedback loops and indirect drivers of changes within the social-ecological system. Note that the colour coding of the variables has been changed from those provided in Tables 4.2. Variables which could be considered social (human centred) are here shown in red, and those who are from the biophysical (ecological) system are shown in blue

Appendix D7. Combined conditional probability tables (CPTs) for the principal variables and output variable

Table D7.1. CPT for 'Economy' variable

ECONOMY:

Sufficient	Insufficient	SKIPPER_TRAINING	ACCESS_EQUIPMENT	PROFIT_MARGIN	Participants
0	1	Insufficient	Insufficient	Insufficient	Participant1
0	1	Insufficient	Insufficient	Insufficient	Participant2
0	1	Insufficient	Insufficient	Insufficient	Participant3
0	1	Insufficient	Insufficient	Insufficient	Participant4
0	1	Insufficient	Insufficient	Insufficient	Participant5
0	1	Insufficient	Insufficient	Insufficient	Participant6
0	1	Insufficient	Insufficient	Sufficient	Participant1
0	1	Insufficient	Insufficient	Sufficient	Participant2
0.1	0.9	Insufficient	Insufficient	Sufficient	Participant3
0.1	0.9	Insufficient	Insufficient	Sufficient	Participant4
0.2	0.8	Insufficient	Insufficient	Sufficient	Participant5
0.85	0.15	Insufficient	Insufficient	Sufficient	Participant6
0.5	0.5	Insufficient	Sufficient	Insufficient	Participant1
0	1	Insufficient	Sufficient	Insufficient	Participant2
0.4	0.6	Insufficient	Sufficient	Insufficient	Participant3
0.5	0.5	Insufficient	Sufficient	Insufficient	Participant4
0.4	0.6	Insufficient	Sufficient	Insufficient	Participant5
0.1	0.9	Insufficient	Sufficient	Insufficient	Participant6
1	0	Insufficient	Sufficient	Sufficient	Participant1
0.1	0.9	Insufficient	Sufficient	Sufficient	Participant2
0.6	0.4	Insufficient	Sufficient	Sufficient	Participant3
0.8	0.2	Insufficient	Sufficient	Sufficient	Participant4
1	0	Insufficient	Sufficient	Sufficient	Participant5
0.4	0.6	Insufficient	Sufficient	Sufficient	Participant6
0	1	Sufficient	Insufficient	Insufficient	Participant1
0	1	Sufficient	Insufficient	Insufficient	Participant2
0	1	Sufficient	Insufficient	Insufficient	Participant3
0	1	Sufficient	Insufficient	Insufficient	Participant4
0.5	0.5	Sufficient	Insufficient	Insufficient	Participant5
0	1	Sufficient	Insufficient	Insufficient	Participant6
0	1	Sufficient	Insufficient	Sufficient	Participant1
0.2	0.8	Sufficient	Insufficient	Sufficient	Participant2
0.4	0.6	Sufficient	Insufficient	Sufficient	Participant3
0.2	0.8	Sufficient	Insufficient	Sufficient	Participant4
0.7	0.3	Sufficient	Insufficient	Sufficient	Participant5
0.1	0.9	Sufficient	Insufficient	Sufficient	Participant6
0	1	Sufficient	Sufficient	Insufficient	Participant1
0	1	Sufficient	Sufficient	Insufficient	Participant2
0.6	0.4	Sufficient	Sufficient	Insufficient	Participant3
0	1	Sufficient	Sufficient	Insufficient	Participant4
0.4	0.6	Sufficient	Sufficient	Insufficient	Participant5
0.05	0.95	Sufficient	Sufficient	Insufficient	Participant6
1	0	Sufficient	Sufficient	Sufficient	Participant1
1	0	Sufficient	Sufficient	Sufficient	Participant2
1	0	Sufficient	Sufficient	Sufficient	Participant3
1	0	Sufficient	Sufficient	Sufficient	Participant4
1	0	Sufficient	Sufficient	Sufficient	Participant5
1	0	Sufficient	Sufficient	Sufficient	Participant6

Table D7.2. CPT for' Policy' variable

POLICY:

Favourable	Unfavourable	ACCESS_RIGHTS	SIZE_KOB	INSHORE_TRAWL_POLICING	Participants
0	1	NoAccess	TooBig	Inadequate	Participant1
0.05	0.95	NoAccess	TooBig	Inadequate	Participant2
0	1	NoAccess	TooBig	Inadequate	Participant3
0	1	NoAccess	TooBig	Inadequate	Participant4
0	1	NoAccess	TooBig	Inadequate	Participant5
0	1	NoAccess	TooBig	Inadequate	Participant6
0	1	NoAccess	TooBig	Adequate	Participant1
0.1	0.9	NoAccess	TooBig	Adequate	Participant2
0.1	0.9	NoAccess	TooBig	Adequate	Participant3
0	1	NoAccess	TooBig	Adequate	Participant4
0	1	NoAccess	TooBig	Adequate	Participant5
0	1	NoAccess	TooBig	Adequate	Participant6
0	1	NoAccess	SmallEnough	Inadequate	Participant1
0.1	0.9	NoAccess	SmallEnough	Inadequate	Participant2
0.1	0.9	NoAccess	SmallEnough	Inadequate	Participant3
0	1	NoAccess	SmallEnough	Inadequate	Participant4
0.5	0.5	NoAccess	SmallEnough	Inadequate	Participant5
0	1	NoAccess	SmallEnough	Inadequate	Participant6
0	1	NoAccess	SmallEnough	Adequate	Participant1
0.2	0.8	NoAccess	SmallEnough	Adequate	Participant2
0.4	0.6	NoAccess	SmallEnough	Adequate	Participant3
0	1	NoAccess	SmallEnough	Adequate	Participant4
0.3	0.7	NoAccess	SmallEnough	Adequate	Participant5
0	1	NoAccess	SmallEnough	Adequate	Participant6
0.1	0.9	Access	TooBig	Inadequate	Participant1
0.1	0.9	Access	TooBig	Inadequate	Participant2
0.6	0.4	Access	TooBig	Inadequate	Participant3
0.5	0.5	Access	TooBig	Inadequate	Participant4
0	1	Access	TooBig	Inadequate	Participant5
0	1	Access	TooBig	Inadequate	Participant6
1	0	Access	TooBig	Adequate	Participant1
0.05	0.95	Access	TooBig	Adequate	Participant2
0.8	0.2	Access	TooBig	Adequate	Participant3
1	0	Access	TooBig	Adequate	Participant4
0.3	0.7	Access	TooBig	Adequate	Participant5
0.1	0.9	Access	TooBig	Adequate	Participant6
0	1	Access	SmallEnough	Inadequate	Participant1
0.5	0.5	Access	SmallEnough	Inadequate	Participant2
0.8	0.2	Access	SmallEnough	Inadequate	Participant3
0	1	Access	SmallEnough	Inadequate	Participant4
0.5	0.5	Access	SmallEnough	Inadequate	Participant5
0.1	0.9	Access	SmallEnough	Inadequate	Participant6
1	0	Access	SmallEnough	Adequate	Participant1
1	0	Access	SmallEnough	Adequate	Participant2
1	0	Access	SmallEnough	Adequate	Participant3
1	0	Access	SmallEnough	Adequate	Participant4
1	0	Access	SmallEnough	Adequate	Participant5
1	0	Access	SmallEnough	Adequate	Participant6

Table D7.3. CPT for 'Climate_Weather' variable

CLIMATE_WEATHER:

Favourable	Unfavourable	WIND	SST	CURRENT	Participants
0	1	Unfavourable	Unfavourable	Unfavourable	Participant1
0	1	Unfavourable	Unfavourable	Unfavourable	Participant2
0	1	Unfavourable	Unfavourable	Unfavourable	Participant3
0	1	Unfavourable	Unfavourable	Unfavourable	Participant4
0	1	Unfavourable	Unfavourable	Unfavourable	Participant5
0	1	Unfavourable	Unfavourable	Unfavourable	Participant6
0	1	Unfavourable	Unfavourable	Optimal	Participant1
0	1	Unfavourable	Unfavourable	Optimal	Participant2
0	1	Unfavourable	Unfavourable	Optimal	Participant3
0	1	Unfavourable	Unfavourable	Optimal	Participant4
0.7	0.3	Unfavourable	Unfavourable	Optimal	Participant5
0.4	0.6	Unfavourable	Unfavourable	Optimal	Participant6
0	1	Unfavourable	Optimal	Unfavourable	Participant1
0	1	Unfavourable	Optimal	Unfavourable	Participant2
0	1	Unfavourable	Optimal	Unfavourable	Participant3
0	1	Unfavourable	Optimal	Unfavourable	Participant4
0.5	0.5	Unfavourable	Optimal	Unfavourable	Participant5
0.2	0.8	Unfavourable	Optimal	Unfavourable	Participant6
1	0	Unfavourable	Optimal	Optimal	Participant1
0	1	Unfavourable	Optimal	Optimal	Participant2
0	1	Unfavourable	Optimal	Optimal	Participant3
0.8	0.2	Unfavourable	Optimal	Optimal	Participant4
1	0	Unfavourable	Optimal	Optimal	Participant5
0	1	Unfavourable	Optimal	Optimal	Participant6
0	1	Optimal	Unfavourable	Unfavourable	Participant1
0.05	0.95	Optimal	Unfavourable	Unfavourable	Participant2
0.2	0.8	Optimal	Unfavourable	Unfavourable	Participant3
0	1	Optimal	Unfavourable	Unfavourable	Participant4
0.5	0.5	Optimal	Unfavourable	Unfavourable	Participant5
0	1	Optimal	Unfavourable	Unfavourable	Participant6
0	1	Optimal	Unfavourable	Optimal	Participant1
0.9	0.1	Optimal	Unfavourable	Optimal	Participant2
0.2	0.8	Optimal	Unfavourable	Optimal	Participant3
0	1	Optimal	Unfavourable	Optimal	Participant4
0.3	0.7	Optimal	Unfavourable	Optimal	Participant5
0.25	0.75	Optimal	Unfavourable	Optimal	Participant6
0.5	0.5	Optimal	Optimal	Unfavourable	Participant1
0.2	0.8	Optimal	Optimal	Unfavourable	Participant2
0.2	0.8	Optimal	Optimal	Unfavourable	Participant3
0.1	0.9	Optimal	Optimal	Unfavourable	Participant4
1	0	Optimal	Optimal	Unfavourable	Participant5
0.1	0.9	Optimal	Optimal	Unfavourable	Participant6
1	0	Optimal	Optimal	Optimal	Participant1
1	0	Optimal	Optimal	Optimal	Participant2
1	0	Optimal	Optimal	Optimal	Participant3
1	0	Optimal	Optimal	Optimal	Participant4
1	0	Optimal	Optimal	Optimal	Participant5
1	0	Optimal	Optimal	Optimal	Participant6

Table D7.4. CPT for 'Income'

INCOME:

High	Low	POLICY	ECONOMY	CLIMATE_WEATHER	Participants
1	0	Favourable	Sufficient	Favourable	Participant1
1	0	Favourable	Sufficient	Favourable	Participant2
1	0	Favourable	Sufficient	Favourable	Participant3
1	0	Favourable	Sufficient	Favourable	Participant4
1	0	Favourable	Sufficient	Favourable	Participant5
0.5	0.5	Favourable	Sufficient	Favourable	Participant6
0	1	Favourable	Sufficient	Unfavourable	Participant1
0	1	Favourable	Sufficient	Unfavourable	Participant2
0	1	Favourable	Sufficient	Unfavourable	Participant3
0	1	Favourable	Sufficient	Unfavourable	Participant4
1	0	Favourable	Sufficient	Unfavourable	Participant5
0	1	Favourable	Sufficient	Unfavourable	Participant6
0	1	Favourable	Insufficient	Favourable	Participant1
0	1	Favourable	Insufficient	Favourable	Participant2
0.8	0.2	Favourable	Insufficient	Favourable	Participant3
0.8	0.2	Favourable	Insufficient	Favourable	Participant4
0	1	Favourable	Insufficient	Favourable	Participant5
0.1	0.9	Favourable	Insufficient	Favourable	Participant6
0	1	Favourable	Insufficient	Unfavourable	Participant1
0.25	0.75	Favourable	Insufficient	Unfavourable	Participant2
0.4	0.6	Favourable	Insufficient	Unfavourable	Participant3
0.1	0.9	Favourable	Insufficient	Unfavourable	Participant4
0.6	0.4	Favourable	Insufficient	Unfavourable	Participant5
1	0	Favourable	Insufficient	Unfavourable	Participant6
0.1	0.9	Unfavourable	Sufficient	Favourable	Participant1
0	1	Unfavourable	Sufficient	Favourable	Participant2
1	0	Unfavourable	Sufficient	Favourable	Participant3
0	1	Unfavourable	Sufficient	Favourable	Participant4
1	0	Unfavourable	Sufficient	Favourable	Participant5
0.25	0.75	Unfavourable	Sufficient	Favourable	Participant6
0.8	0.2	Unfavourable	Sufficient	Unfavourable	Participant1
0	1	Unfavourable	Sufficient	Unfavourable	Participant2
0.4	0.6	Unfavourable	Sufficient	Unfavourable	Participant3
0.1	0.9	Unfavourable	Sufficient	Unfavourable	Participant4
0.8	0.2	Unfavourable	Sufficient	Unfavourable	Participant5
0	1	Unfavourable	Sufficient	Unfavourable	Participant6
0.1	0.9	Unfavourable	Insufficient	Favourable	Participant1
0.05	0.95	Unfavourable	Insufficient	Favourable	Participant2
0.8	0.2	Unfavourable	Insufficient	Favourable	Participant3
0.2	0.8	Unfavourable	Insufficient	Favourable	Participant4
0.5	0.5	Unfavourable	Insufficient	Favourable	Participant5
0.2	0.8	Unfavourable	Insufficient	Favourable	Participant6
0.1	0.9	Unfavourable	Insufficient	Unfavourable	Participant1
0	1	Unfavourable	Insufficient	Unfavourable	Participant2
0	1	Unfavourable	Insufficient	Unfavourable	Participant3
0.01	0.99	Unfavourable	Insufficient	Unfavourable	Participant4
0	1	Unfavourable	Insufficient	Unfavourable	Participant5
0	1	Unfavourable	Insufficient	Unfavourable	Participant6

Appendix D8

Table D8. Sensitivity analysis of the BBN per contributing factor. The results show the sensitivity of the contributing factors ('Climate_weather', 'Economy' and 'Policy') to changes in the settings of all other variables.

Sensitivity of 'CLIMATE_WEATHER' to a finding at another node:

Node ----	Mutual Info	Percent	Variance of Beliefs
CLIMATE_WEATHER	0.89839	100	0.2156207
SST	0.09914	11	0.0284766
CURRENT	0.09660	10.8	0.0277778
Participants	0.06437	7.16	0.0204253
INCOME	0.05550	6.18	0.0174312
WIND	0.05157	5.74	0.0151085
ECONOMY	0.00165	0.184	0.0004975
POLICY	0.00000	2.96e-05	0.0000001
PROFIT_MARGIN	0.00000	0	0.0000000
ACCESS_EQUIPMENT	0.00000	0	0.0000000
SKIPPER_TRAINING	0.00000	0	0.0000000
INSHORE_TRAWL_POLICING	0.00000	0	0.0000000
SIZE_KOB	0.00000	0	0.0000000
ACCESS_RIGHTS	0.00000	0	0.0000000

Sensitivity of 'ECONOMY' to a finding at another node:

Node ----	Mutual Info	Percent	Variance of Beliefs
ECONOMY	0.92241	100	0.2235938
ACCESS_EQUIPMENT	0.13264	14.4	0.0391710
PROFIT_MARGIN	0.12683	13.7	0.0375391
INCOME	0.06376	6.91	0.0205713
Participants	0.03850	4.17	0.0116146
SKIPPER_TRAINING	0.00619	0.671	0.0019141
CLIMATE_WEATHER	0.00165	0.179	0.0005159
POLICY	0.00026	0.0278	0.0000799
INSHORE_TRAWL_POLICING	0.00000	0	0.0000000
SIZE_KOB	0.00000	0	0.0000000
ACCESS_RIGHTS	0.00000	0	0.0000000
CURRENT	0.00000	0	0.0000000
WIND	0.00000	0	0.0000000
SST	0.00000	0	0.0000000

Sensitivity of 'POLICY' to a finding at another node:

Node ----	Mutual Info	Percent	Variance of Beliefs
POLICY	0.87873	100	0.2091623
ACCESS_RIGHTS	0.18333	20.9	0.0487674
INSHORE_TRAWL_POLICING	0.06299	7.17	0.0177778
SIZE_KOB	0.03353	3.82	0.0095877
Participants	0.03293	3.75	0.0094488
INCOME	0.01622	1.85	0.0048937
ECONOMY	0.00026	0.0292	0.0000748
CLIMATE_WEATHER	0.00000	3.66e-05	0.0000001
PROFIT_MARGIN	0.00000	0	0.0000000
ACCESS_EQUIPMENT	0.00000	0	0.0000000
SKIPPER_TRAINING	0.00000	0	0.0000000
SST	0.00000	0	0.0000000
WIND	0.00000	0	0.0000000
CURRENT	0.00000	0	0.0000000

Appendix D9

Table D9. Sensitivity analysis of the BBN per participant. The results show the sensitivity of the outcome node ('income') to changes in the settings of all other variables in the BBN per participant

```
                         sensitivity all participants.txt
Probability of findings = 16.6667 %.
----------------------------------------------------------------------

Participant 1: Sensitivity of 'INCOME' to a finding at another node:

Node                     Mutual      Percent   Variance of
----                     Info                  Beliefs
INCOME                   0.74205     100       0.1660727
ECONOMY                  0.16857     22.7      0.0410197
ACCESS_EQUIPMENT         0.08656     11.7      0.0186453
PROFIT_MARGIN            0.02979     4.01      0.0067123
POLICY                   0.02213     2.98      0.0045161
ACCESS_RIGHTS            0.00702     0.946     0.0016074
CLIMATE_WEATHER          0.00612     0.824     0.0013509
INSHORE_TRAWL_POLICING   0.00574     0.773     0.0013158
SKIPPER_TRAINING         0.00325     0.438     0.0007458
SST                      0.00267     0.36      0.0006141
CURRENT                  0.00096     0.129     0.0002211
WIND                     0.00011     0.0144    0.0000246
SIZE_KOB                 0.00002     0.00213   0.0000036
Participants             0.00000     0         0.0000000

Participant 2: Sensitivity of 'INCOME' to a finding at another node:

Node                     Mutual      Percent   Variance of
----                     Info                  Beliefs
INCOME                   0.32726     100       0.0563593
POLICY                   0.07383     22.6      0.0066633
SIZE_KOB                 0.01644     5.02      0.0012100
ACCESS_RIGHTS            0.01028     3.14      0.0007744
INSHORE_TRAWL_POLICING   0.00250     0.764     0.0001936
CLIMATE_WEATHER          0.00083     0.255     0.0000678
WIND                     0.00032     0.0976    0.0000249
ECONOMY                  0.00027     0.0817    0.0000218
CURRENT                  0.00019     0.0575    0.0000147
PROFIT_MARGIN            0.00005     0.0165    0.0000042
SKIPPER_TRAINING         0.00004     0.0118    0.0000030
ACCESS_EQUIPMENT         0.00003     0.00792   0.0000020
SST                      0.00000     0.00131   0.0000003
Participants             0.00000     0         0.0000000
```

sensitivity all participants.txt

Participant 3: Sensitivity of 'INCOME' to a finding at another node:

Node ----	Mutual Info	Percent	Variance of Beliefs
INCOME	0.91866	100	0.2223443
CLIMATE_WEATHER	0.23744	25.8	0.0739296
WIND	0.06129	6.67	0.0184824
CURRENT	0.01507	1.64	0.0046206
SST	0.01507	1.64	0.0046206
POLICY	0.00419	0.456	0.0012928
ECONOMY	0.00240	0.261	0.0007443
ACCESS_RIGHTS	0.00178	0.193	0.0005476
ACCESS_EQUIPMENT	0.00070	0.0763	0.0002161
PROFIT_MARGIN	0.00019	0.0209	0.0000593
INSHORE_TRAWL_POLICING	0.00017	0.0183	0.0000518
SIZE_KOB	0.00017	0.0183	0.0000518
SKIPPER_TRAINING	0.00013	0.014	0.0000397
Participants	0.00000	0	0.0000000

Participant 4:Sensitivity of 'INCOME' to a finding at another node:

Node ----	Mutual Info	Percent	Variance of Beliefs
INCOME	0.53764	100	0.1077969
CLIMATE_WEATHER	0.10104	18.8	0.0179744
POLICY	0.05024	9.34	0.0081624
SST	0.03988	7.42	0.0055986
CURRENT	0.03148	5.86	0.0044820
ACCESS_RIGHTS	0.02582	4.8	0.0037102
INSHORE_TRAWL_POLICING	0.00906	1.68	0.0013357
SIZE_KOB	0.00099	0.185	0.0001484
WIND	0.00094	0.174	0.0001396
ECONOMY	0.00004	0.00833	0.0000067
ACCESS_EQUIPMENT	0.00001	0.00239	0.0000019
PROFIT_MARGIN	0.00001	0.00152	0.0000012
SKIPPER_TRAINING	0.00000	0	0.0000000
Participants	0.00000	0	0.0000000

Participant 5:Sensitivity of 'INCOME' to a finding at another node:

Node ----	Mutual Info	Percent	Variance of Beliefs
INCOME	0.94806	100	0.2322174
ECONOMY	0.38737	40.9	0.1103835
PROFIT_MARGIN	0.05596	5.9	0.0177056
ACCESS_EQUIPMENT	0.04266	4.5	0.0135559
SKIPPER_TRAINING	0.02163	2.28	0.0069163
CLIMATE_WEATHER	0.01386	1.46	0.0044999
SST	0.00373	0.394	0.0012000
CURRENT	0.00093	0.0983	0.0003000
WIND	0.00034	0.0354	0.0001080
POLICY	0.00000	0.000345	0.0000010
SIZE_KOB	0.00000	9.35e-05	0.0000003
ACCESS_RIGHTS	0.00000	2.16e-05	0.0000001
INSHORE_TRAWL_POLICING	0.00000	0	0.0000000
Participants	0.00000	0	0.0000000

Participant 6:Sensitivity of 'INCOME' to a finding at another node:

Node ----	Mutual Info	Percent	Variance of Beliefs
INCOME	0.55987	100	0.1137575
POLICY	0.15971	28.5	0.0347693
ACCESS_RIGHTS	0.04129	7.38	0.0061358
SIZE_KOB	0.02811	5.02	0.0042609
INSHORE_TRAWL_POLICING	0.02811	5.02	0.0042609
CLIMATE_WEATHER	0.01380	2.47	0.0023917
ECONOMY	0.01177	2.1	0.0016809
PROFIT_MARGIN	0.00377	0.674	0.0005917
CURRENT	0.00235	0.42	0.0003695
WIND	0.00072	0.129	0.0001140
SST	0.00054	0.0971	0.0000857
ACCESS_EQUIPMENT	0.00028	0.0499	0.0000440
SKIPPER_TRAINING	0.00003	0.00555	0.0000049
Participants	0.00000	0	0.0000000

Appendix D10. BBN Sensitivity analysis results

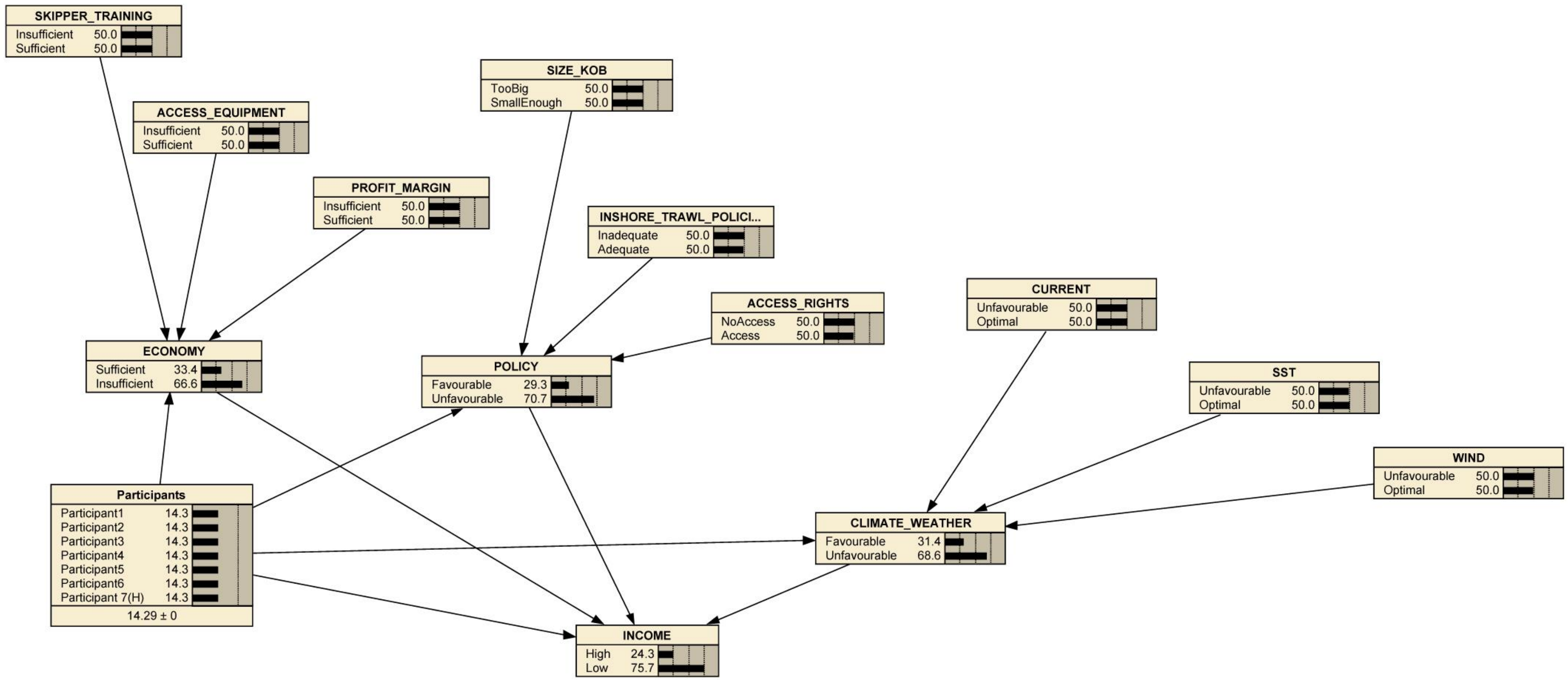

Figure D10.1. Manipulated probability outputs with a duplicate participant (7H) added (iteration 1). The CPTs added were a duplicate of those provided by a participant (participants 1) who indicated 'Economy' as being the most important principal driver.

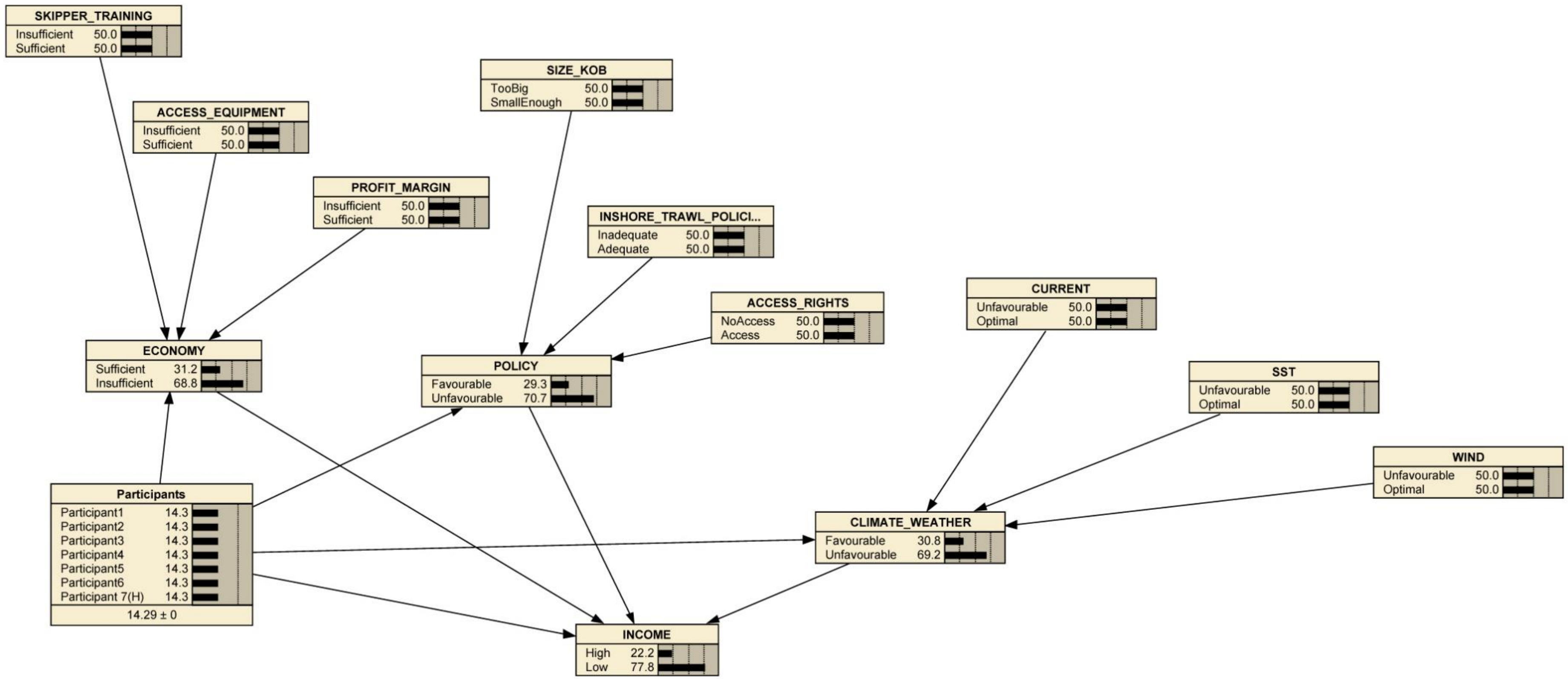

Figure D10.2. Manipulated probability outputs with a duplicate participant (7H) added (iteration 2). The CPTs added were a duplicate of those provided by a participant who indicated 'Policy' as being the most important principal driver

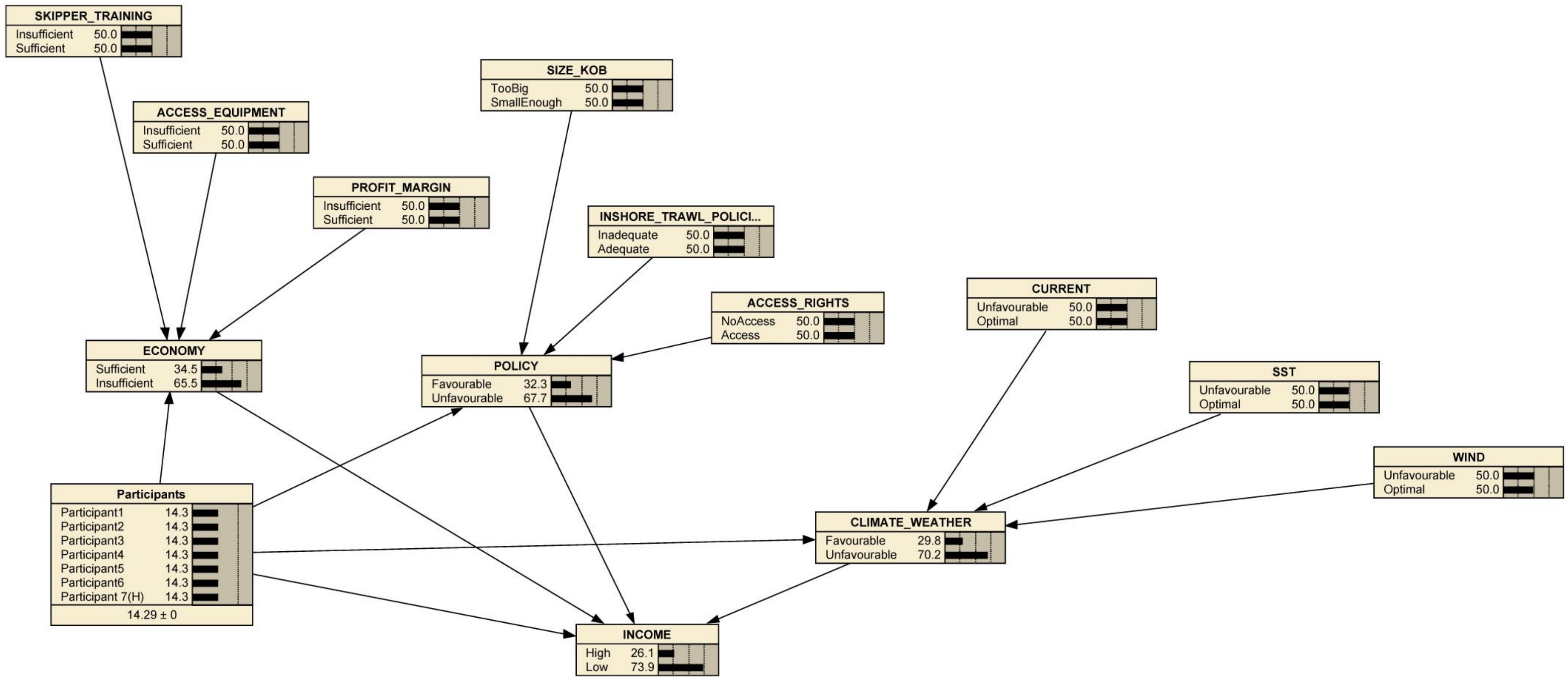

Figure D10.3. Manipulated probability outputs with a duplicate participant (7H) added (iteration 3). The CPTs added were a duplicate of those provided by a participant (participants 3) who indicated 'Climate_Weather' as being the most important principal drive