Understanding the relationships between commercial linefishing and Marine Protected Area governance in KwaZulu-Natal, South Africa

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By

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“When we try to pick out anything by itself, we find it hitched to everything else in the universe”

- John Muir “My First Summer in the Sierra” (1911)

ABSTRACT

A social-ecological systems (SES) approach, viewing humanity as a component of natural systems, has been widely recognised as necessary for conservation, especially considering the prevalence of wicked problems in this discipline. Despite a supportive policy and research environment, this approach has not yet been implemented in South African Marine Protected Area (MPA) management. The MPAs in KwaZulu-Natal (KZN) share goals to facilitate linefish stock recovery, the sustainable use of linefish resources and, often, to protect cultural heritage. The offshore commercial linefishing sector (CLS) is a small commercial sector that uses traditional methods (linefishing with rod and reel) to catch fish off small boats (<10m). It is considered the oldest fishing sector in the country and supports many livelihoods. Commercial linefishers are generally experienced fishers, with documented expertise in their field.

This study aims to contribute knowledge on the relationship between the CLS and MPAs associated with the fishery in KZN, which can be used in a SES management baseline for long-term MPA monitoring. To do this, an interdisciplinary, mixed methods approach was taken, drawing on ecological and social science approaches. For the ecological component, the population structure of 26 commercially important linefish species (chosen with input from fishers) was analysed using Baited Remote Underwater Stereo-Video sampling methods (n=271 deployments), comparing mesophotic reefs inside three MPAs (Pondoland, uThukela and iSimangaliso) with fished areas outside, and comparing management strategies within MPAs, using Generalised Additive Mixed Models. The social component is based on interviews with 21 commercial linefishing rights-holders in KZN to understand their perceptions of MPAs, including their governance, management and social-ecological impacts.

Results indicate that from an ecological perspective, MPAs, especially No-Take Areas, effectively protect linefish species and contribute to improved population dynamics. From a social perspective, interviews found that: 1. Fishers believe that MPAs are effective and necessary for fisheries sustainability; 2. Monitoring and enforcement of fisheries and MPA regulations are poor and must be improved; 3. A poor relationship between fisheries managers, MPA managers, and commercial linefishers hinders the effectiveness of MPAs; and 4. A lack of diverse sources of information leads to misguided decision-making and long-term unsustainability of MPAs and fishery management. Together, these results show that the governance and management processes relating to MPAs (and fisheries more broadly) need to be

revisited to enable integrated, holistic management of the SES. The final chapter explores a potential change pathway to action this goal by building a Theory of Change focusing on improving relationships among and between people and the ecological system, with communication and societal engagement with MPA management as key points of focus.

TABLE OF CONTENTS

..... I
ABSTRACT I
TABLE OF CONTENTS III
LIST OF ACRONYMS VII
LIST OF FIGURES VIII
LIST OF TABLES XIII
DEDICATION XV
ACKNOWLEDGEMENTS XVI
DECLARATION XVIII
1 PROVIDING CONTEXT: TRANSDISCIPLINARY CONSERVATION SCIENCE, FISHERIES MANAGEMENT, AND MARINE PROTECTED AREAS 19
1.1 Reflection 19
1.2 Conservation science: shifting times 20
1.2.1 Transdisciplinarity in conservation 21
1.3 Fisheries management and the need for marine conservation 22
1.3.1 Marine Protected Areas 23
1.3.2 Human dimensions of MPAs 26
1.3.3 Transdisciplinarity in Marine conservation 26
1.3.4 Baselines in MPA management 27
1.4 The linefishing sector 29
1.4.1 The commercial linefishing sector in South Africa 30
1.5 Contextualising this project 32
1.5.1 Study area 32
1.5.2 Research environment: The SMART Zone Project 34
1.6 Aims, Objectives, and Thesis Structure 35
1.6.1 Project Aim 35
1.6.2 Objectives 35
1.6.3 Thesis structure, Chapter Aims and Objectives 35
2 METHODOLOGY: FRAMEWORKS, ONTOLOGIES, AND EPISTEMOLOGIES 37
2.1 Reflection 37
2.2 Interdisciplinary and mixed methods research for social-ecological systems 38
2.3 Methodological overview 38
2.4 Theoretical background 40
2.4.1 Social-Ecological Systems 40
2.4.2 SES as Complex Adaptive Systems 42
2.5 Ontology, epistemology and social-ecological systems research 44
2.5.1 A process-relational perspective 45
2.6 Conclusion: Diagram of frameworks used in this thesis 46

3 ABOUT THE FISH: IMPACTS OF MPAS ON COMMERCIAL LINEFISH POPULATIONS 47

3.1 Reflection 47

3.2 Introduction 48

3.2.1 The Commercial Linefishing Sector from an Ecological Perspective 48

3.2.2 MPA monitoring using Baited Remote Underwater Stereo- Video Systems 49

3.2.3 Methodical considerations 50

3.3 Aim: 52

3.4 Chapter objectives: 52

3.4.1 Expected outcomes 52

3.5 Methods 54

3.5.1 Study Area 54

3.5.2 Description of marine ecosystems within the study area 55

3.5.3 Ethical clearance 57

3.5.4 Sampling approach 57

3.5.5 Sampling methods 59

3.5.6 Stereo-BRUVs Calibration 64

3.5.7 Choice of fish species for analysis 64

3.5.8 Additional environmental data 66

3.5.9 Video processing and analysis 67

3.5.10 Data preparation 67

3.5.11 Data exploration 69

3.5.12 Statistical Analysis 70

3.6 Results 74

3.6.1 Description of the data 74

3.6.2 The effects of spatial management 76

3.6.3 The effects of Individual MPAs 79

3.6.4 The effects of MPA Zonation 82

3.7 Discussion 86

3.7.1 MPAs protect the breeding population 87

3.7.2 No-Take Areas are critical for MPA effectiveness 88

3.7.3 The value of Controlled Areas for commercially important fish 89

3.7.4 The relationship between mature abundance, mature biomass, and MPA age. 90

3.7.5 The importance of the NEOLI attributes 91

3.7.6 The importance of immature fish for understanding the effectiveness of MPAs 94

3.7.7 Study design as a possible source of variation or error 94

3.7.8 Stereo-BRUVs and immature fish 96

3.7.9 A note on the future of MPAs in South Africa 97

3.8 Conclusion 98

4 ABOUT THE FISHERS: PERCEPTIONS OF MPAS AMONG COMMERCIAL LINEFISHERS 99

4.1 Reflection 99

4.2 Introduction 100

4.2.1 Chapter overview 101

4.2.2 Using perceptions to assess marine conservation outcomes 101

4.2.3 Fishers´ perceptions of MPAs globally 105

4.3 Aim and research questions 107

4.3.1 Aim 107

4.3.2 Research questions 107

4.4 Methods 108

4.4.1 Interviews 109

4.4.2 Data analysis 110

4.5 Results 115

4.5.1 Research participants 115

4.5.2 Overview of fishers´ perceptions: Content Analysis 116

4.5.3 Qualitative results 120

4.6 Discussion 132

4.6.1 The history of fishery and MPA management in KZN and implications for results 132

4.6.2 MPA effectiveness 133

4.6.3 Implications for governance and management of MPAs 134

4.7 Conclusion 139

5 A THEORY OF CHANGE FOR HOLISTIC MPA GOVERNANCE AND MANAGEMENT 141

5.1 Reflection 141

5.2 Purpose and methods of this chapter 142

5.3 Overview of the problem space 144

5.3.1 The linefishery as a complex multi-stakeholder context and social justice considerations 146

5.4 A shared vision for an ideal future for Marine Protected Areas in KwaZulu-Natal 147

5.5 Imagining a better future: a Theory of Change 148

5.5.1 Improving communication 151

5.5.2 Improving trust 152

5.5.3 Co-management agreements 154

5.5.4 Commitment to shared values among stakeholders 156

5.6 Conclusion 157

6 CONCLUSION AND RECOMMENDATIONS FOR FURTHER RESEARCH, POLICY AND PRACTICE 160

6.1 Conclusion 160

6.2 Recommendations for further research 162

6.3 Recommendations for policy and policy implementation 164

6.4 Recommendations for practice 164

7 ABOUT THE RESEARCHER: PERSONAL REFLECTION 166

8 REFERENCES 170

9 APPENDIX 196

A.1: Appendix 1 196

A.2: Appendix 2 207

A2.1: Interview Questionnaire 207

A2.2: Consent form 210

A2.3: Code Book 215

A2.4 Methodical reflections 225

A2.5 Sankey diagrams 226

A2.6 Ethical approval letters 230

A2.6.1 Ethical approval for human research 230

A 2.6.2 Ethical clearance extension letter for human research 231

A 2.6.3 Ethical approval for animal research 232

LIST OF ACRONYMS

AI	Artificial Intelligence
AIC	Akaike Information Criterion
BOFFFF	Big Old Fat Fecund Female Fish
CAS	Complex Adaptive Systems
CI	Confidence Intervals
CIF	Commercially Important Fish
CLS	Commercial Linefishing Sector
CPUE	Catch per Unit Effort
DFFE	Department of Fisheries, Forestry, and Environment, South Africa
EBM	Ecosystem-Based Management
EBMP	Ecosystem-Based Management Project
EEZ	Exclusive Economic Zone
EKZNW	Ezemvelo KZN Wildlife
FCO	Fisheries Control Officer
FIE	Fisheries Induced Evolution
GAMM	Generalised Additive Mixed Models
ICCAT	International Commission for the Conservation of Atlantic Tuna
IOTC	International Ocean Tuna Commission
IUU	Illegal, Unreported and Unregulated
KZN	KwaZulu-Natal
LMP	Linefish Management Protocol
MaRIP	Marine Remote Imagery Platform at SAIAB
MPA	Marine Protected Area
NBA	National Biodiversity Assessment
NEOLI	No-Take, Enforced, Old, Large, Isolated
NMLS	National Marine Linefish System
O&C	DFFE Department of Oceans and Coast
OECM	Other Affective area-based Conservation Measures
ORI	Oceanographic Research Institute
REML	Restricted Maximum Likelihood
RFMO	Regional Fisheries Management Organisations
SAIAB	South African Institute for Aquatic Biodiversity
SES	Social-Ecological System
SMART	Specific, Measurable, Achievable, Relevant, Time-Bound
TA	Thematic Analysis
TAC	Total Allowable Catch
TAE	Total Allowable Effort
ToC	Theory of Change
VIF	Variance Inflation Factor
VMS	Vessel Monitoring System

LIST OF FIGURES

Figure 1.1: The (exact) conceptual diagram of the Social-Ecological System surrounding the South African linefishing sector which was developed by Potts et al. (2020). Note that the authors indicate that the linefishery sectors are scaled according to their participation. DEFF refers to the Department of Forestry, Fisheries and the Environment (now DFFE), and NMLS refers to the National Marine Linefish System, a database holding catch return information from commercial fisheries..... 30

Figure 1.2: Map of the MPAs relevant to this study and their zonation in the context of South African MPAs. Note that no commercial fishing is permitted within the iSimangaliso MPA. The Controlled Area – pelagic linefishing is an area where only pelagic linefishing is allowed. 33

Figure 2.1: The methods used for this thesis and how the methods and components address the aim of this project, which is to contribute knowledge on the relationship between the Commercial Linefishing Sector (CLS) and Marine Protected Areas (MPAs) in KwaZulu-Natal (KZN), which can be used in a social-ecological systems (SES) management baseline for long-term MPA monitoring..... 39

Figure 2.2 The updated SES framework described by McGinnis & Ostrom (2014), redrawn by the author. 42

Figure 2.3: The frameworks used in this research, indicating how they fit together: 1) The process-relational framework by Mancilla García et al. (2020), which frames everything. 2) The Social-Ecological Systems Framework (McGinnis & Ostrom, 2014; Ostrom, 2009), which was built upon by 3) Preiser et al. (2018), describing these systems as CAS. Frameworks 4) by (Malhotra, 2002) and 5) by (Nkhata & McCool, 2012) are used in the social science chapter to explore effective governance and management of the system from a social perspective. 6) Theory of Change is a common methodical tool in development planning, but its use was informed by literature (Mayne, 2017; Taplin et al., 2013). 46

Figure 3.1: The methods and types of data utilised for this ecological research (represented by the blue circle) in the context of the whole research project (which is illustrated in Figure 2.1). The yellow circle on the right represents the social research component of this work, which can be found in Chapter 4 (Figure 4.1), and the green overlapping area indicates the integration of ecological and social research to explore a social-ecological systems perspective, which can be found in Chapter 5 (Figure 5.1). 54

Figure 3.2: The Marine Ecoregions found within South Africa´s Exclusive Economic Zone (EEZ), as shown in The National Biodiversity Assessment (Sink et al., 2019), mapped using data from the South African National Biodiversity Institute (2018). 57
Figure 3.3: Map showing the Marine Protected Areas along the KwaZulu-Natal and Eastern Cape coast and sites where stereo-BRUVs sampling took place, which are marked as dots. Sampling sites in Controlled Areas are light blue, sites in No-Take Areas are dark blue, and sites in the Central Fished Area are pink, while those in the Southern Fished Area are purple. Note that this map only contains the MPAs which were declared at the time of sampling (excluding the small Trafalgar MPA), so the extended Aliwal Shoal MPA and the Protea Banks MPA are not shown, compared to Figure 1.2. 61
Figure 3.4: Schematic of a Baited Remote Underwater Stereo-Video system adopted from (Bernard et al., 2014), showing: (A) the stainless-steel frame, (B) Pins for holding weights, (C) a rigid centre bar, onto which (D) a temperature logger, (E) two camera housings and (F) one white LED light are mounted. (G) is the bait canister, attached to the stereo-BRUVs. (H) attaches to a rope and surface marker buoys to ensure that the stereo-BRUVs are retrievable. 63
Figure 3.5: Prediction plot for m1, showing the effect of spatial management on the mature biomass of commercially important fish, with the predicted mean indicated by points and 95% confidence intervals indicated by the lines above and below points. 77
Figure 3.6: Prediction plot for m2, showing the effect of spatial management on the mature abundance of commercially important fish, with the predicted mean indicated by points and 95% confidence intervals indicated by the lines above and below points. 78
Figure 3.7: Prediction plot for m3, showing the effect of spatial management on the proportion of immature commercially important fish, with the predicted mean indicated by points and 95% confidence intervals indicated by the lines above and below points..... 78
Figure 3.8: Prediction plot for m4, showing the effect of individual MPAs (without zonation considered) on the mature biomass of commercially important fish, with the predicted mean indicated by points and 95% confidence intervals indicated by the lines above and below points 80
Figure 3.9: Prediction plot for m5, showing the effect of individual MPAs (without zonation considered) on the mature abundance of commercially important fish, with the predicted mean indicated by points and 95% confidence intervals indicated by the lines above and below points. 81
Figure 3.10: Prediction plot for m6, showing the effect of individual MPAs (without zonation considered) on the proportion of immature commercially important fish, with the predicted mean indicated by points and 95% confidence intervals indicated by the lines above and below points. 81

Figure 3.11: Prediction plot of m7, showing the effects of zonation within MPAs on the biomass of mature commercially important fish, with two areas outside MPAs for comparison. The predicted mean is indicated by points, and 95% confidence intervals are indicated by the lines above and below points. ..83
Figure 3.12: Prediction plot of m8, showing the effects of zonation within MPAs on the abundance of mature commercially important fish, with two areas outside MPAs for comparison. The predicted mean is indicated by points, and 95% confidence intervals are indicated by the lines above and below points. 84
Figure 3.13: Prediction plot of m9, showing the effects of zonation within MPAs on the proportion of immature commercially important fish, with two areas outside MPAs for comparison. The predicted mean indicated by points and 95% confidence intervals are indicated by the lines above and below points. ...85
Figure 4.1: The methods for this chapter and its context in this research project (illustrated in Figure 2.1). The yellow oval on the right represents the social science research on which this chapter focuses and contains a brief overview of methods for this chapter. The blue circle on the left represents ecological research, conducted in the previous chapter (Figure 3.1), and the green overlapping area indicates the integration of social and ecological results for a social-ecological systems perspective, which will be explored in the following chapter (Figure 4.1). 108
Figure 4.2: Pie charts showing fishers´ responses to Yes / No questions from the interviews. Note that more categories were created when fishers did not conform to Yes / No answers, to capture the diversity of their perceptions as accurately as possible. The "unassigned" category accounts for the number of fishers who refrained from answering a question. The sample size for this data was 22.....118
Figure 4.3: Pie charts indicating commercial linefishers´ responses to questions which were answered either according to predefined answers or on a Likert rating scale, with 1 generally being the most negative answer and 5 the most positive answer. The sample size for this data was 22. 119
Figure 4.4: A framework for the coupling of management and governance processes through planning, adapted from Nkhata & McCool (2012). Governance is a process of ensuring that societal values and mental models are adequately incorporated into policy and other legal frameworks, while management is a process of implementation of agreed-upon protected area goals, through enforcement, research, and bidirectional communication with stakeholders regarding research outputs and enforcement. Planning processes are where governance and management meet to ensure that the two subsystems are adequately linked and respond to societal demands from protected areas. Adaptations to the framework are in lighter coloured circles within the larger spheres, which depict the original framework.....139

Figure 5.1: A graphical overview of this chapter´s contents in the context of the whole research project. The blue oval indicates ecological research conducted for Chapter 2, while the yellow oval indicates social research conducted for Chapter 3. The green overlapping area indicates the integrated social-ecological perspective which will be explored in this chapter. 144

Figure 5.2: Theory of Change diagram for improving the relationships between the Department of Forestry, Fisheries, and Environment, the commercial linefishers, and Ezemvelo KwaZulu-Natal Wildlife. Responsibility ceilings, indicated by grey dotted lines, indicate when an outcome is achieved, and interventions which cross a responsibility ceiling enable the achievement of outcomes above and below the responsibility ceiling. The outcome pathway is within the green coloured band. Interventions are either intended to improve compliance and enforcement (red band), commitment to shared values among stakeholders (yellow band), or the monitoring of MPA effectiveness inside and outside MPAs (blue band). Note that only 2 assumptions are made explicit here, although it is possible that more exist. ... 151

Figure A 1. 1: Term plots for parametric and smooth terms for m1, which looked at the effect of spatial management on the mature biomass of commercially important fish. 198

Figure A 1.2: Term plots for parametric and smooth terms for m2, which looked at the effect of spatial management on the mature abundance of commercially important fish. 199

Figure A 1. 3: Term plots for parametric and smooth terms for m3, which looked at the effect of spatial management on the proportion of immature commercially important fish. 200

Figure A 1. 4: Term plots for parametric and smooth terms for m4, which looked at the effect of individual MPAs on the mature biomass of commercially important fish. 201

Figure A 1. 5: Term plots for parametric and smooth terms for m5, which looked at the effect of individual MPAs on the mature abundance of commercially important fish. 202

Figure A 1. 6: Term plots for parametric and smooth terms for m6, which looked at the effect of individual MPAs on the proportion of immature commercially important fish. 203

Figure A 1. 7: Term plots for parametric and smooth terms for m7, which looked at the effect of MPA Zonation on the mature biomass of commercially important fish. 204

Figure A 1.8: Term plots for parametric and smooth terms for m8, which looked at the effect of MPA Zonation on the mature abundance of commercially important fish. 205

Figure A 1. 9: Term plots for parametric and smooth terms for m9, which looked at the effect of MPA Zonation on the proportion of immature commercially important fish. 206

Figure A 2.5.10: Sankey diagram showing the relative code density of sub-categories within the "Observations" category. 226

Figure A 2.5.11: Sankey diagram showing the relative code density of sub-categories within the “Positive Perceptions” category..... 227

Figure A 2.5.12: Sankey Diagram showing the relative code density of sub-categories within the “Negative Perceptions” category..... 228

Figure A 2.5.13: Sankey diagram showing the relative code density of sub-categories within the “Suggestions for improvements” category..... 229

LIST OF TABLES

Table 2.1: The methods, objectives and research questions for each component of this project 40
Table 3.1: Sampling details, indicating when each area was sampled and how many samples (i.e. stereo-BRUVs deployments) were taken. No-Take Areas inside MPAs do not allow fishing, while Controlled Areas allow fishing, but with restrictions. 59
Table 3.2: Additional environmental variables that were measured, and their measurement units. 66
Table 3.3: The nine models that were run to analyse the effects of different spatial management methods on commercially important fish (CIF) populations. 72
Table 3.4: The species that were included in the analysis, and how many individuals of each were found in each MPA (as a whole, excluding zonation), and in fished areas. Fished areas are those outside MPAs. The four species and one grouped genus that are greyed out were marked for inclusion but were not found within the dataset at all. 75
Table 3.5: The Walds test results of the three analyses looking at the effect of spatial management on the response variables assessed in this study. Where a term was significant in the model, it has been made bold. 76
Table 3.6: The Walds test results of three analyses assessing the effects of individual MPAs on the variables of interest. Where a term was significant in the model, it has been made bold. 79
Table 3.7: The Walds test results of three analyses looking at the effect of MPA zonation on the variables of interest in this study. Where a term was significant in the model, it has been made bold. 82
Table 4.1: The features of expert knowledge (Fazey et al., 2006) which make it suitable for SES research, based on the properties of SES (Preiser et al., 2018), according to my understanding and interpretation of the literature above. 104
Table 4.2: The intended meaning of terms which are sometimes conflated in qualitative analyses. 112
Table 4.3: Variation between DFFE data and field data 116
Table 5.1: A description of terminology relating to Theory of Change (Taplin et al., 2013; Mayne, 2017). 143
Table 6.1: An overview of findings in this thesis, showing how each component addressed an objective of this thesis and its related research questions. 161

Table A 1.1: Parametric coefficients for management analyses. Significant p values are made bold. 196
Table A 1.2: Parametric coefficients for MPA analyses. Significant p values are made bold. 196
Table A 1.3: Parametric coefficients for Zone analyses. Significant p values are made bold. 197
Table A2.4: The attribute codes used for this thesis. Attribute codes are for coding out demographic and attribute information. Each code category is related to an introductory question which was asked of each fisher before perceptions were explored, and the subcodes group the possible short answers. 215
Table A 2.5: Codes in the "Observations" category. Observations have been separated from perceptions in this study, such that observations refer to concrete occurrences which have been experienced by fishers or someone they know. These occurrences could be related to and feed into their perceptions, but are not themselves considered as perceptions. 217
Table A 2.6: Codes in the "Negative perceptions" category. Negative perceptions of MPAs were added into a folder, with categories created where specific impacts or types of impacts are regularly discussed, with more detail in the codes. A category also exists for uncategorised negative perceptions, which are not specific to a commonly mentioned issue but are still relevant 219
Table A 2.7: Codes related to positive perceptions. 222
Table A 2.8: Codes related to fishers´ suggestions for improvements to make MPAs more sustainable. 223

DEDICATION

Two of my supervisors became new parents while this thesis was in gestation.

To Jonah and Imke.

Thank you for your arrival, as inconvenient as the timing was for me.

The world is blessed by your presence.

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DECLARATION

The following thesis has not been submitted to any university other than Rhodes University, Makhanda, South Africa. The work presented here is that of the author.

Artificial Intelligence (AI) was used only twice for this research. Otter.ai (Otter.ai, 2022) was used during interviews for initial transcription, which was then checked for errors and fixed accordingly by the researcher. The second instance of AI being used was for assistance with statistical analyses for the ecological component, where Chat GPT (OpenAI, 2024) was used as a source of information for how to interpret results and check for errors in the modelling process. In both instances, AI was used as advised by a supervisor.

CHAPTER 1

1 PROVIDING CONTEXT: TRANSDISCIPLINARY CONSERVATION SCIENCE, FISHERIES MANAGEMENT, AND MARINE PROTECTED AREAS

1.1 REFLECTION

CONSERVATION
/kɒnsəˈveɪʃᵊn/

1) Saving and protecting the environment.
2) Saving and protecting historical objects or works of art such as paintings, sculptures, or buildings.
3) The conservation of a supply of something is the careful use of it so that it lasts a long time.

(The Collins Online Dictionary, 2023)

REFLECTION:

The definitions of conservation by the Collins dictionary are problematic, in that they have not evolved to meet the current state of thinking. The fact that sustainability is something which is only mentioned in the third definition of conservation is problematic. The fact that one must choose between definitions of conserving the environment or conserving culture is problematic. To me, the only definition of conservation which would ring true would be an amalgamation of the three. Fortunately, the dictionary is not quite up to date with the theory. We have, at least in theory, moved past the dichotomy of the conservation of nature at the exclusion of people and their cultures, or vice-versa. At least in theory, we understand that we cannot conserve the one without also conserving the other. Of course, conserving both in tandem means that we must consider the immense complexity of humanity alongside that of nature. This multiplicity has been seen and acknowledged by research. Now it is time to embrace it in practice. The new challenge is learning how to go about initiating this tender yet thorny embrace.

1.2 CONSERVATION SCIENCE: SHIFTING TIMES

Conservation science is a discipline which has been at the centre of much debate around its ethics, with the philosophical underpinnings of the day playing an interesting role in the way that it is conceived by the public and practitioners (Washington et al., 2024). This has led to a shift from early systems of conservation, which were exclusionary and have been described as colonial, towards systems of community conservation and the inclusion of local people in pursuing conservation goals (Brockington, 2015). Washington et al. (2024) point out that this shift coincides with a shift in the literature from a time when ecological justice (ecojustice) was the primary reason for conservation, to a current focus on social justice. This shift away from "ecojustice at the cost of social justice" is important and necessary, they argue, but conservation researchers and practitioners should beware of straying too far in the opposite direction, such that ecojustice no longer has a place. The ideal position should be one where ecojustice and social justice enjoy equality. Neither should be more important than the other if we are to remain true to conservation as a discipline. This central position makes sense but also poses significant challenges, as conservation policy and management must consider how both people and nature are affected by decision-making (Bennett & Dearden, 2014a; Wolff et al., 2019), and should be able to adapt to incorporate new information (McCarthy & Possingham, 2007). The recent White Paper on the Conservation and Sustainable Use of South Africa´s Biodiversity (DFFE, 2023) firmly places South African policy in alignment with existing research in this regard, defining conservation as:

> "Protection, management, care, sustainable use, maintenance, rehabilitation, restoration, and recovery of ecological and evolutionary processes, biological diversity and its components, for their intrinsic and instrumental value, to improve the wellbeing of people and nature."

Furthermore, the four goals set out by the white paper lend equal weight to ecojustice and social justice, making it a truly remarkable policy document. The implementation of such a stance in conservation becomes quite complex, however, due to the various types of feedback and monitoring which are necessary to balance the needs of people and natural systems (Fox et al., 2014; Margules et al., 2020), as well as the complex local and global power dynamics which influence the way resource use decisions are made (Van Assche, Beunen & Duineveld, 2017). This has led to a shift in conservation toward a social-ecological systems (SES) approach, which views humanity as a part of the system being managed, and is the stance taken for this research. The SES framework will be described in more detail in Chapter 2 section 2.4.1.

1.2.1 TRANSDISCIPLINARITY IN CONSERVATION

Recognition of this complexity has led to a more recent focus on employing transdisciplinary modes of enquiry in conducting conservation research, planning, and management in terrestrial and marine environments globally (Reyers et al., 2010; Dick et al., 2017; Margules et al., 2020). Transdisciplinarity is defined by Jahn et al. (2012) as:

> "…a critical and self-reflexive research approach that relates societal with scientific problems, [producing] new knowledge by integrating different scientific and extra-scientific insights, [with the aim] to contribute to both societal and scientific progress…"

Transdisciplinarity, therefore, relies on interdisciplinarity (the integration of scientific disciplines) as well as the inclusion of extra-scientific knowledge (i.e. practitioner knowledge, local expert / indigenous knowledge, and any forms of knowledge held outside scientific institutions) in attempting to better understand and solve problems relevant to society. This makes it highly suitable for solving "wicked problems"- those for which a single, clearly defined, optimal solution is not available - which are common in conservation science and become even more so as the balance of ecojustice with social justice is pursued. The suitability of transdisciplinarity for wicked problem-solving stems from the fact that, as well as relying on various disciplines and knowledge systems, there is a focus on relationship-building and the co-creation and implementation of solutions, with iterative processes playing an important role (Yeung et al., 2021). Iterative learning and implementation processes are especially important in solving conservation issues, as they foster double-loop learning and critical introspection, allowing for adaptation to new knowledge which arises after the implementation of a strategy (Argyris, 1991; Rist, Campbell & Frost, 2013). The debate of what does and does not constitute "true transdisciplinarity" is ongoing and complex, with definitions of transdisciplinarity rife in the field and much debate around how much implementation, iteration, and interrogation of self is necessary before a body of work attains true transdisciplinary status (Rigolot, 2020). Recently, Reed et. al (2023) published an adjusted set of guiding principles for the social processes in transdisciplinary sustainability research and practice, which were established in a collaborative effort between academic researchers and Indigenous and local communities working on transdisciplinary projects. These principles are:

1. Honour self-determination and nationhood
2. Commit to reciprocal relationships
3. Co-create the research agenda

4. Generate meaningful benefits for communities
5. Approach research in a good way: Embed relational accountability
6. Ensure equity, diversity, and inclusion
7. Emphasize critical reflection and sharing

These principles ensure that where local people are involved in knowledge co-production, they receive benefits from their participation, ensuring that research is not extractive and exhausting for participants. Transdisciplinary research and practice are fundamentally complex, time-consuming and demanding (Sellberg et al., 2021), and not all projects that are designed in alignment with the principles of transdisciplinarity and the transdisciplinary philosophy of work are capable of fulfilling the need for iterative implementation and feedback, due to time or budgetary constraints, which are especially common in transdisciplinary research (Deininger et al., 2021). Despite these constraints to conducting "truly transdisciplinary work", it remains possible for a shorter, multidisciplinary or interdisciplinary project to work on a component of a larger transdisciplinary process or to be aligned with the principles established by Reed et al. (2023) in their engagement with the public, while recognising that it is not capable of filling all the requirements to be considered "truly transdisciplinary". Multidisciplinary research is another category along the spectrum of transdisciplinarity and is defined as knowledge production which involves more than one discipline, but does not necessarily aim to integrate the findings from these disciplines (Strand et al., 2022). For the purpose of this thesis, any work aligned with the long-term enablement of transdisciplinary processes as described above will be referred to as "transdisciplinary-aligned" and this terminology includes interdisciplinary and multidisciplinary work as well as true transdisciplinary work. This research project is interdisciplinary, and is conceptualised as a transdisciplinary-aligned project.

1.3 Fisheries management and the need for marine conservation

Fisheries management is a relatively new scientific field (Ricker, 1968) and, much like conservation science, has undergone changes in its approach and philosophies throughout its existence. The management of marine resources was not deemed necessary for a very long part of human history, since the ocean and its inhabitants were widely perceived as a resource that would be impossible to deplete because of its sheer size (Lackey, 2005). It was only as recently as 1985 that most countries had recognised that declining fish populations required attention. This incentivised the first efforts to manage their marine resources by declaring an Exclusive Economic Zone (EEZ) of 200 nautical miles offshore from their

coastal margin, allowing them legal rights over marine resources and the capacity to start implementing management strategies (Hilborn, 2012). An initially open-access market was slowly closed and managed more and more strictly as it became evident that fish stocks continued to decline. In the 1980´s, management was conducted mostly through open and closed fishing seasons and limitations on the size of vessels and fishing net mesh. Today, management of fish stocks is much more controlled and occurs almost exclusively through the limitation of the amount of fish that can be caught for any given species (Total Allowable Catch, TAC) and/or through limiting the number of vessels and/or fishers that are allowed to catch fish commercially (Total Allowable Effort, TAE). For widely distributed cosmopolitan species such as tuna, the TAC is calculated as a global number for international fisheries (or regional for more spatially constrained species) normally by Regional Fisheries Management Organisations (RFMOs) such as the International Commission for the Conservation of Atlantic Tuna (ICCAT) or the Indian Ocean Tuna Commission (IOTC). The global TAC is then separated into smaller by-country TACs, which can then be distributed according to the country´s decision-making frameworks, often using TAE. For the calculation of TAC, an index of fish abundance called Catch Per Unit Effort (CPUE) is generally used in various fishery models and a TAC has to be agreed upon before it can be subdivided. CPUE is normally calculated using catch returns from commercial fishing vessels (fisheries dependent data) and is an indicator of how much fish is caught per fishing hour, per vessel, or some other agreed-upon unit of fishing effort (Hilborn, 2012).

Over time it has become clear, however, that many fish stocks are generally still in decline, and effective marine resource management needs to focus on more than just limiting fishing effort (TAE) and catch (TAC). Effective fisheries management requires an ecosystem-based approach, which still focuses on managing the human component (as in traditional fisheries management), but includes an additional focus on the conservation of fish species and their associated habitats through spatial protection using Marine Protected Areas (Pikitch et al., 2004) and Other Effective area-based Conservation Measures (OECM´s) (Gurney et al., 2021).

1.3.1 Marine Protected Areas

Conservation in the marine realm is different to that on land, due to the open, complex, often stochastic nature of these systems and the impossibility of closing or fencing off an area completely (Agardy, 1994). The need for Ecosystem-Based Management (EBM) has led to the increased uptake of Marine Protected Areas (MPAs) as a management tool for protecting marine ecosystems and species for fisheries sustainability, as well as for biodiversity conservation purposes. Since the first establishment of MPAs, a debate has existed regarding whether they benefit fisheries outside their borders or not, although

scientists often found that they do playa role in achieving conservation targets (Pendleton et al. 2018). Their success at protecting and rehabilitating declining fish stocks and other sensitive marine species and ecosystems has, however, been well-documented globally (Lester et al., 2009), including a review in South Africa (Kirkman et al. (2021). Marine Protected Areas with No-Take Areas (where no fishing is allowed) have been widely hailed as one of the most important tools in fisheries management, provided that the management, design, and site selection are in accordance with this purpose (Ward et al., 2001; Edgar et al., 2014). No-Take Zonation refers to the zonation of an area where no fishing or extractive use may take place (RSA, 2019a). Four major benefits for fisheries management are often ascribed to MPAs containing No-Take Areas (Kenchington, Ward & Hegerl, 2003):

1. Support for fish stock management
2. Improved socio-economic outcomes for local communities (through processes such as spillover)
3. Support for fishery stability
4. Act as ecological offsets

One of the most cited effects of MPAs that is relevant to stock management is the spillover effect, whereby a large mature population of fishery target species builds up within a No-Take MPA and ultimately leads to the density-dependent movement of individuals from the MPA into the neighbouring, unprotected marine space (due to intraspecific competition), where they replenish populations available to fishers (Stobart et al., 2009). This phenomenon has been shown to support stocks of both resident and migratory species, where spatially predictable spawning aggregation sites of the latter are protected (Medoff, Lynham & Raynor, 2022). Spillover and, the more difficult-to-detect, larval spillover or "seeding" (the spillover of eggs and larvae from inside a No-Take Area to the area outside) has been documented in South Africa for roman (*Chrysoblephus laticeps*) in the area surrounding the Goukamma MPA (Kerwath et al., 2013). More recent South African research (Duncan et al., 2019) found further benefits of MPAs for fisheries under climate change conditions, through the discovery that fish inside MPAs generally have better capacity for adaptation to the variable temperatures predicted to occur in the ocean with climate change. This helps to improve the resilience of fish stocks to future scenarios, as genetics for resilience will seep out of MPAs and into the rest of the ocean through spillover. Other important functions for fish stock management that can be provided by MPAs include the spatial protection of sensitive life history stages, such as nursery grounds and the protection of important feeding or breeding grounds. This is particularly true for species which aggregate to spawn, such as seventy-four (*Polysteganus undulosus*), dusky kob (*Argyrosomus japonicus*) and geelbek (*Atractoscion aequidens*), which become both spatially

and temporally vulnerable to targeting by linefishing (described on page 29) during spawning. MPAs also allow for multiple-use zonation, which dictates what activities may take place in certain zones. For example, Controlled Areas (in a South African context) dictate who may fish in an area, what species may be caught and/or what fishing gear may be used, enabling fishery managers to ensure that benefits from protection accrue equitably to the surrounding user community or that areas that are sensitive to certain types of fishing gear (e.g. trawling) are not exploited by fisheries that can cause irreparable damage (Weigel et al., 2014).

A study by Edgar et al. (2014) highlighted five key features which were linked to improved ecological effectiveness of MPAs. These are known as the NEOLI principles and include N = no-take zonation, E = strong enforcement of rules, O = old age (more than 10 years), L = large size (over 100km^2) and I = isolation either by deep water or sand. Given the poor status of many of South Africa's linefish stocks and the overwhelming evidence for their effectiveness, the South African public and research communities called for the proclamation of more MPAs in South Africa to safeguard stocks for future use (Dunlop & Mann, 2013). Following intensive marine biodiversity mapping and stakeholder engagement processes (Mann-Lang et al., 2021), the proclamation of 20 new or extended MPAs in 2019 brought South Africa's mainland marine protection up to 5.4% of our EEZ (RSA, 2019a; Sink et al., 2019). The new MPAs of 2019 were all declared with the NEOLI principles in mind, a fact which has contributed to the documented ecological effectiveness of many of South Africa's MPAs (Kirkman et al., 2021).

Similar to other conservation endeavours, the monitoring of MPAs is an important component of their management, and is critical to demonstrate their success (Mangubhai et al., 2011; Dunham et al., 2020). Monitoring becomes even more necessary if we consider the accepted importance of Adaptive Management (Keith et al., 2011), which responds to new information about the functioning of a system as it is uncovered. One of the main problems facing MPAs globally and in South Africa is inadequate management and a lack of enforcement and compliance (Gill et al., 2017; Kirkman et al., 2021; 2023). This lends urgency to the need for the most efficient and effective monitoring programs possible to be developed and implemented, as these are the backbone of any good management program (Fox et al., 2014).

1.3.2 Human dimensions of MPAs

Human dimensions (also known as social dimensions in SES literature)[1] are considered a sub-discipline within conservation but also refer more broadly to people´s attitudes, beliefs, perceptions, and preferences regarding conservation rules, as well as the ways that people use conservation spaces and how well they comply with rules (Bennett et al., 2017; Barreto, Di Domenico & Medeiros, 2020). The human dimensions of MPAs have recently started gaining recognition as being of critical importance in planning and management processes. In a review of human dimensions research for MPAs, Barreto et al. (2020) found that it generally fits into five categories, namely, research on governance, economic, political, cultural, and social aspects. These aspects of MPAs are considered under-researched but are important to understanding the dynamics of the system in a holistic way (as a whole system, including all its components in its conceptualisation), to ensure effective management that responds to the reality on the ground. The marine conservation sector relies disproportionately on the compliance behaviour of people, as MPAs are often not as well-enforced as they ideally should be, due to capacity and funding shortfalls (Arias et al., 2015; Gill et al., 2017; Kirkman et al., 2023). It has been found that positive perceptions around the governance and social impacts of MPAs are a stronger predictor for compliance behaviour than perceived evidence of their ecological success (Bennett et al., 2019). Even so, the majority of MPA research today still focuses on proving or measuring their ecological effectiveness, and insufficient attention has been paid to monitoring socio-economic and governance metrics in MPAs globally and in South Africa (Fox et al., 2014; Mann-Lang et al., 2021; Kirkmann et al. 2023). However, this does not mean that ecological monitoring is not also important. Research has found that where evidence of the ecological impact of an MPA is lacking, compliance will decrease, while a better understanding of MPAs and how they work is correlated to better compliance and more positive perceptions about the MPA (Mann-Lang et al., 2021). Clearly, the situation is complex.

1.3.3 Transdisciplinarity in Marine conservation

Research has come to recognise the important role played by transdisciplinary-aligned approaches within the marine conservation sector, due precisely to the complexity of the social-ecological systems at play in the marine and coastal realms (Blythe & Cvitanovic, 2020; Breckwoldt et al., 2021; Brodie et al., 2022; Agardy, 1994; Wilson et al., 2021). In South Africa, the need for a transdisciplinary-aligned approach to

[1] "Human dimensions" and "social dimensions" are used interchangeably in this thesis, with the same intended meaning for both.

marine conservation is recognised in the National Biodiversity Assessment (NBA) of 2018 for the marine realm (Sink et al. 2019). This report consistently highlights the need for management approaches that include both ecological and social objectives to enable effective marine conservation and drives home the importance of transdisciplinary lines of enquiry in uncovering approaches that are likely to succeed (Sink et al., 2019). The shifting focus towards more transdisciplinary-aligned research in South Africa´s marine realm is reiterated by the Marine and Arctic Research Strategy, which emphasises a move towards 'transdisciplinary, collaborative, solution-oriented research' (RSA, 2016).

1.3.4 BASELINES IN MPA MANAGEMENT

Baselines in fisheries management are often ecological reference points which are used to assess the impact of management interventions in conservation. Traditionally, these reference points are from a time before anthropogenic impact affected an area (often referred to as a "pristine or unfished condition") and are used as a baseline towards which conservation efforts hope to restore a natural ecosystem (Kopf et al., 2015). In a seminal postscript, Pauly (1995) coined the term "Shifting Baseline Syndrome" to discuss the generational amnesia that affects fisheries management, whereby each successive generation of fisheries scientists accepts the stock numbers that occur at the beginning of their careers as a baseline from which to measure fisheries status and continually declining fish stocks. This leads to a gradual acceptance of lower fish stocks as normal with each successive generation, while the ocean continues to be depleted with ever-improving technology. This issue is compounded by new fish stock assessment techniques, which require ever greater data volumes, thereby making older data insufficient for new models and causing new fisheries scientists to ignore older datasets or anecdotes (Pinnegar & Engelhard, 2008). It is, therefore, necessary to practice extreme caution when embarking on an attempt to establish true baselines.

Ecological baselines are often conceptualised differently from the traditional baselines described above, in that they constitute a reference point from which to measure the *relative* improvement or decline of a conservation-related metric after management interventions have taken place, rather than indicating some prior population status to which management aims to return the population. Findings from an ecological baseline study by Edgar et al. (2004) showed that MPA site selection in the Galapagos had been made in such a way that certain species were naturally more abundant in areas outside the MPA than they were inside. Had the initial ecological baseline not been set, the unequal distribution of species before the declaration of the MPA network could have resulted in an inaccurate interpretation of monitoring data which was collected later. This study highlighted the need for ecological baselines to be

determined before an intervention takes place which aims to conserve and restore the ecology of an area. Understanding the need for ecological baselines, the shifting baseline phenomenon can unfortunately not be avoided except through acute awareness of the problem and a concerted effort to avoid the trap through effective communication regarding the type of baseline being established.

There is growing recognition of the benefits of considering human dimensions in MPA management and monitoring. Not only does it result in greater acceptance of MPAs, but it allows managers, through various monitoring programs, to assess how management decisions may lead to either improved or reduced compliance. A good monitoring program which includes regular interaction with local and traditional knowledge holders, as well as experiential knowledge holders (Fazey et al., 2006), can allow issues brought up by these people to be addressed before they become problematic, affecting the ecological success of an MPA through a decrease in support and a resulting decrease in compliance (Charles & Wilson, 2009). The establishment of management baselines, which include both ecological and social metrics for monitoring, is an important research gap in South African MPAs (Mann-Lang et al., 2021). A recent publication by Berkes & Franz (2025, p.124) describes an inverse relationship between the complexity of a system and the degree of precision that can meaningfully describe that system, and advocates for the use of fuzzy logic, which seeks to categorise objects (thereby decreasing the complexity of the problem), in working to solve complex social-ecological system problems in small-scale fisheries. Johannes (1998) takes such an approach to laying a baseline for fisheries management decision-making. He notes that accurately assessing and managing all marine fisheries to achieve optimum yields according to traditional data-driven techniques has an unrealistically high demand for time, money, and trained personnel. In response to this issue, Johannes (1998) recommends a data-less precautionary management approach, which he defines as using knowledge from sound, locally relevant ecological research (such as MPA research) in combination with local fishers´ knowledge, as a baseline from which to make management decisions aimed at ensuring the viability of fish stocks into the future. This thesis seeks to develop such a baseline for the commercial linefishing sector in KZN and its relevant MPAs. This project does not attempt to implement any management actions, so it cannot claim to conduct precautionary data-less management, merely to support it through knowledge production. Therefore, to avoid confusion with the terminology around baselines, from here on out, the type of “data-less” knowledge baseline for which Johannes (1998) advocates will be called a “Social-Ecological Systems (SES) Management Baseline”.

1.4 THE LINEFISHING SECTOR

Linefishing in South Africa is defined as fishing occurring with hooks and lines, either from a handline or using a rod and reel, but it excludes longlining. Spearfishing is also included in this sector for management purposes, although the method is different. The linefishing sector is divided into a commercial sector, which is the focus of this study (see below), a small-scale/subsistence sector and a recreational sector (Mann, 2013;Figure 1.1). The small-scale/subsistence fishery generally consists of people from a low-income background who live within walking distance of the coast, use low-technology methods, and rely on fishing for their livelihood and main source of food. There are an estimated 28 000 households that rely on subsistence fishing in some way in South Africa (Clark et al., 2002). The marine recreational fishery is an open-access fishery and is comprised of several sectors including shore angling, estuarine angling, offshore boat angling and spearfishing. There are an estimated 1.3 million recreational anglers in South Africa of which ~728 000 (56%) are marine or estuarine anglers with the remainder being freshwater anglers (Potts et al., 2022). There is considerable overlap between the various linefishing sectors, leading to a complex governance context for the fishery and infighting between the sectors, mostly due to competition for dwindling resources and the need to address social injustice due to the effects of Apartheid in the allocation of fishing rights (Potts et al., 2020; Sunde & Erwin, 2020).

The linefishery has undergone many changes in the past 100 years, as many of the target species have been overfished largely due to their vulnerable life history traits (they are slow growing, highly resident, form spawning aggregations, etc.) (Sink et al., 2019). This has led to serial depletion of some species, a phenomenon whereby fishers change their target species as certain prized species become less common (Penney et al., 1999). Some of the most important management interventions in the past 25 years have included: i) Introduction of a licensing system for recreational fishers in 1998; ii) Development of the Linefish Management Protocol (LMP) (Griffiths et al. 1999); iii) Recognition of subsistence/small-scale fishers as an separate fishing sector and later development of a policy to manage the small-scale commercial fishery; iv) Implementation of a ban on beach driving in 2002; v) A ~70% cut in commercial fishing effort (number of boats and crew) during the mid-term (2003) and long-term (2006) rights allocation process; and vi) Implementation of an updated suite of species-specific fishing regulations in 2005 (see summary by Mann, 2013). Figure 1.1 shows the first SES conceptual diagram for the linefishing sector, developed by Potts et al. (2020). This diagram provides a good overview of the institutional and governance context within which this study is situated.

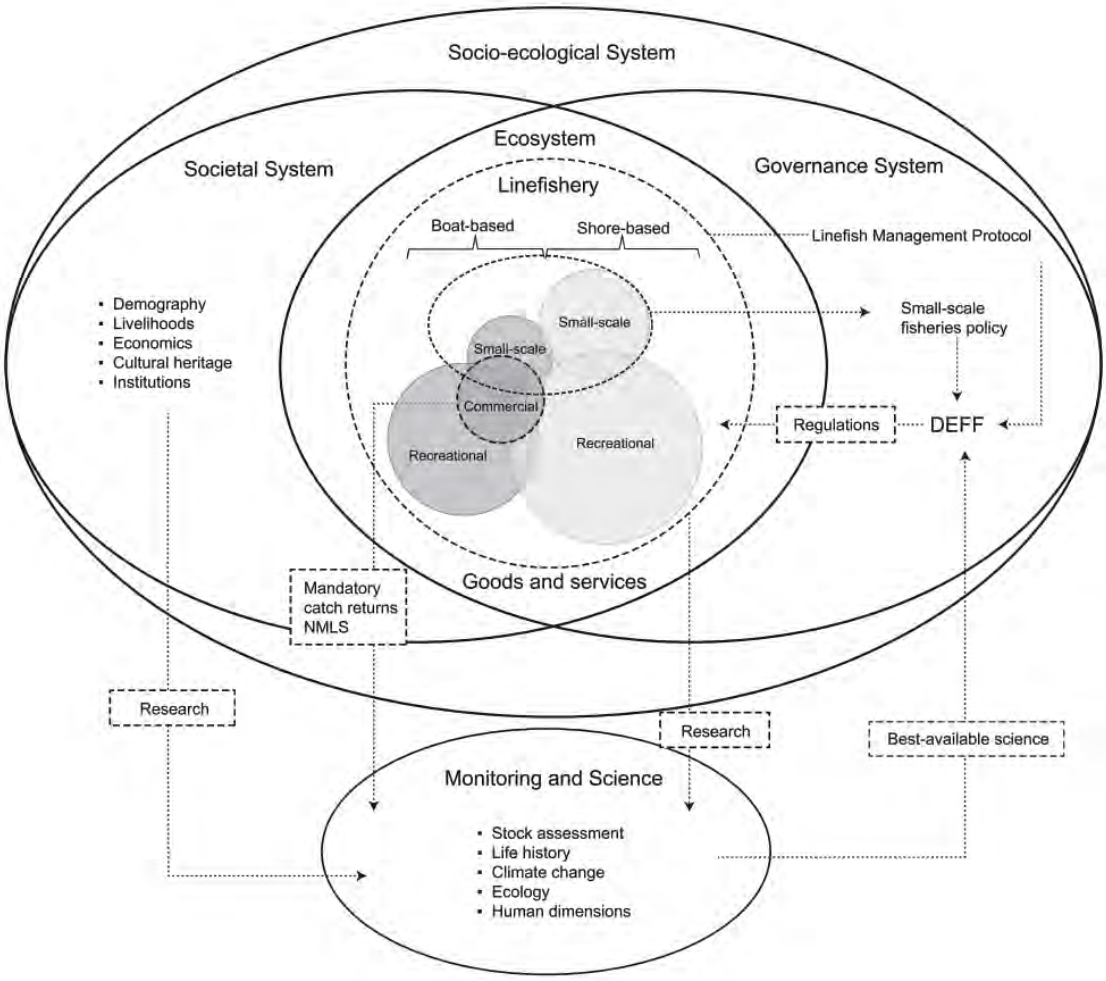

Figure 1.1: The (exact) conceptual diagram of the Social-Ecological System surrounding the South African linefishing sector which was developed by Potts et al. (2020). Note that the authors indicate that the linefishery sectors are scaled according to their participation. DEFF refers to the Department of Forestry, Fisheries and the Environment (now DFFE), and NMLS refers to the National Marine Linefish System, a database holding catch return information from commercial fisheries.

1.4.1 The commercial linefishing sector in South Africa

The commercial linefishing sector (CLS) is a special fishing sector for several reasons. Commercial linefishing in South Africa dates back to the 1500´s, making it the oldest commercial fishing sector in the county (Anderson et al., 2014). The commercial linefishery has the largest fleet (in terms of the number of commercial fishing vessels) in the country, and yet only makes up about 6% of the total economic value of all commercial fisheries (Sink et al., 2019). It also employs the most people of all commercial fishing

sectors (Mather et al., 2003). Despite its relatively small economic value, the commercial linefishery is therefore critical for many livelihoods and is valuable to South African heritage due to its long history.

Management of the CLS is conducted mainly using Total Allowable Effort (TAE), which restricts the number of boats and crew that are allowed to fish in a given area. The CLS is divided into three smaller sectors, namely the traditional linefishing sector, with a national TAE of 455 vessels and 3450 crew; the hake-handline sector, with a TAE of 130 vessels and 785 crew; and the tuna-pole sector, with a TAE of 200 vessels and 3600 crew (Mann, 2013). The traditional linefishing sector is further separated into three management areas namely the west coast (Area A), the south coast (Area B) and the east coast (Area C). This project focuses only on the traditional commercial linefishing sector in the KwaZulu-Natal (KZN) province (Management Area C). The TAE for this portion of the fishery is set at 52 vessels with 354 crew (Dunlop & Mann, 2013), although only 33 fishing vessels have currently activated their fishing rights (Sven Kerwath, DFFE, pers. comm.). This number is down by about 81% from the 1994-1996 number, when there were approximately 176 active commercial linefishing vessels in KZN (Sauer et al., 1997). Commercial linefishers in KZN typically use ski-boats between 6-8m long (up to a permitted maximum of 10 m), with twin outboard motors, and will launch either from the beach at designated surf launch sites or from larger ports such as the Durban or Richard´s Bay Harbour. Commercial linefishers do not generally have restrictions on the amount of fish that they may catch, but they are limited to targeting certain species and are excluded from fishing in certain areas such as MPAs that are zoned for no-take or specifically exclude commercial fishing (Dunlop & Mann, 2013).

Commercial Linefishers in KZN cannot strictly be classified as artisanal fishers (Mann et al., 2014), but the impact of their fishing is relatively low compared to other commercial and industrial fisheries (Everett, 2014). Most commercial linefishers are experts in their field, as they spend every possible good weather day on the ocean fishing, often for many hours a day, and generally have a much higher CPUE than recreational or charter linefishing vessels (Dunlop, 2011). This makes their perceptions and opinions about the network of MPAs (aka: MPA network) in KZN especially valuable, as their regular interaction with the MPAs, either fishing inside controlled areas which are designated for their sector, or in adjacent areas outside MPAs, means that they have a more thorough grasp of the day-to-day realities being faced through direct interaction with the MPA network. Their experiential knowledge is therefore extremely valuable in understanding and monitoring the progress of the MPAs in attaining their stated objectives (Fazey et al., 2006). They are also the primary user group that relies on the fish that are being protected

by MPAs for their livelihoods and, therefore, have a vested interest in the long-term success of the ability of MPAs to assist in the sustainable use and recovery of overexploited linefish stocks.

1.5 CONTEXTUALISING THIS PROJECT

1.5.1 STUDY AREA

This project focuses on the MPA network located off KZN, South Africa, and the commercial linefishing sector which utilises the marine resources both inside and outside these MPAs. There are five MPAs that are relevant to this province. From North to South, these are: iSimangaliso MPA, uThukela MPA, Aliwal Shoal MPA, Protea Banks MPA (which is adjacent to the small Trafalgar MPA), and, although not in KZN but immediately adjacent to the southern border of the province and therefore relevant to fisheries in the area; the Pondoland MPA (Figure 1.2). The MPA expansion of 2019 affected these MPAs in the following ways: The oldest portion of the iSimangaliso MPA was established in 1979 (previously known as the St Lucia Marine Reserve), this and the adjacent Maputaland Marine Reserve established in 1986 were incorporated into the iSimangaliso MPA (previously known as the Greater St Lucia Wetland Park) in 2000. In 2019, the iSimangaliso MPA was extended both offshore and further south to become the largest MPA off mainland South Africa. uThukela Banks MPA was established in 2019 and is currently the second largest MPA off mainland South Africa. Aliwal Shoal MPA was established in 2004 and was then expanded offshore and further north in 2019. Protea Banks MPA was established in 2019 and shares a border for one of its No-Take Areas with the Trafalgar MPA, which is a small coastal MPA that was established in 1979 and allows for shore fishing but not the collection of invertebrates. Pondoland MPA was established in 2004, and incorporated the smaller Mkambati MPA, which was established in 1991. Pondoland remained unaffected by the 2019 MPA expansion and lies just south of the provincial border in the Eastern Cape. It was incorporated into this study due to its close proximity and its relevance to commercial linefisheries in KZN. Figure 1.2 shows these MPAs and their zonation in the context of all current South African mainland MPAs.

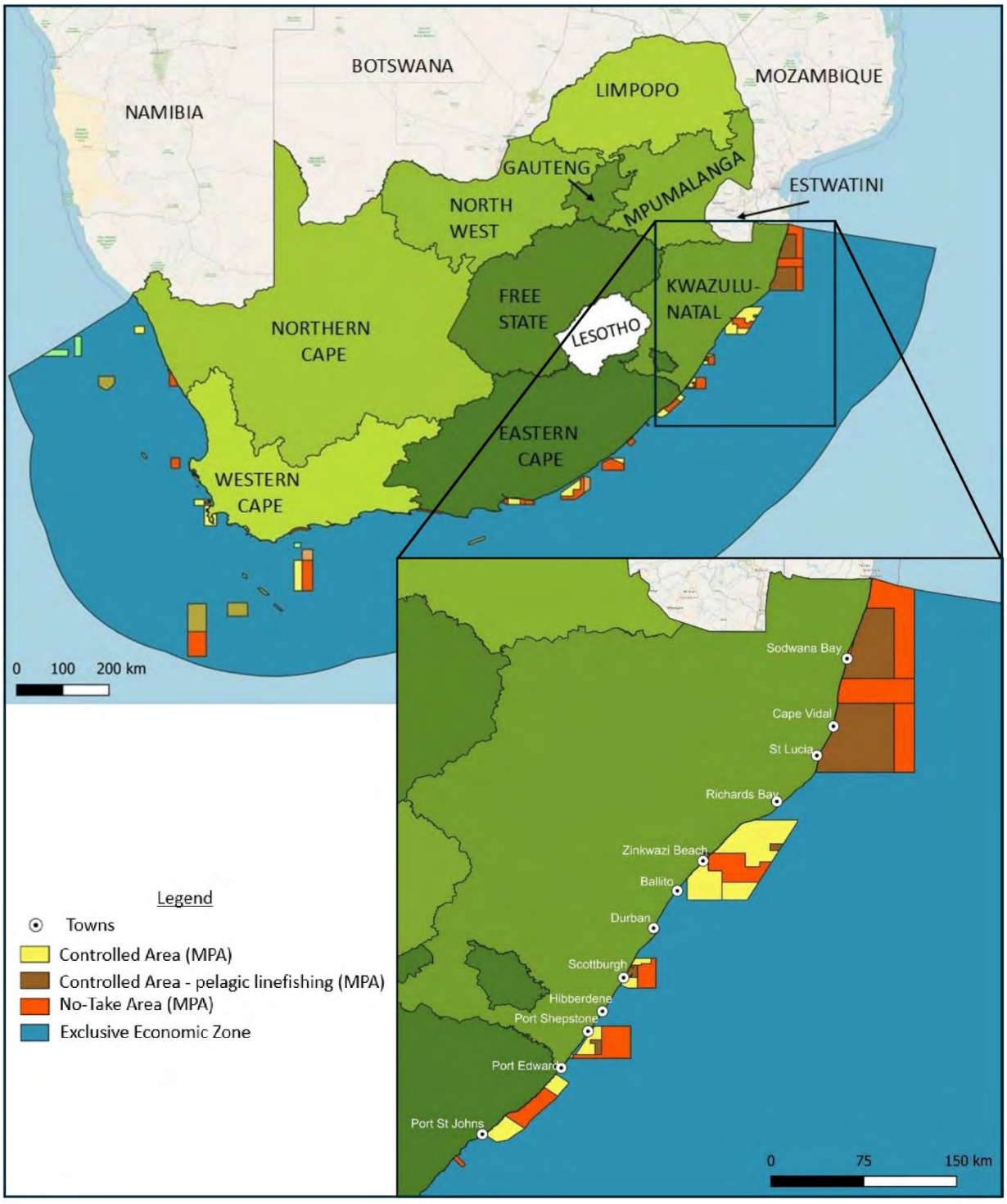

Figure 1.2: Map of the MPAs relevant to this study and their zonation in the context of South African MPAs. Note that no commercial fishing is permitted within the iSimangaliso MPA. The Controlled Area – pelagic linefishing is an area where only pelagic linefishing is allowed.

All five MPAs that are in KZN contain one or more stated objectives specifically aiming to support fisheries management and the recovery of linefish stocks. For example, in the uThukela MPA, one of two objectives specifically aimed at supporting linefish stocks states that a purpose of the MPA is:

"To facilitate species management and sustainable use of linefish by supporting fisheries recovery and enhanced species abundance in fished areas" (RSA (Republic of South Africa), 2004, 2019a).

This is a typical example, and objectives similar to this exist for every MPA relevant to the KZN linefishery, indicating that these MPAs are not purely for biodiversity protection, research, and tourism purposes, but are deliberately intended to also play an important role in the protection of overexploited linefish stocks and ensure that the future of their use by all fishing sectors is sustainable (Sink et al., 2019).

1.5.2 Research environment: The SMART Zone Project

Transdisciplinary-aligned research and its subsequent implementation are well underway at the new uThukela Banks MPA, where two projects are working to implement a transdisciplinary-aligned, Ecosystem-Based Management Plan (Lombard & Harris, 2021; WILDTRUST, 2022). The SMART Zone Project (which this study forms part of) was one of the first projects to be implemented in the new uThukela MPA. This multidisciplinary project aims to collect baseline data to be used for building an ecosystem-based adaptive management plan, which will rely on the SMART framework. The acronym "SMART" refers to building a management evaluation framework which contains five key elements: It is Specific (in its objectives), Measurable (in its outcomes), Achievable (given limited resources), Relevant (in the indicators being measured), and Time-Bound (in terms of outputs). This five-year project (2021-2026) will result in the production of a management plan for the uThukela Banks MPA that considers both social and ecological objectives in its implementation and associated monitoring plans (Lombard & Harris, 2021). The uThukela Banks MPA Ecosystem-Based Management Project (EBMP) will use the results of the SMART Zone Project, as well as other data collected for its own purpose, to build and implement an Ecosystem-Based Management Plan for the entire coastal zone adjacent to the uThukela Banks MPA. This coastal zone Management Plan will take a social-ecological systems approach (Ostrom, 2009) to the management and monitoring of the ecosystem and people living adjacent to the MPA, with the aim of ensuring social and environmental sustainability of management interventions. The EBMP will run for five years (1 March 2022 – 28 February 2027) and aims to provide capacity to the managing body of the MPA (Ezemvelo KwaZulu-Natal Wildlife - EKZNW) and its surrounding nature reserves to enable them to conduct more complete, ecosystem-based management going forward. The project is unique in that it

will work with local communities to better understand their needs, while also working with researchers to identify suitable ecological monitoring priorities.

1.6 Aims, Objectives, and Thesis Structure

1.6.1 Project Aim

This thesis aims to contribute knowledge on the relationship between the Commercial Linefishing Sector (CLS) and Marine Protected Areas (MPAs) in KwaZulu-Natal (KZN), which can be used as a social-ecological systems (SES) management baseline (defined in 1.3.4) for long-term MPA monitoring.

Each of the empirical chapters of this thesis will contain its own set of objectives, which will, together, fulfil the overall aim of the project. These are as follows:

1.6.2 Objectives

1. [Chapter 3] Use Baited Remote Underwater Stereo-Video Systems (stereo-BRUVs) data to determine how the MPA network in KZN affects populations of Commercially Important Linefish, in terms of biomass and maturity.
2. [Chapter 4] Understand perceptions of Commercial Linefishers in KZN regarding the MPA network and its current governance, as well as their perceptions around how this may be improved in future.
3. [Chapter 5] Integrate the results of the previous two chapters to investigate options for improving the sustainability of the MPA network in KZN from a social-ecological perspective.

1.6.3 Thesis structure, Chapter Aims and Objectives

Although none of this work has been published yet, this thesis takes a paper format: The two empirical chapters (Chapters 3 & 4) are written as potential scientific papers, each with its own introduction, aim and objectives, methods, results, discussion and conclusion. The discussion chapter (Chapter 5) is written as a potential discussion paper. Each chapter is prefaced by a relevant reflection on my experience with this project, allowing me to situate myself in the work and respond to the need for reflexivity in transdisciplinary ways of working (Popa, Guillermin & Dedeurwaerdere, 2015). The thesis draws to a close with a conclusion chapter, followed by a brief personal reflection on my positionality and experience with this project. There may be some minor repetition between chapters as a result of its paper-based format.

Chapter 1: Providing context: Transdisciplinary conservation science, fisheries management, and Marine Protected Areas

This chapter introduces the concepts and context necessary for this project as it relates to the conservation discipline, Transdisciplinarity in conservation, fisheries management, MPAs, the commercial linefishing sector, and the research environment in which this project takes place.

Chapter 2: Methodology: Frameworks, ontologies, and epistemologies

An overview of the methodological considerations (frameworks, theories, philosophies, and contextual considerations) which led to the current design of the project. The methods of data collection and analysis employed for each research component are described in the relevant chapter.

Chapter 3: About the Fish: Impacts of MPAs on commercial linefish populations

This chapter focuses on the ecological component of this project and uses Stereo-BRUVs methods and Generalised Additive Mixed Models (GAMMs) to understand the impacts of MPAs on fish populations targeted by the commercial linefishing sector in KZN, in terms of their biomass, abundance, and proportion immaturity.

Chapter 4: About the fishers: Perceptions of MPAs among commercial linefishers

This chapter explores the perceptions of commercial linefishers in KZN regarding MPAs, to understand how MPAs impact their sector, how they perceive the ecological aspects, governance, legitimacy, and social aspects of MPAs, and how they imagine MPAs could be improved.

Chapter 5: A theory of change for holistic MPA governance and management

This chapter integrates the results and knowledge about the strengths and weaknesses of the current MPA governance and management space, gleaned from the ecological and social science components, to explore a pathway toward better holistic governance of the Social-Ecological System.

Chapter 6: Conclusion and recommendations for further research

The sixth chapter is a short conclusion and summary of the most important results, with some recommendations for further research.

Chapter 7: About the researcher: Personal reflection

The final chapter of this thesis is a space where I reflect on my personal experience with this project, my growth as a researcher, and the way that my positionality impacts the work that I do.

Chapter 8: References

All the references used in this thesis

Chapter 9: Appendix

Additional graphs, figures, and tables for reference

CHAPTER 2

2 METHODOLOGY: FRAMEWORKS, ONTOLOGIES, AND EPISTEMOLOGIES

2.1 REFLECTION

METHODOLOGY

/ˌmɛθəˈdɒlədʒɪ/

1. The system of methods and principles used in a particular discipline

2. The branch of philosophy concerned with the science of method and procedure.

(The Collins Online Dictionary, 2023)

REFLECTION:

The methodology for this project has been a nightmare for me to get my head around. I knew the methods - the steps taken to collect the data - from the get-go. I knew these things before I was even sure what I would be trying to find. The methodology, however – the system of methods, principles, and philosophies that I use to justify my approach and declare the validity of this work to the reader – initially confused me and hence, made me read far more widely than I expected to. This education in the philosophy of science, ontologies, epistemologies, and worldviews, has broadened my understanding of life itself but has also confirmed something I knew innately: With all the talk and chatter, all the debate, and all the ego, nobody can describe reality just the way it is, in its entirety. It´s too complex for absolute terms. Sometimes things work one way; sometimes, another. That´s why there are so many philosophies to pick from. Much like religion, most philosophies claim some absolute truth and are too rigid for the true bits of other worldviews to be included, assimilated, and used as building blocks to better understand reality. The philosophies are often irreconcilable, and each way of doing things needs a philosophy that fits. So here we are. For all our brainpower and knowledge, we can´t really grasp the whole truth. I think the rise in transdisciplinarity has created an impetus to close the loop, though. It seems like people are trying harder than ever before to find philosophies and worldviews that make sense for everything we do, at once.

2.2 INTERDISCIPLINARY AND MIXED METHODS RESEARCH FOR SOCIAL-ECOLOGICAL SYSTEMS

Just as transdisciplinarity is widely accepted to bring a more holistic understanding (relating to the whole system) of complex conservation issues to the forefront (See Chapter 1.2 & 1.3.3), using mixed methods within a single case study can allow for the exploration of an issue from a variety of perspectives, and result in a broader understanding thereof (Newing et al., 2011). "Mixed methods" refers to using both qualitative and quantitative methods, with the integration of results to answer one question or achieve one goal at the end of data analysis (Newing et al., 2011). Under this definition, the social component of this project is a mixed methods component on its own, as its primary objective was explored using both quantitative and qualitative data analysis. Furthermore, the social and ecological components each have their own, independent objectives, which together give an overview of the SES that allows the project aim to be addressed in depth. This project is, therefore, also interdisciplinary in that it relies on combining and integrating knowledge from the social sciences and ecological science to address its aim (Pooley et al., 2014). A range of disciplines within the social sciences have informed this work to various degrees, including sociology, anthropology, history, and some psychology, which all helped to inform the interpretation of results for the social component and the final integration of results from the social and ecological chapters.

The decision to use mixed methods and an interdisciplinary approach for this project stemmed from a recognition of the limitations of single methods or disciplines in the context of SES, which are comprised of intertwined social and ecological subsystems, each with methods best suited to understanding them, with their associated strengths and weaknesses. By working in an interdisciplinary way, this project aims to find and use more of the available evidence than would be achieved using one discipline alone. By having more evidence available, we can move beyond the scope of a single discipline to provide richer insight (Darbellay, 2015) and start building a picture of the MPA SES as it pertains to the commercial linefishery in KwaZulu-Natal (KZN). The understanding that evolves from this enquiry can then be used to develop monitoring and management plans that are better suited to ensure sustainability for the whole system, rather than creating sustainability for the ecological component at the cost of social sustainability, or vice versa.

2.3 METHODOLOGICAL OVERVIEW

This work has been conducted as a mixed methods project, relying on both qualitative and quantitative data, as well as various theories and philosophies which were used in combination to develop an

understanding of commercial linefishers´ relationships with MPAs in KZN and how this can be improved. The diagram below (Figure 2.1) shows how each component contributes to the overall project design. Table 2.1 describes in more detail the objectives and research questions for each component and the methods used to address them. These graphics together provide an overview of the conceptualisation of the project from a pragmatic perspective and clarify how each component builds knowledge to address the project's aim. The rest of this short chapter will focus on explaining how various methodological considerations have been assimilated to clarify the theoretical and philosophical basis for this work. Methodical considerations (relating to the way that data were collected) are covered in the chapters relevant to their disciplines and will receive no further attention in this chapter.

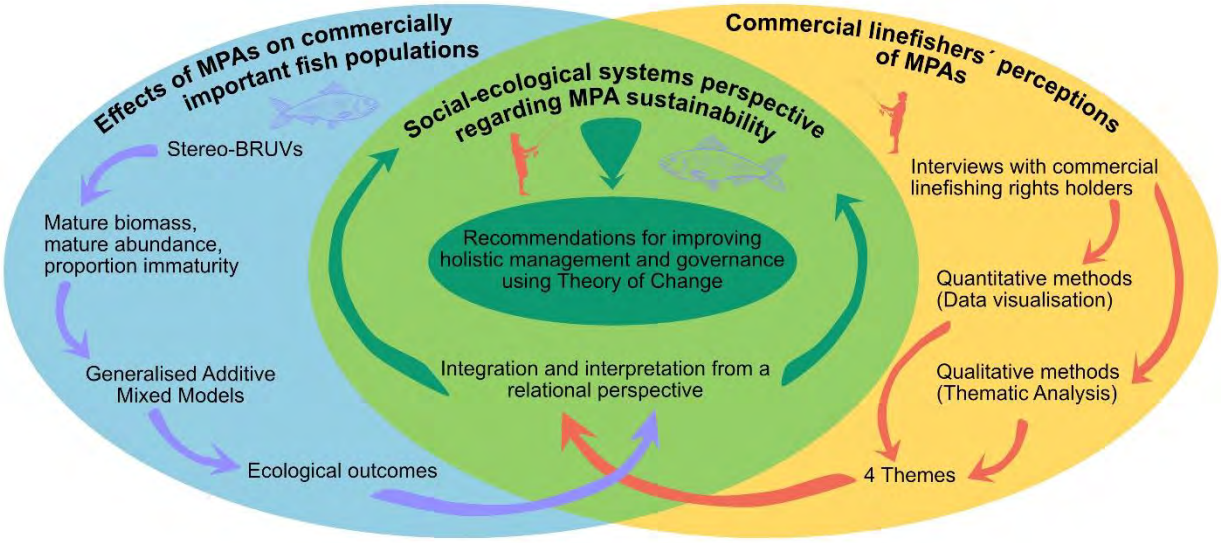

Figure 2.1: The methods used for this thesis and how the methods and components address the aim of this project, which is to contribute knowledge on the relationship between the Commercial Linefishing Sector (CLS) and Marine Protected Areas (MPAs) in KwaZulu-Natal (KZN), which can be used in a social-ecological systems (SES) management baseline for long-term MPA monitoring.

Table 2.1: The methods, objectives and research questions for each component of this project

	Objective	Research Questions	Methods
Component 1: Ecological research	Determine how MPAs affect the populations of Commercially Important Fish (CIF) in KZN, in terms of biomass, abundance, and proportion of immature fish.	Are the populations of mature CIF different within MPAs, compared to fished areas outside?	Stereo-BRUVs and video analysis using EventMeasure software. Statistical analysis of results using R and R Studio.
		Are the populations of mature CIF different in different MPA management zones?	
		How do MPAs affect the population structure of CIF?	
Component 2: Social research	Understand perceptions of Commercial Linefishing rights holders in KZN regarding the MPA network and its current governance, as well as how this may be improved in future.	How do commercial linefishing Rights holders perceive MPAs?	Semi-structured interviews with commercial linefishing rights holders, analysis using Atlas.ti.
		How do commercial linefishing rights holders believe MPAs could be improved?	
Component 3: Integration of ecological and social results, recommendations for improved governance and management of MPAs	Integrate results from the previous components to investigate options for improving the sustainability of the MPA network in KZN from a social-ecological systems perspective	What key insights from this work can inform a SES management approach aiming to ensure that MPAs reach their potential for enabling the sustainable use of linefish?	A Theory of Change, relying on findinigs of from previous components, literature review, workshops with fishers, and application of relevant theory and research.
		How can knowledge gained through this research be used to improve governance and management processes?	

2.4 THEORETICAL BACKGROUND

2.4.1 SOCIAL-ECOLOGICAL SYSTEMS

The concept of social-ecological systems (SES) has evolved to its current understanding from an initial recognition that the well-being of humans and nature are inextricably intertwined with one another (Berkes et al., 1998; Berkes & Folke, 1993). Humans need a healthy environment to survive, and environmental health is dependent on the way that humans choose to interact with and use nature. Without a positive relationship with nature, where humans respect and value the needs of natural systems, these systems will collapse and no longer be able to support a growing human population (Biggs

et al., 2022). This understanding has led researchers to the concept of SES, whereby natural and human dynamics are seen as constantly interacting components of one larger system, rather than two smaller, separate systems which are sometimes interrelated. This concept became generally accepted but it quickly became obvious that this new understanding of the human-nature connection drastically increased the complexity of sustainability research. Work by McGinnis & Ostrom (2014; 2009) was a huge advancement for SES sustainability research, as this provided a general framework for understanding the relationships in an SES and clarified how different subsystems fit together and interact in a general model. The framework itself is relatively simple (Figure 2.2) and consists of four subsystems which interact with one another in the SES under study, to bring about the focal situation being investigated. Two of these subsystems, the resource system and resource units, denote ecological (or non-human) systems and their components, while the other two subsystems, "governance systems" and "actors", are related to social aspects. The SES itself is denoted in Figure 2.2 by the dark green box with the dotted outline, indicating that the boundary of the SES is arbitrarily imposed in the system under study, making it highly permeable to and directly influenced by factors outside the system itself, including social aspects (social, economic and political settings), and well as ecological/non-human (related ecosystems). Each of these subsystems is further described as being made up of variables that determine and describe their structure and functioning, allowing for complex modelling of SES, such as that being done in systems dynamics modelling processes (Schlüter et al., 2014).

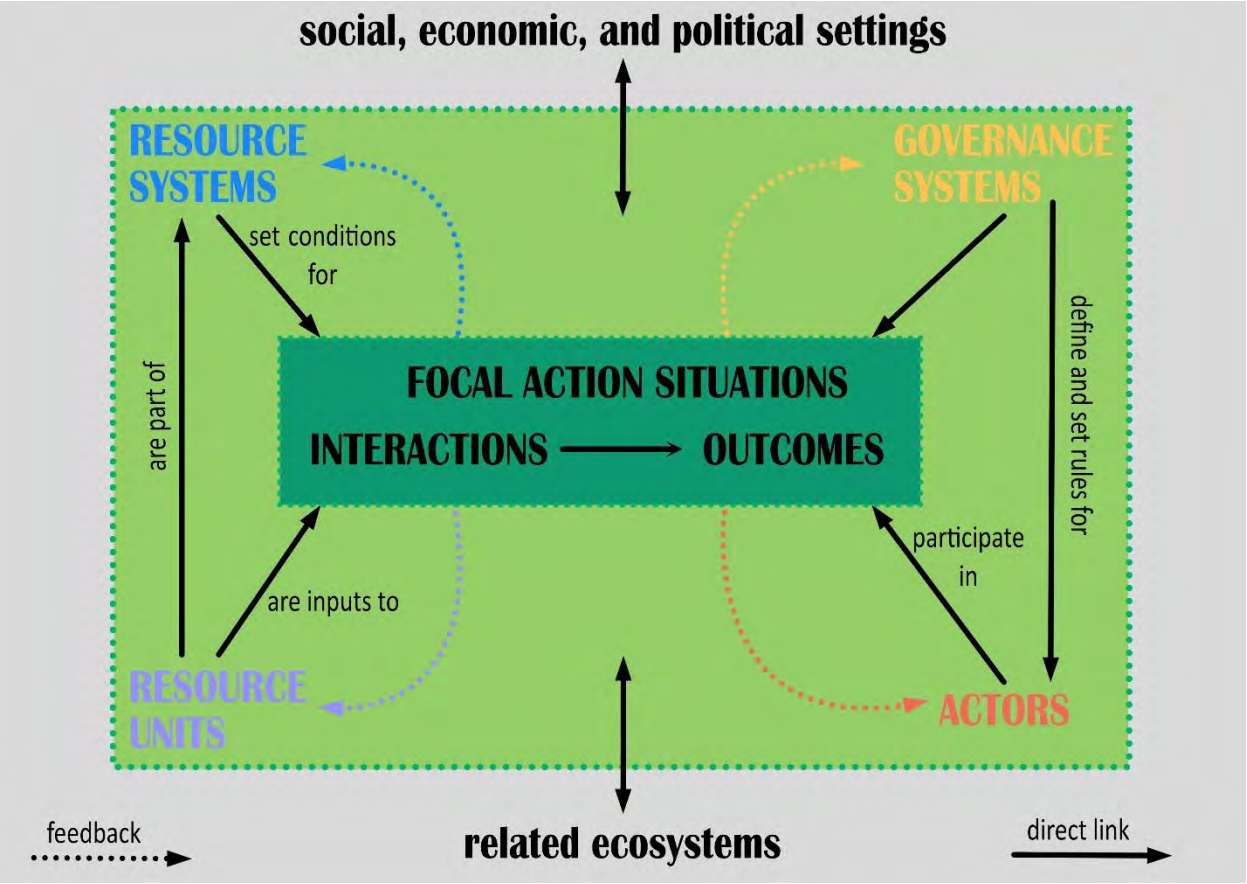

Figure 2.2 The updated SES framework described by McGinnis & Ostrom (2014), redrawn by the author.

2.4.2 SES as Complex Adaptive Systems

Preiser et al. (2018) expanded on the understanding of SES by describing how these systems can, in fact, be classified even further as Complex Adaptive Systems (CAS). Prior to this the complex, adaptive nature of SESs had not been explicitly described. The adaptive nature of SES is one of the big reasons why conservation efforts have faced so many difficulties, as the properties of CAS make their behaviour unpredictable. I briefly summarise these properties from Preiser et al. (2018) below:

1. **CAS are constituted relationally:** This means that the relationships between the constituent components of CAS define their structure and functioning more than any of the system components do on their own. These relationships are constantly in flux and allow CAS to self-organise and thereby display adaptive and dynamic behavioural patterns. An example of this in MPAs would be the way that relationships between governing bodies and fishers may impact fish stocks through improved or decreased compliance with rules (Bennett et al., 2019).

2. **CAS have adaptive capacities:** These systems generate their own organisational capacities in response to the relations between their constituent components, adapting and evolving to their environment and internal structure as change is introduced. An example of this in the fisheries / MPA space is the tendency of fishers to change their target species according to the abundance of species they target (Penney et al., 1999).
3. **Dynamic processes generate CAS behaviour:** Nonlinear feedback loops can either dampen or amplify their response to change, making them highly unpredictable in a management situation. This makes CAS particularly difficult to control and manage for a particular desired outcome. For example, the arrival of adult geelbek *Atractoscion aequidens* in KZN waters to spawn during the winter months results in commercial fishers changing their target species to capitalize on the temporary availability of geelbek. However, this abundance of fish also encourages recreational ski-boat fishers to target geelbek and sell them illegally thus flooding the local market and making it difficult for commercial fishers to sell their fish at a good price.
4. **CAS are radically open**: Energy, information and matter flow freely into and out of these systems, making it very difficult to impose boundaries on them. Whichever boundaries are imposed on the system for the sake of research or management will by nature be arbitrary and permeable, meaning that any number of external influences can affect the system that has been delineated. What is occurring inside the SES will always affect what happens outside, and vice versa. For example, fish can move into or out of MPAs freely and even resident species may move out of an MPA if the conditions are right (Kerwath et al., 2013; Medoff et al., 2022).
5. **CAS are contextually determined:** Due to the radically open nature of CAS, dynamic interactions both within the system and outside of it have a very strong influence on the system itself, such that the context in which the CAS is located strongly influences and determines the behaviour of the system. This means that the functioning of these systems can be affected also by influencing the system´s environment and not just by direct action on the focal system. For example, MPAs in tropical areas would contain a very different community of fish than in temperate areas, and fishers would therefore naturally target different species.
6. **Novel qualities emerge through complex causality:** The outputs of one component or subsystem of a CAS can also be the inputs for another, and small influences on one component can cause much larger effects for other components of the system. This means that these systems display emergent properties which cannot be attributed to only one component or component relationship. The components of these systems, therefore, cannot be used in

isolation to understand or predict the system´s response to change. This complex causality is the core difference between Complex Adaptive Systems such as SES and other types of complicated systems, which can be understood as a whole by breaking them down into their components and understanding each individual portion and how it relates to the whole. This deconstruction does not make sense for CAS as it does for other systems. For example, the effectiveness of MPAs for protecting fish stocks may be related to the direct effect of spatial protection of fish populations, but could be improved or hampered by governance decision-making processes or communication. These are not directly related to fish habitats and ecology, but could influence people´s awareness or valuation of MPAs, leading to changes in compliance on MPA rules, and subsequently have a massive effect on fish stocks (Bennett, 2016).

These six principles together describe why conservation as a discipline has remained so difficult to "do right", and why it will always remain a "wicked problem" – a complex problem characterised by a lack of a single, clearly optimal solution (Yeung et al., 2021). We simply cannot understand what will happen due to our interactions with SES, until after action has taken place and the results become obvious. This is largely why adaptive management has been found to be successful (e.g. Burger et al., 2004): it allows us to closely monitor the impacts of the changes we bring into these systems and respond to unexpected reactions to change timeously, before feedbacks in the system render our efforts pointless or cause more harm (Salafsky & Margoluis, 2003).

2.5 Ontology, epistemology and social-ecological systems research

The philosophy of science has grappled with the question of what constitutes reality for a very long time, and there is a strong debate around epistemology (the philosophy of knowledge) and ontology (the philosophy of the nature of reality) which underpins research (Goertz & Mahoney, 2012). These two areas of philosophy are, by nature, intertwined, with certain epistemologies being compatible or related to certain ontologies, but not to others (Bracken, 2010). In SES research, this incompatibility plays out as follows: The social sciences often tend towards constructivism. This epistemology contends that social reality is constructed by socio-historically situated practices, and therefore, in order to understand reality, we must understand how groups of people construct it. The ontological implication is that reality is not completely objective. The ecological sciences, on the other hand, usually embrace a positivist epistemology – which asserts that real knowledge is that which is discoverable by an objective viewer – as well as an essentialist ontology, which dictates that objects have fundamental properties that can be discovered through rigorous, objective science (Braun & Clarke, 2019; Goertz & Mahoney, 2012). These

epistemologies make sense for their relevant disciplines, and each has brought a wealth of new knowledge into the world, but their associated ontological implications are irreconcilable.

It therefore becomes necessary to find a new epistemology for SES research, which can foster a deep understanding of society´s inner workings, while also allowing for the empirical observation of phenomena. This is especially important when we consider that SES are CAS and display emergent properties which may arise due to a combination of social and ecological factors that cannot be understood in isolation from the system (Preiser et al., 2018). SES research requires epistemological agility (Haider et al., 2018) and methodological pluralism (Norgaard, 1989), and is by nature aligned with the transdisciplinary way of generating and uncovering knowledge (de Vos et al., 2019). SES research can therefore benefit from advances in the philosophical positioning of transdisciplinary work. Recently, such advances have included a move toward a process-relational worldview for sustainability, which aligns with the aims of this project as well as the study of SES more generally (Mancilla García et al., 2020).

2.5.1 A PROCESS-RELATIONAL PERSPECTIVE

Mancilla García et al. (2020) explain that adopting a process-relational worldview allows us to study SES as complete systems by removing the human-nature dichotomy. In this worldview, *processes* bring about the *objects* that we tend to focus on as the constituents of reality, for example, fish and people or governance systems and institutions. These *processes* are described as patterns or dynamics, and their properties and functions are defined by their relationships (or linkages) with one another and the *objects* they act on. Processes span over various realms (e.g. the human and the natural) and affect all the objects that have a relation to them. This worldview is particularly useful in the context of SES work precisely because it places the highest importance on processes and relationships as the primary constituents of reality. The process-relational worldview, therefore, relates well to the first property of SES as CAS, described above: That they are constituted relationally. It also provides a coherent philosophical underpinning for the integration of knowledge from different disciplines which otherwise are philosophically incompatible and can therefore not be integrated properly due to said incompatibility. If both the ecological and the social research in this project are conduced with the same philosophical worldview; the process-relational perspective; it means that findings from the two disciplines can complement and build one another, working together to inform an understanding of the processes and relationships at play in the system.

2.6 Conclusion: Diagram of frameworks used in this thesis

The below diagram (Figure 2.3) shows how various theoretical frameworks have been used for this thesis. Note that this chapter only provides an overview of frameworks which describe the conceptual positioning of this research project as a whole. Therefore, not all frameworks were explicitly described in this chapter. Some are specific to the chapter they appear in and will be described in the relevant chapter.

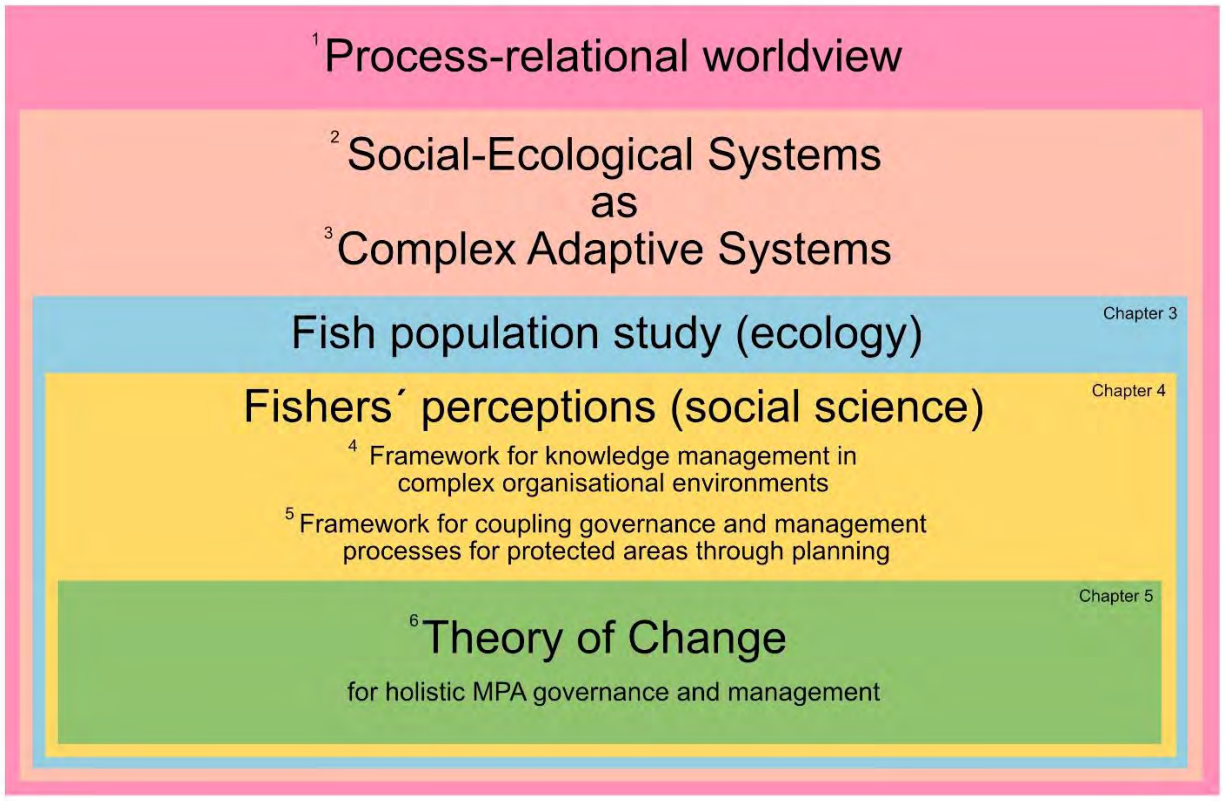

Figure 2.3: The frameworks used in this research, indicating how they fit together: 1) The process-relational framework by Mancilla García et al. (2020), which frames everything. 2) The Social-Ecological Systems Framework (McGinnis & Ostrom, 2014; Ostrom, 2009), which was built upon by 3) Preiser et al. (2018), describing these systems as CAS. Frameworks 4) by (Malhotra, 2002) and 5) by (Nkhata & McCool, 2012) are used in the social science chapter to explore effective governance and management of the system from a social perspective. 6) Theory of Change is a common methodical tool in development planning, but its use was informed by literature (Mayne, 2017; Taplin et al., 2013).

CHAPTER 3

3 ABOUT THE FISH: IMPACTS OF MPAS ON COMMERCIAL LINEFISH POPULATIONS

3.1 REFLECTION

ECOLOGY

/iˈkɒl.ə.dʒi/

The study of the relationships between plants, animals, people, and their environment, and the balances between these relationships.

(The Collins Online Dictionary, 2023)

REFLECTION:

It is difficult for me to conceptualise this ecological chapter, seeing that everything is so connected. The very definition of Ecology includes humans, yet these days it is hardly studied in its completeness. This is the Anthropocene. No ecology exists separately from human society anymore, and yet we continue to insist that every ecology that meaningfully includes the human dimension must be labelled separately, to clarify that this is social ecology, or the socio-economics of an ecology, or socio-…whatever. Never just "Ecology". It is, by its own definition, not interdisciplinary to include humans in ecology, and yet, somehow, with our siloes so firmly in place, it very much is. Our separation from nature, in this case, is not even linguistic. It is purely cognitive; a social construct pervasive to the point of being normalised. This chapter will try to remain in the silo that has been, perhaps unwittingly, built around the word; "Ecology". It will focus only on the well-being of the fish and not on that of the humans who catch the fish, despite the obvious connectedness of the two realities – a connectedness that I think would regularly warrant the two being studied in tandem, were it not for the fact that one of them is a human. The work done here is only a baseline from which to explore some small part of the Ecology of KwaZulu-Natal´s MPAs in the full wealth and meaning of the word.

3.2 INTRODUCTION

3.2.1 THE COMMERCIAL LINEFISHING SECTOR FROM AN ECOLOGICAL PERSPECTIVE

The boat-based linefish fishery, which includes both commercial and recreational linefishers, is an important consideration in fisheries management and planning, due to both its socio-economic importance and the impact of the fishery on marine ecosystems (Mather et al., 2003). In 1999, an assessment of the long-term catch and effort data in KwaZulu-Natal (KZN) showed that several linefish stocks were rapidly declining and that most of the resident species were overexploited(Penney et al., 1999). This, combined with other research and the development of a Linefish Management Protocol (LMP) in 1999 (Griffiths, 1999; Mann, 2013), led to the declaration of a state of emergency by the Minister of Environmental Affairs and Tourism in 2000 (Government Notice 4727 of 2000), with an associated reduction of approximately 70% in commercial linefishing effort and the establishment of long-term fishing rights between 2003-2006 (Mann, 2013). Additional steps were taken in 2005 to control recreational linefishing through the introduction of more realistic, species-specific, minimum size limits and lower daily bag limits for more vulnerable species. These interventions have been deemed at least partially successful and some of the important fish stocks that were collapsed or nearing collapse at the time of the declaration of the emergency, including slinger (*Chrysoblephus puniceus)* and santer (*Cheimerius nufar*) the two most commercially important linefish species caught in KZN, have shown positive signs of recovery (Maggs et al., 2017 a; Maggs et al., 2017b). However, other stocks, such as seventy-four (*Polysteganus undulosus*), red steenbras (*Petrus rupestris*) and dusky kob (*Argyrosomus japonicus*) are still considered heavily depleted or collapsed (Mann, 2013; Kerwath et al., 2019; IUCN, 2024). In the case of dusky kob, this has been ascribed to the overlap of multiple sectors targeting the species, as well as the degradation of estuarine nursery areas, while in the case of seventy-four and red steenbras it has been attributed to a lack of compliance on moratoria and other fishing regulations, as well as ineffective protection of spawning grounds and offshore refugia, which, if sufficiently protected, should ultimately aid in stock recovery (Anderson et al., 2014). In general, collapsed stocks which remain subjected to prolonged, intense overexploitation have lower resilience and consequently recover more slowly, meaning that the decisive and timely reduction of harvest rates is critical to sustainable fisheries management (Neubauer et al., 2013).

The literature related to linefisheries in KZN paints a picture of declining fish stocks causing fishers to change their target species as the most popular species become less common, a phenomenon known as serial depletion (Cardinale, Nugroho & Jonson, 2011). In 1999, it was reported that boat-based

linefisheries in KZN had switched from targeting mainly larger endemic reef fishes such as the now Critically Endangered seventy-four, Endangered red steenbras, and Endangered yellowbelly rockcod (*Epinephelus [Proposed: Mycteroperca] marginata*) (Craig & Hastings, 2007) to smaller, more common sparids such as slinger and santer (Penney et al., 1999). By 2013, slinger was the top species being landed (by number and weight) in KZN´s recreational and commercial boat-based linefishing sectors (Dunlop & Mann, 2013), and was considered optimally exploited (Mann & Fennessy, 2013). Santer is the second most important commercial linefishing species in KZN. The most recent assessment of the province´s linefishery found that these two species now made up 88% of commercial catch by weight (Dunlop & Mann, 2013), in stark contrast to the late 1990s, when Penney et al. (1999) found that slinger constituted 30% of the catch, and the combined catch of slinger, santer, blueskin (*Polysteganus lineopunctatus)*, Englishman (*Chrysoblephus anglicus)*, and other unspecified "red-fish" species only made up 50% of the total catch weight. This trend is concerning, to say the least. Fortunately, fish stocks in KZN are also being managed with an important and powerful tool which shows great promise, namely Marine Protected Areas (MPAs). The history of MPAs and their uptake for fisheries management and as a conservation measure is covered in the Introduction chapter and will not be reiterated here.

3.2.2 MPA MONITORING USING BAITED REMOTE UNDERWATER STEREO- VIDEO SYSTEMS

Baited Remote Underwater Stereo-Video Systems, or stereo-BRUVs, have shown promise for monitoring fish in South African MPAs, due to the non-invasive nature of their use, their ability to monitor both carnivorous and herbivorous fish, and the capacity for various metrics to be obtained from stereo-BRUVs data, such as presence/absence data, abundance data, length data, and, stemming from length data, biomass and maturity metrics (Bernard, 2012; Parker et al., 2016). Since 2012, BRUVs and stereo-BRUVs have been gaining popularity in MPA monitoring in South Africa (De Vos, 2012; Jackson, 2020), and have allowed much more detailed information on the ecological situation relating to our MPAs to be obtained (Heyns-Veale et al., 2019; Mann, Maggs, et al., 2022). The South African Institute for Aquatic Biodiversity (SAIAB) has a Marine Remote Imagery Platform (MaRIP) which focuses specifically on using stereo-BRUVs for monitoring and makes their equipment available to the public for this purpose since the initial cost of equipment is quite high. This platform also maintains a large nationwide database which has been maintained since 2013 and enables researchers to store and share their data. Managers and researchers focussing on MPA monitoring and research can benefit from using both the equipment (stereo-BRUVs) and the large existing dataset in their work to assess MPA effectiveness from a fish population perspective.

3.2.3 METHODICAL CONSIDERATIONS

3.2.3.1 STEREO-BRUVS AND FISH MATURITY METRICS

Stereo-BRUVs, in particular, are an excellent tool for understanding how MPAs affect populations of Commercially Important Fish (CIF) since they are non-invasive and enable the calculation of mature fish biomass. Mature fish biomass is a metric that is very useful as an indicator of MPA success (Smit et al., 2023), and one which fishers can relate to, since their catch limits (i.e. minimum size limits) are directly related to the size-at-maturity of their target species (Mann, 2013). This fact makes it easier to communicate with the commercial linefishers, the community of interest in this study, about the ways that MPAs impact the resources they depend on and, in turn, their livelihoods. Communicating the results of this project is important for the intention behind this work, which is to contribute positively to the management and efficacy of the MPA network in KZN. Furthermore, an aspect of MPA success can be related to the amount of mature fish (biomass and abundance) conserved, since one of the main objectives of South African MPAs is the recovery of fish stocks. Mature fish are those which are reproductively active and, hence, will be the only portion of fish populations which effectively contribute to this purpose. Using the mature fish biomass metric in combination with mature fish abundance is important because bigger female fish are well known to be better spawners, with larger females producing exponentially more eggs than those which have only recently reached maturity (Hixon, Johnson & Sogard, 2014). Spillover of eggs and larvae from MPAs with a larger proportion of BOFFFFs (Big, Old, Fat, Fecund Female Fish) will therefore be much higher from MPAs with bigger, mature fish protected within them (Harrison et al., 2012). Understanding how MPAs affect mature fish populations is also of interest to research and management decision-making, as it provides an indication of population viability and reproductive potential of the population under study. Research has shown that it is important to protect an old-growth age structure and to focus on protecting a broad spatial distribution of spawning and recruitment areas for long-term population sustainability, but that these aspects are often not sufficiently considered in MPA and fisheries management (Berkeley et al., 2004). Using metrics such as mature fish biomass and abundance allows management decision-makers to zoom in on the efficacy of an MPA against these goals and adjust their management accordingly. Finally, fishing preferentially removes larger fish from the ocean (Cooper et al., 2013), and even low fishing pressure is highly likely to remove the largest fish (Barnett et al., 2017). As larger, mature fish are impacted by fishing pressure first, studies focussing on mature fish populations can presumably provide better insight into the direct impacts of fishing on populations in different locations. Small, immature fish can be assumed to be less vulnerable

to targeted fishing pressure (partially due to hook size selectivity), and by removing them from the dataset, differences between sites using only mature fish could be more distinct than if the full-population size spectrum was considered. These differences may then be attributed to fishing pressure with slightly more confidence, although other potential impacts, such as differences in habitat and the impacts of coastal pollution, should not be overlooked as possible causes for observed differences in fish population structure. Similarly, focusing on comparing the proportion of immature fish in an area could provide insight into the effect of fishing pressure on fish populations more generally, as areas with higher fishing pressure are likely to contain fewer mature individuals, increasing the proportion of immature fish in the area.

3.2.3.2 Focussing on Mesophotic reefs

Mesophotic reefs are defined as those occurring between 30 m and 150 m and have received less research attention than shallower reefs due to logistical and financial constraints which make them more difficult to study (Turner et al., 2019). For a long time, these reef ecosystems were understood to be similar to shallower reefs, and it was presumed that they could act as a refuge for species that are susceptible to climate change at shallower depths (e.g. Lindfield et al., 2016). However, newer research has found that mesophotic reef ecosystems are not only very different to shallow reef ecosystems; they are also threatened by a variety of impacts and are in desperate need of research attention and protection (Rocha et al., 2018). Additionally, most of the species in this study, including the two most important species for commercial linefishers in KZN[2] are regularly found at mesophotic depths, making these reefs an important resource system for the sector (Dunlop & Mann, 2013; Mann, 2013). Deeper reefs have also been found to harbour more of the larger, sexually mature fish in South African waters (Heyns-Veale et al., 2016), and this makes them a targeted fishing area. By focussing on understudied mesophotic reef systems, this research therefore responds to the need for further research on these systems, while also focussing on a depth range that fishers prefer to utilise.

[2] slinger and santer, which make up over 80% of their catch

3.3 AIM:

The aim of this chapter is to use the stereo-BRUVs dataset available at MaRIP (SAIAB) to compare different spatial management strategies inside and outside Marine Protected Areas (MPAs) to understand how they affect the populations of commercially important linefish (CIF) in KwaZulu-Natal.

3.4 CHAPTER OBJECTIVES:

1. Compare the biomass and relative abundance of mature CIF inside MPAs to those in fished areas outside.
2. Compare the biomass and relative abundance of mature CIF under various spatial management strategies (No-Take MPA Zonation, Controlled MPA Zonation and Fished Areas) to understand their contribution to MPA objectives.
3. Compare the proportion of immature fish inside and outside MPAs to determine how MPAs affect the population structure of CIF.

3.4.1 EXPECTED OUTCOMES

As described in the introduction, the extent to which MPAs are designed in accordance with the NEOLI criteria[3] has a significant impact on their effectiveness for the preservation and recovery of fish stocks (Edgar et al., 2014). In 2021, an assessment of South African MPAs against the NEOLI criteria found that the Pondoland and iSimangaliso MPAs (alongside Tsitsikamma and De Hoop in the Western Cape) scored the highest against these criteria, ranking them among South Africa´s most ecologically effective MPAs (Kirkman et al., 2021). Other MPAs in KZN did not score as well. Aliwal Shoal is one of the older and better-enforced MPAs in the province, which led to it receiving the second-highest score in the KZN cohort, with the reason for its lower score being that it is less isolated than the Pondoland and iSimangaliso MPAs. However, the older No-Take portion is very small (2.5 km^2) and only protects shallow reef ecosystems, which makes it potentially less effective than other, larger MPAs that protect deeper reefs as well. The small, shallow Trafalgar MPA was assessed separately from the Protea Banks MPA, but received the same score as Protea Banks and uThukela, making them some of the less effective MPAs in the country, with only eight MPAs receiving a worse score (Kirkman et al. 2021). Trafalgar MPA is not relevant to this study, as it does not cover any mesophotic depths, but in summary its only good NEOLI score was due to its old

[3] N= No-Take, E= Enforced, O= Old, L= Large, I= Isolated

age (as it was proclaimed in 1979). uThukela and Protea Banks both scored well for their large size and their No-Take Areas, but lost points due to a lack of enforcement and the fact that they are both very new, having only been declared in 2019. They both scored 2/3 for Isolation, showing that they did not meet this criteria completely, but are relatively isolated compared to others in the assessment. Note that "Isolation" in the Kirkman et al. (2021) study was interpreted differently to its original definition by Edgar et al. (2014).

Given the methods and aim of this chapter, it would be expected that the older, better-scoring MPAs (iSimangaliso and Pondoland) should contain more and bigger fish than the newer MPAs with lower scores. Fish populations in these older MPAs should have had more time to recover from fishing pressure that occurred prior to their declaration: they scored the highest possible score for their old age and their large size, they are quite isolated, contain sizeable No-Take Areas, and are relatively well enforced by South African standards. Given the known importance of No-Take Areas for MPAs and fish populations, it is also expected that these areas will contain more and bigger CIF, as well as lower proportions of immature CIF, than either the Controlled Areas (inside MPAs) or the Fished Areas (outside MPAs). Importantly, the Controlled Areas of the iSimangaliso MPA do not allow recreational or commercial bottom fishing (Figure 1.2), so for the species of interest in this study, it should have a similar pattern of fish biomass, abundance, and proportion immaturity, as No-Take Areas do.

3.5 METHODS

Figure 3.1 below is a graphic representation of the methodical approach and types of data used for this research component, in the context of the whole project. Details and additional considerations for this work will be described further below.

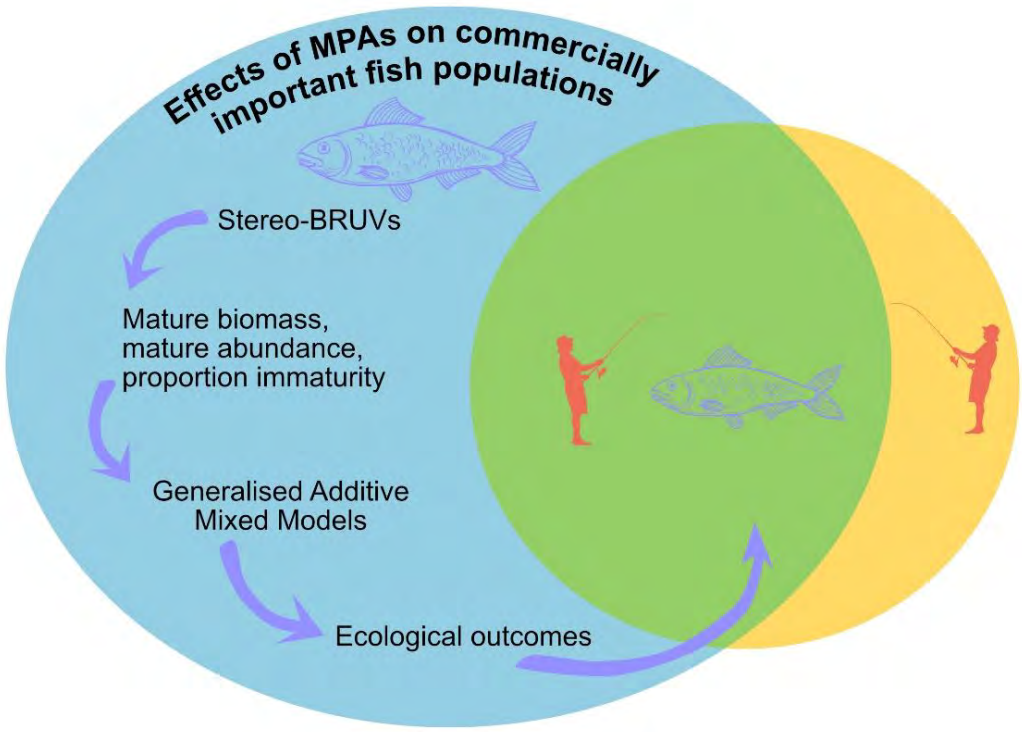

Figure 3.1: The methods and types of data utilised for this ecological research (represented by the blue circle) in the context of the whole research project (which is illustrated in Figure 2.1). The yellow circle on the right represents the social research component of this work, which can be found in Chapter 4 (Figure 4.1), and the green overlapping area indicates the integration of ecological and social research to explore a social-ecological systems perspective, which can be found in Chapter 5 (Figure 5.1).

3.5.1 STUDY AREA

This study took place in the marine subtropical Delagoa and Natal Ecoregions of South Africa, focussing on the offshore marine environment between depths of 30 m to 200 m on reef and near-reef habitats. Comparisons were made between the No-Take Areas and nearby fished areas for three out of five MPAs in and adjacent to the province of KZN. The MPAs that were compared in this study were, from North to South: iSimangaliso, uThukela Banks, and Pondoland. For the Pondoland MPA, the Controlled Area allows commercial and recreational bottom fishing with catch regulations equivalent to areas outside MPAs,

which means that for the fish populations of interest to this analysis, the Controlled Area is effectively not protected. The same is true for the Controlled Areas in the uThukela MPA, with the exception of the Controlled Pelagic Linefishing Zone. Trafalgar MPA is too shallow for the depth zones sampled in this study, and current stereo-BRUVs data for the Aliwal Shoal and Protea Banks MPAs were not available, as these sites had last been sampled in 2017 before they were declared as MPAs. Although a portion of Aliwal Shoal had been declared as an MPA in 2004, the No-Take Area was very small (2.5 km^2) and shallow (< 25m), and only four samples were taken there after its extension in 2019, which did not lend enough power for accurate statistical analysis. Newer stereo-BRUVs data from Protea Banks (collected in 2022) had not yet been processed, so for accuracy of comparison, the 2017 data for the sites which have now been declared as Protea Banks and Aliwal Shoal MPAs were included in the Fished Area category (i.e. they were still being fished prior to their establishment/extension in August 2019). Finally, only four samples were available from mesophotic depths at the Pondoland Controlled Area, so these data points were also removed as they were not sufficient for robust analysis. Figure 1.2 in the introduction chapter shows these MPAs and their zonation.

3.5.2 Description of marine ecosystems within the study area

The Natal Ecoregion (originally referred to as a Bioregion) was described in the most recent National Biodiversity Assessment as the marine area ranging from Cape Vidal in KZN to the Mbashe River in the Eastern Cape (Sink et al., 2019; Figure 3.2). This ecoregion is characterised by a sub-tropical climate and the presence of the fast, southward-flowing, warm Agulhas Current, with high inshore turbidity particularly during the summer months as a result of many large, muddy rivers entering the ocean. The high marine biodiversity associated with this region (Turpie, Beckley & Katua, 2000; Awad, Griffiths & Turpie, 2002; Mann et al., 2006) is due to the diverse seafloor topology on the continental shelf and the variety of ecosystem types associated with it throughout the coastline (Sink et al. 2019). The area is also an important transition zone between the tropics to the north and a warm-temperate region to the south, which has resulted in relatively high levels of endemicity (Mann et al., 2006; Celliers et al., 2007; Olbers, Celliers & Schleyer, 2009; Porter, Branch & Sink, 2013).

The Natal Ecoregion can be further sub-divided into two subregions, namely the Southern KZN and Wild Coast subregion and the KZN Bight subregion, with the break occurring at Durban. The Southern KZN and Wild Coast subregion consists of a relatively narrow continental shelf with a steep shelf edge and is dominated by the southward flowing Agulhas Current. In the northern part of the Southern KZN and Wild

Coast subregion, periodic cyclonic eddies (referred to as the Natal Pulse) form inshore of the Agulhas current on the continental shelf and result in occasional "reverse currents" with inshore water moving in a northward direction (Yamagami, Tozuka & Qiu, 2019; Guastella & Roberts, 2016). The KZN Bight subregion is an area of coastline with a length of approximately 160 km between Durban and Richards Bay, where the continental shelf is much wider than along the remainder of the KZN coast (Fennessy, Roberts & Paterson, 2016). Off the Thukela River, the shelf reaches a maximum width of ~45 km offshore, and here, the Agulhas Current moves further offshore following the shelf edge (Lutjeharms, 2006). North of Durban the inshore current persistently flows in a northward direction as part of the Natal Gyre (Lutjeharms, 2006).

The more tropical Delagoa Ecoregion is also relevant to this study, because the iSimangaliso MPA largely falls within this ecoregion. In addition, many of the commercial fish species investigated in this study have a distribution extending into the iSimangaliso MPA (especially in the cooler deep water) and there is high connectivity between ecoregions due to the predominant southward flowing Agulhas Current and the intermittent reverse currents (Mann et al., 2022; Mann et al., 2023). This ecoregion extends north from Cape Vidal to Bazaruto in Mozambique (Sink et al., 2019; Figure 3.2). Along the South African coast, the Delagoa Ecoregion is characterised by a narrow continental shelf, with a width of ~11 km to the 200 m isobath. In contrast to the Natal Ecoregion, this region is characterised by warm, clean, oligotrophic[4] waters due to the lack of rivers flowing into the sea and the continental shelf is intersected by several submarine canyons formed during periods of lower sea levels.

The continental shelf of the entire Natal and Delagoa Ecoregions is characterised by the formation of several narrow reef systems comprised of consolidated sandstone or "beach-rock" that were formed during lower sea levels during the late Pleistocene (Ramsay, 1996). These former dune cordons are exposed at depths of approximately 50 and 100 m running parallel to the coast (Garratt, 1985). In terms of the commercial linefishery in KZN, which is the focus of this thesis, much of the fishing takes place on these mesophotic reef systems where the bulk of the target species are found.

[4] Nutrient-poor, with abundant oxygen

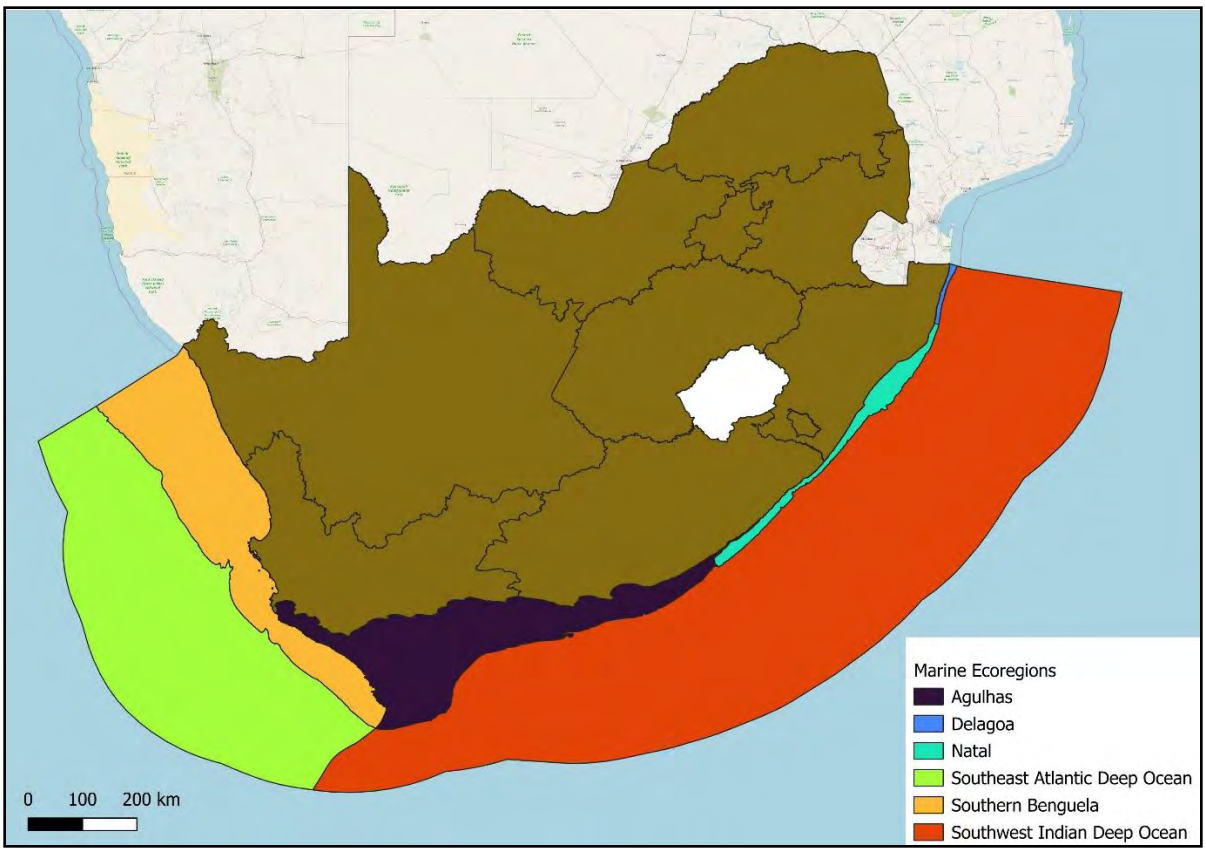

Figure 3.2: The Marine Ecoregions found within South Africa´s Exclusive Economic Zone (EEZ), as shown in The National Biodiversity Assessment (Sink et al., 2019), mapped using data from the South African National Biodiversity Institute (2018).

3.5.3 ETHICAL CLEARANCE

Ethical clearance for this ecological component of the work was sought and gained through a blanket ethics application under Dr Anthony Bernard (A 2.6.3 Ethical approval for animal research Approval number: 2022-5444-6596), which served as ethical approval for all students supervised by Dr Bernard under the SMART Zone project, and allowed the team to collect new data at the uThukela MPA for this project.

3.5.4 SAMPLING APPROACH

Data for this project was acquired from existing datasets from the ecological monitoring programme for MPAs at MaRIP (SAIAB), as well as new field surveys which were conducted in the new uThukela MPA in 2022. The existing data had been collected following a similar sampling protocol to that described below for the uThukela MPA and contained data on the complete fish community at each sampling site. This

project focussed only on understanding the impacts of MPAs and their different management strategies on commercially important fish species (see section 3.5.7) found at mesophotic depths. Relevant data from the MaRIP database were isolated and then underwent statistical analysis together with the data collected from uThukela Banks. This meant that the data used in this study were collected in different years and different management zones in three different MPAs (Pondoland, iSimangaliso, and uThukela) and in fished areas outside MPAs, to allow a comparative sampling design (Table 3.1, Figure 3.3). The reliance on available data meant that certain imperfections were present in the sampling design:

1. No samples from the Pondoland Controlled Area were used, as only four of the available samples were taken on mesophotic reefs and this did not lend sufficient statistical power for their inclusion into modelling. Extensive sampling was not carried out in this area due to the absence of extensive mesophotic reef habitat in this zone.
2. The number of samples was unbalanced within different zones of the same MPA (e.g., uThukela No-Take Area has n = 14, while its Controlled Area has n = 63).
3. The number of samples was unbalanced between different MPAs (e.g., uThukela has n = 77, while Pondoland has n =28).
4. Samples were collected in different years (e.g., uThukela MPA = 2022, while Pondoland MPA = 2014 – 2017).
5. Samples were collected in different seasons (e.g., uThukela MPA = June + July (mid-winter), while some samples at iSimangaliso were collected in November (mid-summer).

The statistical modelling process (Section 3.5.12) was selected to take these constraints into account as far as possible.

Table 3.1: Sampling details, indicating when each area was sampled and how many samples (i.e. stereo-BRUVs deployments) were taken. No-Take Areas inside MPAs do not allow fishing, while Controlled Areas allow fishing, but with restrictions. Note that the data is unbalanced, with different numbers of samples collected at each MPA and in each type of zonation (Controlled or No-Take). Additionally, no Controlled Area samples were used for the Pondoland MPA, as there were insufficient samples available from mesophotic reefs in this area for accurate statistical analysis (n=4). Samples were collected for each MPA in different years, but different zones within each MPA were sampled within the same timeframe. The "Fished Area South" category refers to the fished sites which were sampled from Scottsburgh to the Port Edward, while "Fished Area Central" refers to the fished areas that were sampled near Durban.

Management Area	Sampled (month, year)	Number of samples
uThukela Banks MPA No-Take Area	Jun 2022	14
uThukela Banks MPA Controlled Area	Jun & July 2022	63
Total: uThukela Banks MPA		**77**
Pondoland MPA No-Take Area	Jan 2014, May 2015, Apr 2017	28
Total: Pondoland MPA		**28**
iSimangaliso MPA No-Take Area	Nov 2016, Jun 2017, Jun 2018	23
iSimangaliso MPA Controlled Area	Nov 2016, Jun 2017, Jun2018	56
Total: iSimangaliso MPA		**79**
Fished Area South	Jan 2014, May 2015, Apr 2017	44
Fished Area Central	Apr 2017, Jul 2022	43
Total: Fished Areas		**87**
Total stereo-BRUVs samples used in this study		**271**

3.5.5 SAMPLING METHODS

3.5.5.1 PREPARATION FOR FIELD SAMPLING

The site selection process was carried out in QGIS (QGIS Development Team, 2022) according to the following workflow. A map of the South African MPAs, including their zonation, was used as a base map. Seafloor depth raster maps for each reef complex were sourced from collaborators on the SMART Zone Project, who used multi-beam echosounder bathymetry mapping techniques (Wanda et al., 2023). Depth rasters were used to create slope rasters, which were then used to create slope contours for four-degree and ten-degree slopes separately. The resulting contours were fixed so that they could be converted into polygons. Polygons showed two categories of reef, namely high-profile reef (ten-degree slope or more), and low-profile reef (between four- and ten-degree slope). Areas where the slope was less than four degrees were assumed to be sand. The random points generator function in QGIS was used to generate a minimum of 20 random sampling sites per reef complex, evenly distributed among the low-profile and high-profile reefs and with a minimum distance of 400m between adjacent sampling sites. These sampling

sites were checked to ensure that the software had given the required results before they were used for sampling. After the completion of a sampling day, the actual sampling locations, as taken by the GPS on the boat, were compared to the planned sampling points by overlaying them on the initially generated points. Where there were points that were too close to each other or too far away from the intended sampling site, these were checked against the boat´s onboard GPS system to make sure that human error in data capture was not the problem. After checking for human error, all samples had taken place close enough to the intended sites and there was no need for resampling.

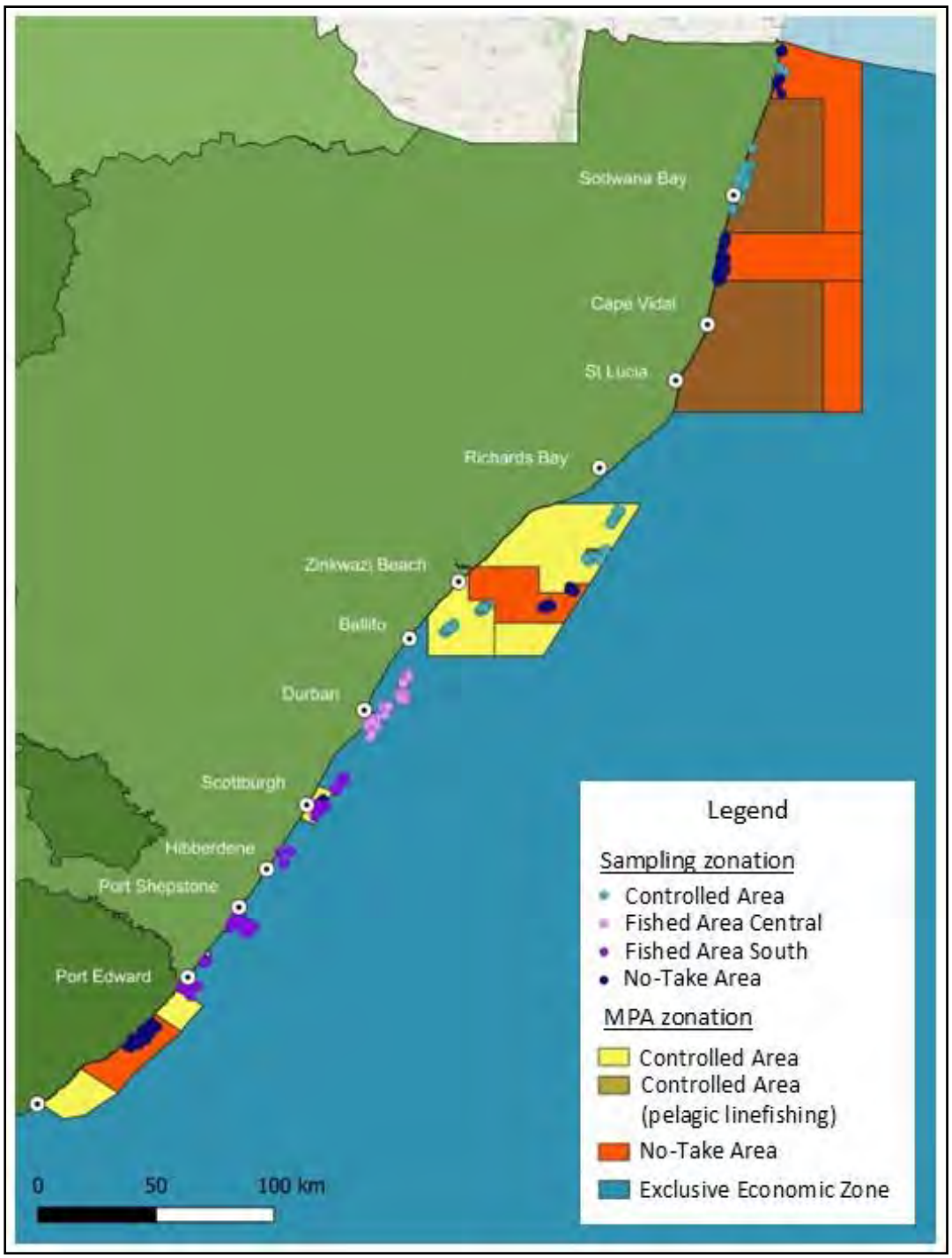

Figure 3.3: Map showing the Marine Protected Areas along the KwaZulu-Natal and Eastern Cape coast and sites where stereo-BRUVs sampling took place, which are marked as dots. Sampling sites in Controlled Areas are light blue, sites in No-Take Areas are dark blue, and sites in the Central Fished Area are pink, while those in the Southern Fished Area are purple. Note that this map only contains the MPAs which were declared at the time of sampling (excluding the small Trafalgar MPA), so the extended Aliwal Shoal MPA and the Protea Banks MPA are not shown, compared to Figure 1.2.

3.5.5.2 SAMPLING METHODS

Field sampling was conducted on reef complexes in and adjacent to the uThukela MPA during 2022. Within each reef complex, sampling followed a stratified-random design with a balanced distribution of samples between high- and low-profile reef or near-reef habitats (classified according to Table 3.2). All data were collected using stereo-BRUVs in accordance with a standardised protocol as described by Langlois et al. (2020), thus allowing for the comparison of results and minimising sampling bias. This also allowed the results of this study to be comparable with future monitoring which may be done in these locations.

A stereo-BRUVs consists of two HD video (GoPro Hero 5 Black) cameras in underwater housings (Figure 3.4, E) mounted 70 cm apart on a rigid basebar (Figure 3.4, C) to provide a landscape view. The cameras are positioned to provide an overlapping field of view (7^{o} inward convergence), to enable stereo-video calibration and precise photogrammetric measurement of fish body size (Harvey, Fletcher & Shortis, 2001). White LED lighting (Figure 3.4, F) was used to illuminate fish up to 5 m away from the cameras during sampling. The weight of each stereo-BRUVs was approximately 50 kg, which ensured that it remained stationary in deep waters with strong currents that are common in the study area. When currents were very strong, an additional 10-20 kg of weights were added to the system until it was stable underwater. Between 800 grams and one kg of crushed sardines (*Sardinops sagax*) was used for bait and placed into the bait canister, which was attached to the stereo-BRUVs prior to deployment (Figure 3.4, G).

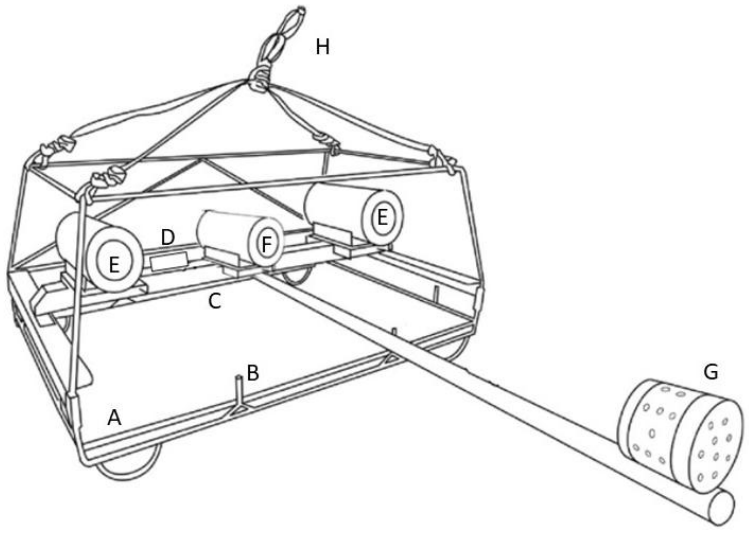

Figure 3.4: Schematic of a Baited Remote Underwater Stereo-Video system adopted from (Bernard et al., 2014), showing: (A) the stainless-steel frame, (B) Pins for holding weights, (C) a rigid centre bar, onto which (D) a temperature logger, (E) two camera housings and (F) one white LED light are mounted. (G) is the bait canister, attached to the stereo-BRUVs. (H) attaches to a rope and surface marker buoys to ensure that the stereo-BRUVs are retrievable.

Each stereo-BRUVs was deployed onto the seafloor for at least one hour from the research vessel *Hispidus,* which belongs to SAIAB. A davit arm and capstan winch system was used to deploy and retrieve the stereo-BRUVs to and from the seafloor. The descent of each stereo-BRUVs through the water column was monitored using a GPS-linked echo sounder, and the descent rate was reduced when it was near the bottom so that it settled gently with minimal disturbance to sensitive growth forms on the seafloor. As soon as the apparatus landed, the exact location of the drop-point was recorded using a GPS. A surface marker buoy was attached to each stereo-BRUVs on a rope at least twice as long as the sampling depth for easy retrieval of the apparatus after sampling. Once a stereo-BRUVs had been deployed and the videos were running, other systems were deployed at other sampling sites on the same reef complex, thereby allowing for concurrent data capture as far as possible. For retrieval of the stereo-BRUVs, the skipper manoeuvred the boat into position to retrieve the buoys and manoeuvred the boat directly above the system while deck hands took up slack in the rope. The stereo-BRUVs was then lifted off the seafloor using the davit arm and capstan winch system. Videos were recorded on labelled 32 MB SD cards, which were carefully stored on the boat after retrieval until they could be downloaded onto a hard drive for later analysis.

3.5.6 STEREO-BRUVS CALIBRATION

Stereo-BRUVs were calibrated following best practices both before and after sampling (Langlois et al., 2020). Calibration was conducted in SeaGIS CAL software (SeaGIS, 2022a), which streamlines stereo camera calibration using a multi-step process that integrates image processing, photogrammetry, and optimization techniques. Researchers record video footage of a calibration cube from various angles in a swimming pool before and after each field trip, and then use CAL software to identify and measure target points across the image set in an iterative process. The software guides users through the configuration process for adjustment parameters and executes a sophisticated bundle adjustment algorithm to simultaneously solve for camera lens, sensor and mounting parameters, positions, and orientations. This configuration process produces calibrated stereo-camera files that enable precise 3D measurements in underwater environments. Making calibration videos before and after sampling created redundancy in case a camera was bumped, drowned, or otherwise moved during the field trip, which would have made the pre-trip calibration files null. Calibration files were stored for use during video analysis, when they are loaded into EventMeasure (SeaGIS, 2022b) software during video analysis.

3.5.7 CHOICE OF FISH SPECIES FOR ANALYSIS

In all the datasets that were used for this analysis, the full fish community detectable by stereo-BRUVs was sampled, identified to species level, counted, and measured, where possible. The decision of which species to consider for this study was complex. To ensure that this work was relevant and of interest to the commercial linefishers in KwaZulu-Natal, an iterative decision-making process was followed. First, relevant literature was reviewed to determine which species are known targets for the commercial linefishing sector (e.g. Dunlop & Mann, 2013). Dr Anthony Bernard from SAIAB and Dr Bruce Mann from the Oceanographic Research Institute (ORI), both experienced with this fishery, were also asked for advice on which species to include. This resulted in ten, mostly reef-inhabiting bottom fish (demersal) species initially being marked for analysis, namely: slinger (*Chrysoblephus puniceus*), santer (*Cheimerius nufar*), Scotsman (*Polysteganus praeorbitalis*), Englishman (*Chrysoblephus anglicus*), black musselcracker (*Cymatoceps nasutus*), Natal emperor (*Lethrinus scoparius*), catface rockcod (*Epinephelus [Proposed: Mycteroperca] andersoni*) (Craig & Hastings, 2007), yellowbelly rockcod (*Epinephelus [Mycteroperca] marginatus*), red steenbras (*Petrus rupestris*) and seventy-four (*Polysteganus undulosus*). Seventy-four and red steenbras are two species which were historically important to the commercial linefishing sector in KZN (Penney et al., 1999) but have subsequently been severely depleted and are currently not allowed to be landed by commercial linefishers (Anderson et al., 2014). Nevertheless, these two species were

included as there is hope that their populations are recovering. Santer and slinger were obvious choices as they are currently the two most important commercial linefish species caught in KZN, together making up approximately 88% of the commercial catch by weight (Dunlop & Mann, 2013). Black musselcracker and Scotsman are both resident as juveniles (Maggs et al., 2013; Murray et al., 2019) and are sought-after by commercial linefishermen (Sink et al., 2019). Yellowbelly rockcod, catface rockcod and Natal emperor are non-sparid species which also feature strongly in the catch composition of commercial linefishers in KZN, according to (Dunlop & Mann, 2013).

This project also contains a social component where fishers were interviewed to understand their perspectives on MPAs. The exact methods for this data collection process will be covered in Chapter 4 (section 4.4.1), but face-to-face interviews allowed the researcher to ask commercial linefishers which species they believe should be included in the analyses. Through this process, and with the advice of Dr Mann and Dr Bernard, an additional 18 species were added to the list, as follows: dusky kob (*Argyrosomus japonicus*), geelbek (*Atractoscion aequidens*), white-edged rockcod (a.k.a captain fine, *Epinephelus [Mycteroperca] albomarginatus*), dot-dash rockcod (*Epinephelus [Mycteroperca] poecilonotus*), deep-water red snapper (*Etelis carbunculus*), deepwater longtail red snapper (a.k.a. ruby snapper, *Etelis coruscans*), spangled emperor (*Lethrinus nebulosus*), false fusilier snapper (*Paracaesio sordida*), Yellowtail blue snapper (a.k.a. Protea bream, *Paracaesio xanthura*), wreckfish (*Polyprion americanus*), blueskin seabream (a.k.a trawl soldier, *Polysteganus lineopunctatus*), goldflag jobfish (*Pristipomoides auricilla*), crimson jobfish (a.k.a rosy jobfish, *Pristipomoides filamentosus*), goldbanded jobfish (*Pristipomoides multidens*), oblique-banded snapper (*Pristipomoides zonatus*), greater amberjack (*Seriola dumerili*), longfin yellowtail (*Seriola rivoliana*), and any other *Pristipomoides* species which had been identified in video analysis. *Lethrinus nebulosus* was added due to a recent discovery by Holleman et al. (2022) that the dominant lethrinid species caught in KZN is the Natal emperor *L. scoparius*. However, prior to this publication, *L. scoparius* had been mistakenly called *L. nebulosus* in analysed videos, requiring the inclusion of all sightings labelled as *L. nebulosus* for data accuracy. Wreckfish is another species which is not allowed to be fished commercially, but fishers shared that they would like this species to be included in the analyses as they remain interested in the stock abundance. Fishers indicated that particularly in southern KZN, the jobfishes were making up an increasingly important portion of their catch, leading to the decision to include all *Pristipomoides* species seen during video analysis. This feedback from fishers aligns with previous research which indicates that the species being targeted by the commercial linefishing sector changes over time, often as a result of serial overfishing (Penney et al., 1999).

3.5.8 ADDITIONAL ENVIRONMENTAL DATA

Additional environmental variables for which data were collected included habitat type, underwater visibility, geographic coordinates, sampling depth, wind speed and direction, underwater visibility, sea temperature, natural light levels, and swell and current information (Table 3.2). Light levels, depth and sea temperature were measured using Wildlife Computers TDR-MK9 sensors which were attached to the Stereo-BRUVs. Habitat and underwater visibility were classified and measured from the stereo-BRUVs footage. The classification of habitat includes more variety than the targeted habitats (high-profile reef and low-profile reef) due to the difficulty of dropping stereo-BRUVs in a precise location, which sometimes meant that the habitat surveyed did not fit into these two categories, despite best efforts to sample with precision. The remaining variables were captured either manually or using equipment on the boat during the sampling day.

Table 3.2: Additional environmental variables that were measured, and their measurement units.

Variable	Description
Habitat type	Visually classified as one of the following: Sand, patch reef high, patch reef low, reef high, reef low, or sand inundated reef.
Rugosity	Terrain rugosity index
Visibility	Meters (m). Measured by finding the furthest identifiable fish in EventMeasure and measuring the distance to the fish to determine the underwater visibility
Temperature	Bottom water temperature, in degrees Celsius (°C) measured using a temperature logger
Sampling depth	The depth at which stereo-BRUVs landed on the seafloor for sampling. Measured in meters (m) using an echosounder
Light levels	How much light is present in the sampling location before the light switches on. Measured in relative light units (RLU), which are dimensionless, uncalibrated measurements on alogarithmic scale from approximately 20 to 225.
Swell	Swell height, measured in meters (m) (estimated)
Current	Direction of the current, according to cardinal points (N, NE, E, SE, SW, W, NW)
Water column	% of the field of view of the stereo-BRUVs that faces the water column, as opposed to having something in the foreground (% obstruction). % obstruction + % water column = 100% of the field of view.
Location	The X (longitude) and Y (latitude) co-ordinates of each sampling site, taken using the on-board GPS on the research vessel.

3.5.9 VIDEO PROCESSING AND ANALYSIS

Video data was analysed using EventMeasure (stereo) software (SeaGIS, 2022b). Videos from the left and right cameras of the stereo-BRUVs sample were loaded into the software and synchronised. The calibration files for the stereo-BRUVs were loaded, and the relevant metadata for the sample was recorded. A species list containing all possible species in the sampled marine environment that was uploaded into EventMeasure prior to video analysis to facilitate species annotation. Once all relevant data had been loaded, the video was watched at normal speed by the video analyst. Certain relevant data was extracted from videos including the field of view, underwater visibility, seafloor classification, and habitat type. Analysis of fish populations relied on using MaxN, a metric capturing the maximum number of individuals of a species observed simultaneously in a single frame within the 60-minute analysis period for each sample (Cappo et al., 2003). To find MaxN, an iterative process of identifying, digitally tagging and measuring all fish that were visible within the frame was repeated until the maximum number of each species visible in one frame within the analysis period was found. After identifying MaxN, as many as possible of the individuals occurring at MaxN were measured, so that size and biomass calculations could be made to better understand the fish population structure. FishBase (Froese & Pauly, 2023) and fish identification guides (Heemstra & Heemstra, 2004; King, 2014) were used to assist with identifying fish. After analysis in EventMeasure, data were exported as a .txt file to be cleaned and made ready for analysis.

3.5.10 DATA PREPARATION

Text files generated after the completion of EventMeasure analysis were first imported to Excel and cleaned. Size at 50% maturity information was extracted for each species from the Southern African Marine Linefish Species Profiles (Mann, 2013), or if the information was not available there, it was obtained from FishBase (Froese & Pauly, 2023). If no size at 50% maturity information was available from either of these sources, the length at maturity was estimated as 45% of the maximum known length of the species (see Heyns-Veale et al., 2019), allowing for mature fish to be isolated for subsequent data analysis.

In stereo-BRUVs data, not every individual recorded at MaxN can be measured as they are sometimes not seen in both video cameras (precluding stereo-video measurements). Furthermore, there can be observer level biases in the number of measurements made for the fish at MaxN (i.e. some observers spend more time to maximise the number of measurements obtained than other observers do). Therefore, to account for this, especially considering that multiple datasets were merged for this study, the size data for each

species were extrapolated to standardise for observer bias and estimate the abundance and biomass of the mature population by using the following formulae:

$$x = number\ of\ mature\ individuals/species\ measured\ in\ a\ sample$$ [equation 3.1]

$$MaxN * x \approx abundance\ of\ mature\ fish\ in\ the\ sample$$ [equation 3.2]

This was repeated for each species being assessed so that all data were standardised. The extrapolated MaxN was the metric used for analyses focusing on CIF abundance.

Biomass calculations were also standardised and calculated for each species in each sample. First, the biomass of each mature fish measured in the sample was calculated using the following formula:

$$Biomass\ = a * (fish\ length)^b$$ [equation 3.3]

Where a and b are metrics for Bayesian length-weight ratios, attained from Mann (2013) or from FishBase (Froese & Pauly, 2023). The average biomass of mature fish was then calculated by dividing the sum of mature fish biomass by the number of mature fish:

$$Average\ mature\ biomass\ per\ sample\ = \frac{Total\ biomass\ of\ mature\ fish\ in\ the\ sample}{Number\ of\ mature\ fish\ in\ the\ sample}$$

[equation 3.4]

Lastly, to standardise the mature biomass, the average mature biomass was multiplied by the extrapolated MaxN of mature individuals:

$$Standardised\ mature\ biomass = Extrapolated\ MaxN(mature) * Average\ mature\ biomass$$

[equation 3.5]

For the analysis looking at the proportion of immature individuals within different MPAs, management zones and fished areas, immature MaxN was first extrapolated according to equation 3.1 and equation 3.2 for immature fish. To find the proportion of immature fish, the following formula was used:

$$Proportion\ immature\ fish\ per\ sample\ = \frac{Total\ extrapolated\ immature\ MaxN}{Total\ MaxN} \quad \text{[equation 3.6]}$$

These values were used as proportions in the analysis.

Some CIF species are expected to be more abundant in the South of KZN, while others are more abundant in the North (Bruce Mann pers. comm.). To address this, the final data analysis used the pooled information for all target species in each sample per dependent variable (mature biomass, mature abundance, or proportion of immature fish). This, combined with the large number of species that were analysed, ensured that the models were robust against stratification in the dataset due to differences in the fish community along the coastline.

3.5.11 Data exploration

Statistical analysis was conducted using R (R Core Team, 2023) and RStudio (Posit team, 2024) following the data exploration protocols recommended by (Zuur, Ieno & Elphick, 2010). Outliers in the response variables and continuous explanatory variables (visibility, depth, temperature, and water column) were assessed using boxplots and Cleveland dot plots. No significant outliers were detected, as the range of the response variable was within the expected limits for the fish species studied. Collinearity between continuous explanatory variables was evaluated using Pearson's correlation coefficients and variance inflation factors (VIF). Where strong correlations were found ($r > 0.7$ or $VIF > 3$), the variable more pertinent to the research question was retained in the models. Potential collinearity between categorical and continuous variables was visually inspected using conditional boxplots. Relationships between explanatory variables and the response variable were examined using regression plots, revealing non-linear relationships with depth and visibility. The spatial distribution of samples was mapped in QGIS (QGIS Development Team, 2022), which showed clustering within and between locations, thus necessitating the consideration of spatial dependency in the analysis. Exploration of the response variable distribution revealed moderate zero inflation, suggesting a non-normal distribution. Additionally, categorical covariates were found to be unbalanced across levels, which was taken into account during model selection and interpretation.

3.5.12 Statistical Analysis

Following the data exploration, all data was subsetted in R to only include mesophotic samples. Generalized Additive Mixed Models (GAMMs) were then employed to analyse the effects of MPAs and management approaches on three fish population metrics: mature fish biomass, mature fish abundance (MaxN), and proportion of immature fish. All analyses were conducted using the gamm() function from the mgcv package (Wood, 2011) in R (R Core Team, 2023), with the Restricted Maximum Likelihood (REML) estimation method. The gamm function employs the nlme package (Pinheiro et al., 2023) for fitting the mixed-effects components of the models. GAMMs made sense for this variable dataset because they are robust to unbalanced sampling sizes in different locations and MPA zones and clustering due to spatial variation in sampling. Mixed effect models, such as GAMMs, also allow for random effects to be included, which further takes possible clustering in the data due to location into account. Sampling occurred in such a way that each reef system under study would be extensively sampled, before moving on to the next reef system. This would have resulted in the clustering of samples on reef systems. Including a random effect for "location" (the name of the reef system) in the modelling process ensured that models could take resulting autocorrelation into account.

Biomass data was positively skewed, so a Gamma error distribution was used. MaxN data used a Tweedie error distribution because Poisson model residuals were overdispersed, and Tweedie allowed more flexibility in modelling than the Negative Binomial error distribution. The power index (p) for the Tweedie distribution for each model was found through a process of model comparison, using the Akaike Information Criterion (AIC) to choose the best p-value. Data on the proportion of immature fish used a quasibinomial distribution, as the model residuals from the binomial error distribution were overdispersed.

Initial models incorporated smooth terms (s()) for continuous variables (water column, visibility, depth) using thin plate regression splines (bs="tp"), and included categorical variables (MPA, management, zone, habitat) as parametric terms (Table 3.2). To account for the spatial dependency identified in the data exploration, an exponential correlation structure (corExp) was included, and where appropriate, a random effect for location was added.

Multiple models with different correlation structures and random effects were compared for each analysis. Model selection was based on AIC scores, residual vs. fitted value plots, and inspection of residual distributions using histograms and QQ-plots. The best-fitting models were validated using QQ-plots to

check for normality of residuals and fitted vs. deviance plots to ensure alignment of predicted values with residuals. During model validation, box-plots and Kruskal-Wallis tests showed that visibility was confounded with MPA status due to a very strong correlation between visibility and MPA. The different visibility conditions at each MPA were likely due to differences in location and oceanographic and seasonal variation in sampling at each MPA. In addition, visibility was also strongly correlated with water depth. This confounding effect decreased the power of models to clarify how individual MPAs impacted data and led to the decision to remove visibility as a smooth term from all the models in this study.

To visualize results, means with 95% Confidence Intervals (CIs) were predicted for the variables of interest (e.g., MPA name, Management strategy, or Zonation) from the best-fit model estimates and plotted using ggplot2 (Wickham, 2016). Non-overlapping 95% CIs in these plots were interpreted as indicating significant differences.

Three datasets were used for three sets of analyses, as depicted in Table 3.3. The three sets of analysis were broadly described as “MPA analyses”, “Management analyses” or “Zone analyses”.

“Management analyses” compared the impact of spatial management regulations on a variable, with three categories describing the spatial management, namely: No-Take MPA, Controlled MPA, and Fished area. For these analyses, all data were grouped according to the spatial management strategy and there was no segregation of data coming from different locations.

“MPA analyses” were those comparing the total effect of each MPA on CIF populations relative to fished areas, so there were four categories of data, namely: Pondoland MPA, uThukela MPA, iSimangaliso MPA and all Fished areas (all fished areas grouped). For these analyses, sampling sites were grouped by MPA such that all samples from an MPA (including No-Take Areas and Controlled Areas) were included, and the zonation within each MPA was therefore not considered.

“Zone analyses” subdivided the data even further to compare each type of zonation within each MPA and the adjacent fished areas. This led to seven categories, namely: Pondoland No-Take Area, Fished Area (South), Fished Area (Central), uThukela MPA No-Take Area, uThukela MPA Controlled Area, iSimangaliso MPA No-Take Area, and iSimangaliso Controlled Area. These analyses combine the two previous groups of categories for a detailed overview of the mature CIF population at each sampling location, considering the effects of zonation within MPAs and adjacent areas outside MPAs.

Table 3.3: The nine models that were run to analyse the effects of different spatial management methods on commercially important fish (CIF) populations.

	Analysis category		
Dataset	**Management Analyses**	**MPA Analyses**	**Zone Analyses**
Extrapolated mature biomass	m1	m4	m7
Extrapolated mature abundance (MaxN)	m2	m5	m8
Proportion immature CIF (derived from MaxN)	m3	m6	m9

Below are the final models that were used for each set of analyses:

3.5.12.1 MANAGEMENT ANALYSES:

m1:

Model with random effect of location and spatial autocorrelation:

gamm (Extrapolated mature biomass +0.5 ~ 1 + s(Water column,bs="tp",k=3) + s(Visibility,bs="tp",k=3) + s(Depth,bs="tp") + Management + Habitat, correlation = corExp(form = ~ X + Y), random = list(Location=~1), family = Gamma(link = "log"), method="REML", data = dat2, na.action = na.fail)

m2:

Model with exponential correlation structure for X,Y within Zone:

gamm (Extrapolated mature maxN ~ s(Water column,bs="tp",k=3) + s(Visibility,bs="tp",k=5) + s(Depth,bs="tp") + Management + Habitat, correlation = corExp(form = ~ X + Y|Zone), family = Tweedie(p=1.7,link = "log"), method="REML", data = dat2, na.action = na.fail)

m3:

Model with random effect of location and spatial autocorrelation:

gamm (Proportion of MaxN immature ~ s(Visibility,bs="tp",k=3) + s(Depth,bs="tp") + Management + Habitat, weights = Total MaxN, correlation = corExp(form = ~ X + Y), random = list(Location=~1), family = quasibinomial(link ="logit"), method="REML", data = dat2, na.action = na.fail)

3.5.12.2 MPA ANALYSES:

m4:

Model with random effect of location and spatial autocorrelation:

gamm (Extrapolated mature biomass+0.5 ~1+ s(Depth,bs="tp") + MPA + Habitat, correlation = corExp(form = ~ X + Y), random = list(Location=~1), family = Gamma (link = "log"), method="REML", data = dat2, na.action = na.fail)

m5:

Model with exponential correlation structure for X and Y:

gamm (Extrapolated mature MaxN ~ s(Water column,bs="tp",k=3) + s(Visibility,bs="tp",k=3) + s(Depth,bs="tp") + MPA + Habitat, correlation = corExp(form = ~ X + Y), family = Tweedie(p=1.7,link = "log"), method="REML", data = dat2, na.action = na.fail)

m6:

Model with exponential correlation structure for X and Y:

gamm (Proportion of MaxN immature ~ s(Water column,bs="tp",k=3) + s(Visibility,bs="tp",k=3) + s(Depth,bs="tp") + MPA + Habitat, weights=Total MaxN, correlation = corExp(form = ~ X + Y), family = quasibinomial(link ="logit"), method="REML", data = dat2, na.action = na.fail)

3.5.12.3 Zone Analyses:

m7:

Model with exponential correlation structure for X and Y:

gamm (Extrapolated mature biomass + 0.5 ~ s(Visibility,bs="tp",k=3) + s(Depth,bs="tp") + Zone + Habitat, correlation = corExp(form = ~ X + Y), family = Gamma(link = "log"), method="REML", data = dat2, na.action = na.fail)

m8:

Model with exponential correlation structure for X and Y:

gamm (Extrapolated mature MaxN ~ s(Water column,bs="tp",k=3) + s(Visibility,bs="tp",k=3) + s(Depth,bs="tp") + Zone + Habitat, correlation = corExp(form = ~ X + Y), family = Tweedie(p=1.5,link = "log"), method="REML", data = dat2, na.action = na.fail)

m9:

Model with exponential correlation structure for X and Y:

gamm (Proportion of MaxN immature ~ s(Visibility,bs="tp",k=3) + s(Depth,bs="tp") + Zone + Habitat, weights = Total MaxN, correlation = corExp(form = ~ X + Y), family = quasibinomial(link ="logit"), method="REML", data = dat2, na.action = na.fail)

Note that all models using biomass data contained an offset (+0.5) and defined an intercept of 1 to make the data compatible with a Gamma distribution model.

3.6 RESULTS

3.6.1 DESCRIPTION OF THE DATA

The majority of the fish in this dataset were slinger (*C. puniceus*), followed by santer (*C. nufar*) and Englishman (*C. anglicus*), which together made up approximately 66% of total sightings. The least common fish were ruby snapper (*E. coruscans*), wreckfish (*P. americanus*), goldflag jobfish (*P. auricilla*), and goldbanded jobfish (*P. multidens*), which all appeared only once throughout the dataset. Table 3.4 shows the distribution of each sampled species in the different sampling areas.

Table 3.4: The species that were included in the analysis, and how many individuals of each were found in each MPA (as a whole, excluding zonation), and in fished areas. Fished areas are those outside MPAs. The four species and one grouped genus that are greyed out were marked for inclusion but were not found within the dataset at all.

Species	Fished total	iSimangaliso total	uThukela total	Pondoland total	Total
Argyrosomus japonicus	3	1			4
Argyrosomus thorpei					0
Atractoscion aequidens	6		7		13
Cheimerius nufar	219	253	348	110	935
Chrysoblephus anglicus	170	60	55	152	444
Chrysoblephus puniceus	679	448	680	429	2271
Cymatoceps nasutus	23	11	9	73	116
Epinephelus [Mycteroperca] albomarginatus	5	25	14		44
Epinephelus [Mycteroperca] andersoni	31	2	27	12	72
Epinephelus [Mycteroperca] marginatus	9	31	3	22	65
Epinephelus [Mycteroperca] poecilonotus		83			83
Etelis carbunculus		7			7
Etelis coruscans		1			1
Lethrinus nebulosus	134	33		47	223
Lethrinus scoparius			40		40
Paracaesio sordida		40			40
Paracaesio xanthura	34	124	12		172
Petrus rupestris		3		5	8
Polyprion americanus		1			1
Polyprion oxygeneios					0
Polyprion spp (all)					0
Polysteganus lineopunctatus		312	75	2	389
Polysteganus praeorbitalis	48	74	19	126	267
Polysteganus undulosus	5	1	4	10	20
Pristipomoides auricilla		1			1
Pristipomoides filamentosus		135	4		139
Pristipomoides multidens		1			1
Pristipomoides sieboldii					0
Pristipomoides sp.		54			54
Pristipomoides zonatus		2			2
Seriola dumerili		14	7		21
Seriola rivoliana	27	50	25	4	108
Total fish	**1393**	**1767**	**1329**	**992**	**5541**

3.6.2 THE EFFECTS OF SPATIAL MANAGEMENT

All three analyses focussing on the effect of spatial management had a significant effect (Table 3.5). In m1 and m2, the parametric term for habitat was also significant with high- and low-profile reef containing more fish and a higher biomass than other habitats (Appendix 1; Figure A 1. 1; Figure A 1.2). The smooth terms for depth and visibility (Table 3.5) were also significant in these two models, with an increase in the dependent variable (mature abundance and mature biomass) with increasing depth. For visibility, the term plots showed an increase in the dependent variables with increasing visibility, up to a value between 5 -10 m visibility, after which a plateau occurred (Appendix 1; Figure A 1. 1; Figure A 1.2). For m3, management was the only significant parametric term, and depth was also a significant smooth term (Table 3.5), with more immature fish found at shallower depths (Appendix 1; Figure A 1. 3). Model summaries (Table A 1.1) and term plots (Figure A 1. 1; Figure A 1.2; Figure A 1. 3) for parametric and smooth terms included in management analyses can be found in Appendix 1.

Table 3.5: The Walds test results of the three analyses looking at the effect of spatial management on the response variables assessed in this study. Where a term was significant in the model, it has been made bold.

Spatial Management Analysis results			
Model	m1	m2	m3
Variable Tested	Mature Biomass (kg)	Mature Abundance (MaxN)	Proportion Immature CIF
Parametric terms	**Management *(p = 0.003)*** **Habitat *(p <0.001)***	**Management *(p = 0.001)*** **Habitat *(p<0.001)***	**Management *(p <0.001)*** Habitat *(p=0.378)*
Smooth Terms	Water Column *(p = 0.125)* **Visibility *(p <0.001)*** **Depth *(p < 0.001)***	Water Column *(p=0.240)* **Visibility *(p=0.013)*** **Depth *(p < 0.001)***	Visibility *(p=0.068)* **Depth *(p < 0.001)***
Variance of Residuals	0.875	1.864	3.331
Adjusted R^2	0.409	0.329	0.490

The prediction plot for m1 showed that No-Take Areas had significantly higher mature biomass than all other areas. Controlled Areas were also significantly different to No-Take and Fished Areas, containing more mature biomass than Fished Areas, but less than No-Take Areas (Figure 3.5). M2 showed that No-Take Areas and Controlled Areas contained significantly more mature fish than Fished Areas did (Figure 3.6). In m3, No-Take Areas had a significantly lower proportion of immature fish than both Controlled and Fished Areas, while Controlled Areas contained a lower proportion of immature fish than the Fished Areas did (Figure 3.7).

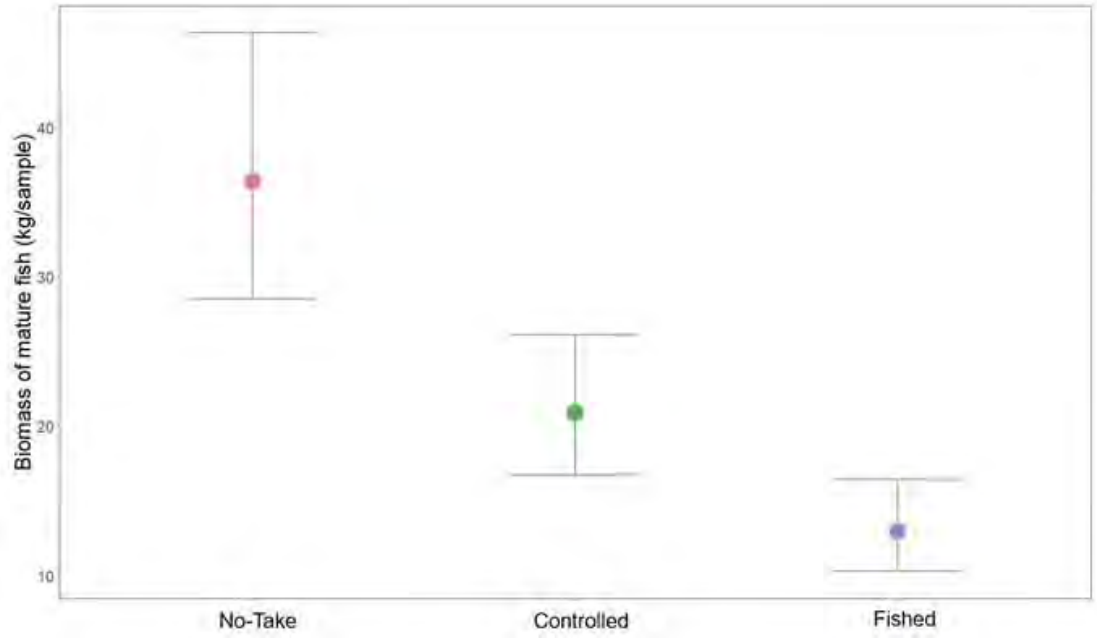

Figure 3.5: Prediction plot for m1, showing the effect of spatial management on the mature biomass of commercially important fish, with the predicted mean indicated by points and 95% confidence intervals indicated by the lines above and below points.

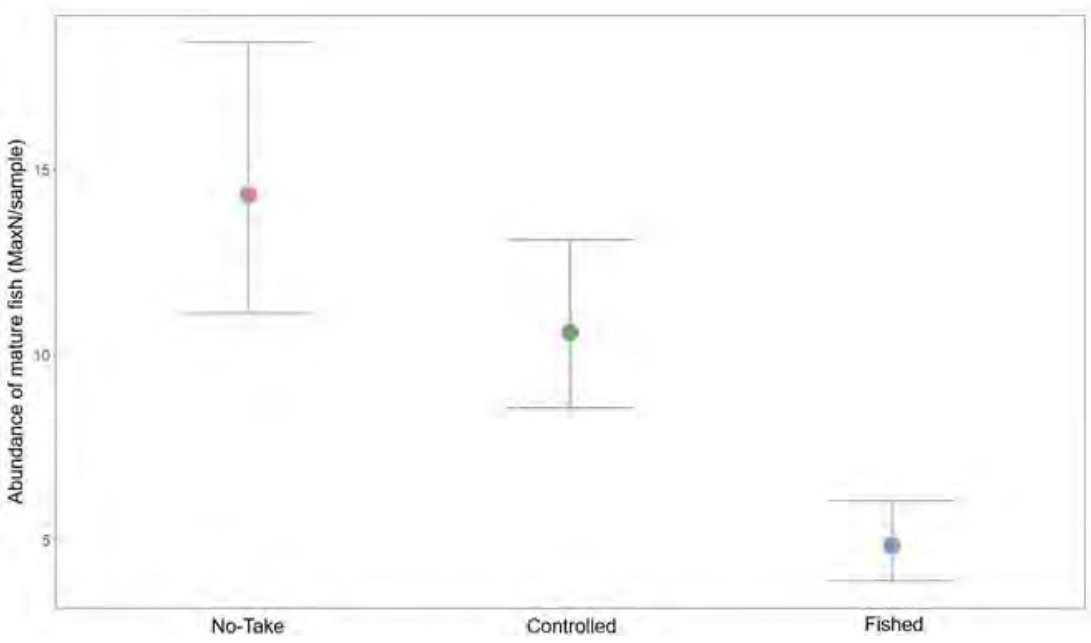

Figure 3.6: Prediction plot for m2, showing the effect of spatial management on the mature abundance of commercially important fish, with the predicted mean indicated by points and 95% confidence intervals indicated by the lines above and below points.

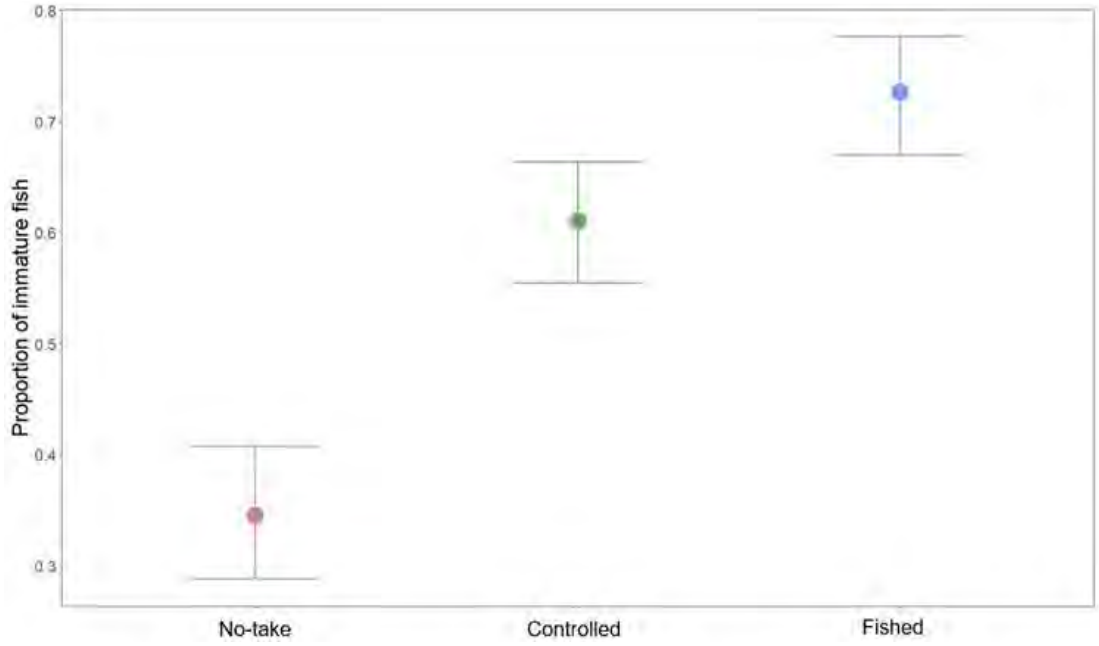

Figure 3.7: Prediction plot for m3, showing the effect of spatial management on the proportion of immature commercially important fish, with the predicted mean indicated by points and 95% confidence intervals indicated by the lines above and below points.

3.6.3 THE EFFECTS OF INDIVIDUAL MPAS

When grouping all data from the No-Take Areas and Controlled Areas within each MPA, the response variables (mature biomass, mature abundance, and proportion of immature fish) varied significantly among the different MPAs in the network. (Table 3.5). In m4 and m5 (but not for m6), the parametric term for habitat was significant, with low- and high-profile reefs containing higher mature biomass and abundances of CIF (Appendix 1; Figure A 1. 4; Figure A 1. 5). The smooth term for depth had a significant effect in all models (Table 3.6), with an increase in the dependent variable correlated to increasing depth for m4 and m5. while in m6, a higher proportion of immature fish was found at shallower depths (Appendix 1; Figure A 1. 6). In m5, the smooth term for visibility was also significant, showing a non-linear relationship, with an increase in abundance correlated with an increase in visibility up to a value between 5m and 10m visibility, after which the term plot showed a plateau (Appendix 1; Figure A 1. 5). The smooth term for water column had no significant effect in m5 and m6 (Table 3.6). Model summaries (Table A 1.2) and term plots (Figure A 1. 4, Figure A 1. 5, Figure A 1. 6) for parametric and smooth terms included in MPA analyses can be found in Appendix 1.

Table 3.6: The Walds test results of three analyses assessing the effects of individual MPAs on the variables of interest. Where a term was significant in the model, it has been made bold.

MPA Analysis results			
Model	m4	m5	m6
Variable Tested	Mature Biomass (kg)	Mature Abundance (MaxN)	Proportion Immature CIF
Parametric terms	**MPA *(p = 0.012)***	**MPA *(p = 0.007)***	**MPA *(p <0.001)***
	Habitat *(p <0.001)*	**Habitat *(p =0.001)***	Habitat *(p = 0.112)*
Smooth Terms	**Depth *(p < 0.001)***	Water Column *(p = 0.200)*	Water column *(p = 0.070)*
		Visibility *(p = 0.014)*	Visibility *(p = 0.283)*
		Depth *(p < 0.001)*	**Depth *(p < 0.001)***
Variance of Residuals	0.835	1.864	3.838
Adjusted R^2	0.362	0.329	0.465

In m4, the iSimangaliso MPA contained a significantly higher mature biomass than the uThukela MPA and Fished Areas but did not show a significant difference from the Pondoland MPA. (Figure 3.8). The Pondoland MPA was not significantly different from the Fished Areas, but did contain a significantly higher mature CIF biomass than the uThukela MPA, which had the lowest mean mature CIF biomass of all areas

in this analysis. The uThukela MPA did not contain a mature CIF biomass that was significantly different to Fished Areas. In m5, all MPAs contained a significantly higher abundance of mature CIF in comparison to Fished Areas. The Pondoland and iSimangaliso MPAs were once again not significantly different to each other and both contained a significantly higher abundance of mature fish than the uThukela MPA. (Figure 3.9). In m6, the iSimangaliso and Pondoland MPAs contained a lower proportion of immature fish than the Fished Areas and uThukela MPA. The uThukela MPA and Fished Areas were not significantly different to each other (Figure 3.10), and Fished areas contained the highest mean proportion of immature fish.

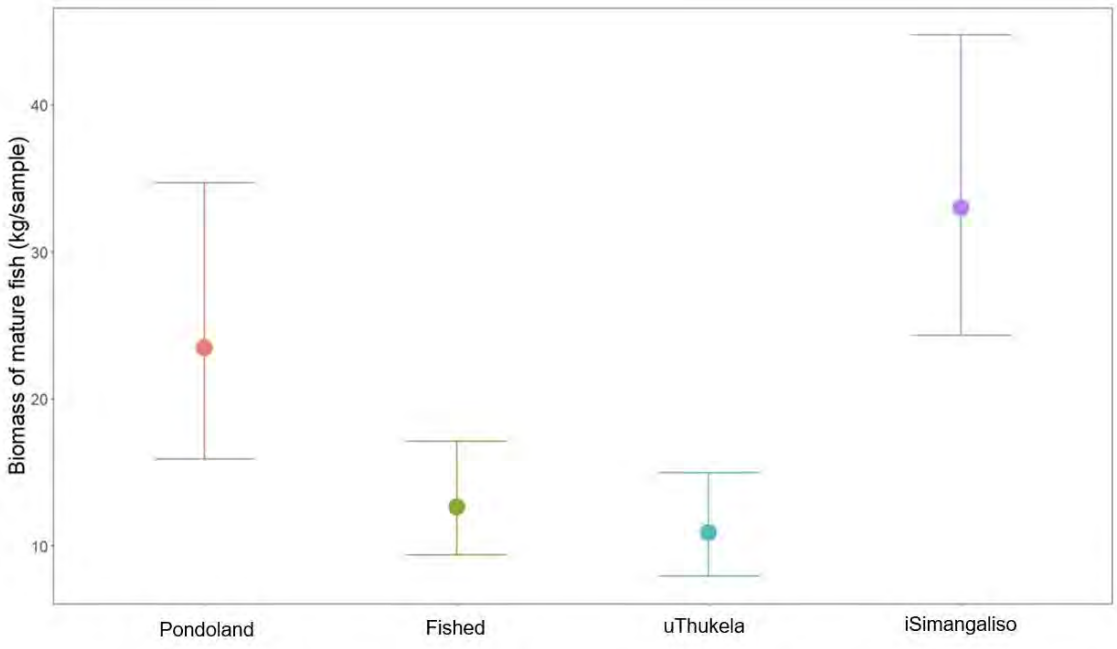

Figure 3.8: Prediction plot for m4, showing the effect of individual MPAs (without zonation considered) on the mature biomass of commercially important fish, with the predicted mean indicated by points and 95% confidence intervals indicated by the lines above and below points

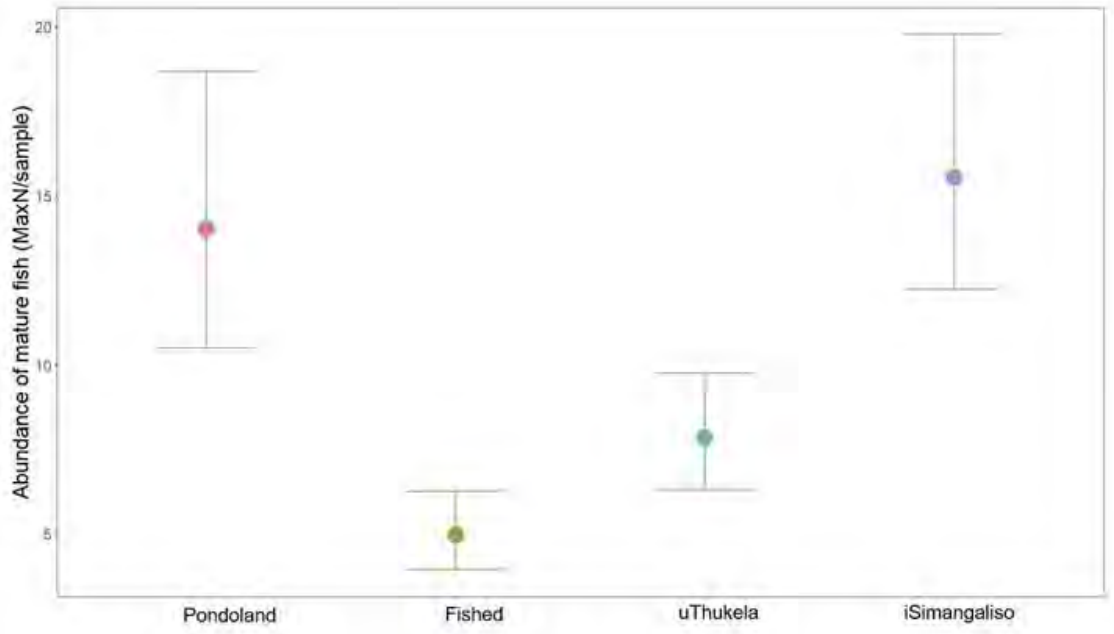

Figure 3.9: Prediction plot for m5, showing the effect of individual MPAs (without zonation considered) on the mature abundance of commercially important fish, with the predicted mean indicated by points and 95% confidence intervals indicated by the lines above and below points.

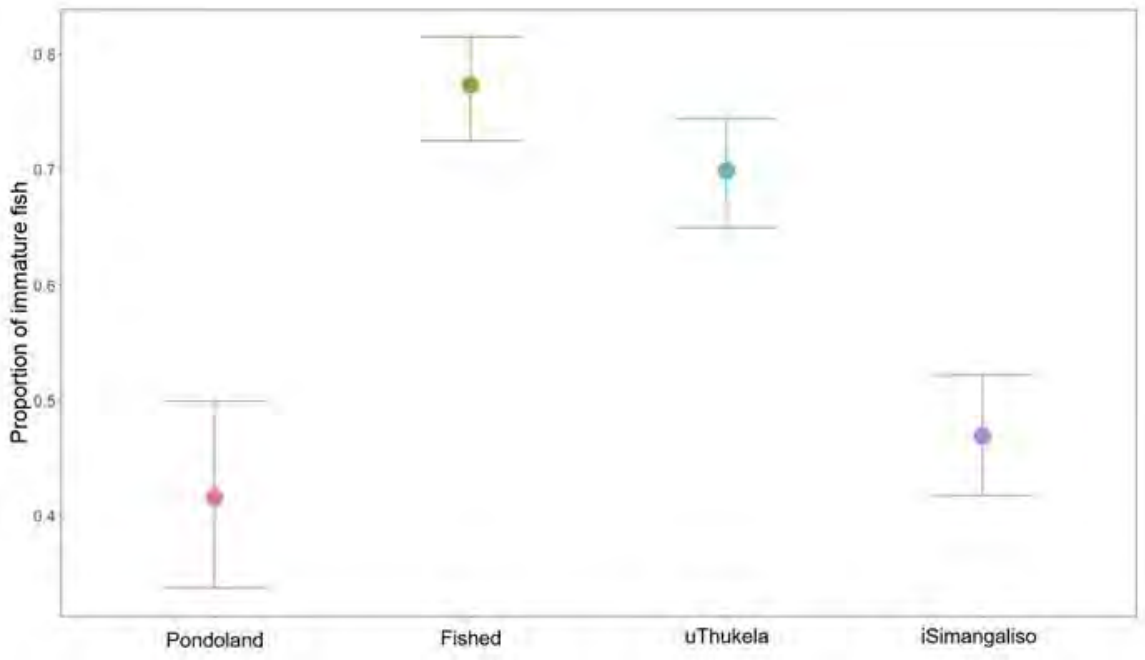

Figure 3.10: Prediction plot for m6, showing the effect of individual MPAs (without zonation considered) on the proportion of immature commercially important fish, with the predicted mean indicated by points and 95% confidence intervals indicated by the lines above and below points.

3.6.4 THE EFFECTS OF MPA ZONATION

The last set of analyses looked at the effect of MPA Zone on the response variables (Table 3.7). Both m7 and m8 indicated that the parametric terms for MPA zone and habitat were significant, with high- and low-profile reefs correlating to higher response variable values (mature biomass and mature abundance) (Appendix 1; Figure A 1. 7; Figure A 1.8). Both m7 and m8 showed that the smooth terms for depth and visibility had been significant in their respective models, showing the same pattern of higher values in the dependent variable correlating to deeper depths, while the term plots for visibility once again showed an increase in the dependent variable with higher visibility values, with a plateau forming between 5 m and 10 m visibility (Appendix 1; Figure A 1. 7; Figure A 1.8). In m9, MPA Zone was the only significant parametric term, and depth was a significant smooth term, again showing that a higher proportion of immature fish occurs at shallower depths (Table 3.7, Appendix 1; Figure A 1. 9) Model summaries (Table A 1.3) and term plots (Figure A 1. 7, Figure A 1.8, Figure A 1. 9) for parametric and smooth terms included in MPA Zone analyses can be found in Appendix 1.

Table 3.7: The Walds test results of three analyses looking at the effect of MPA zonation on the variables of interest in this study. Where a term was significant in the model, it has been made bold.

Zonation Analysis results			
Model	m7	m8	m9
Variable Tested	Mature Biomass (kg)	Mature Abundance (MaxN)	Proportion Immature CIF
Parametric terms	**Zone *(p = 0.012)***	**Zone *(p = 0.006)***	**Zone *(p <0.001)***
	Habitat *(p <0.001)*	**Habitat *(p < 0.001)***	Habitat *(p = 0.130)*
Smooth Terms	**Visibility *(p = 0.001)***	Water Column *(p = 0.262)*	Visibility *(p = 0.298)*
	Depth *(p < 0.001)*	**Visibility *(p = 0.025)***	**Depth *(p <0.001)***
		Depth *(p <0.001)*	
Variance of Residuals	1.070	2.626	3.655
Adjusted R^2	0.419	0.377	0.505

The three No-Take Areas and the iSimangaliso Controlled Area were not significantly different to one another, although only the Pondoland No-Take Area and iSimangaliso No-Take Area and iSimangaliso Controlled Area contained a significantly higher mature biomass than the Fished Areas and uThukela Controlled Area. The uThukela No-Take Area only had a significantly higher mature biomass than its own Controlled Area, showing no significant difference from Fished Areas (Figure 3.11). The two Fished Areas and the uThukela Controlled Area were also not significantly different to one another.

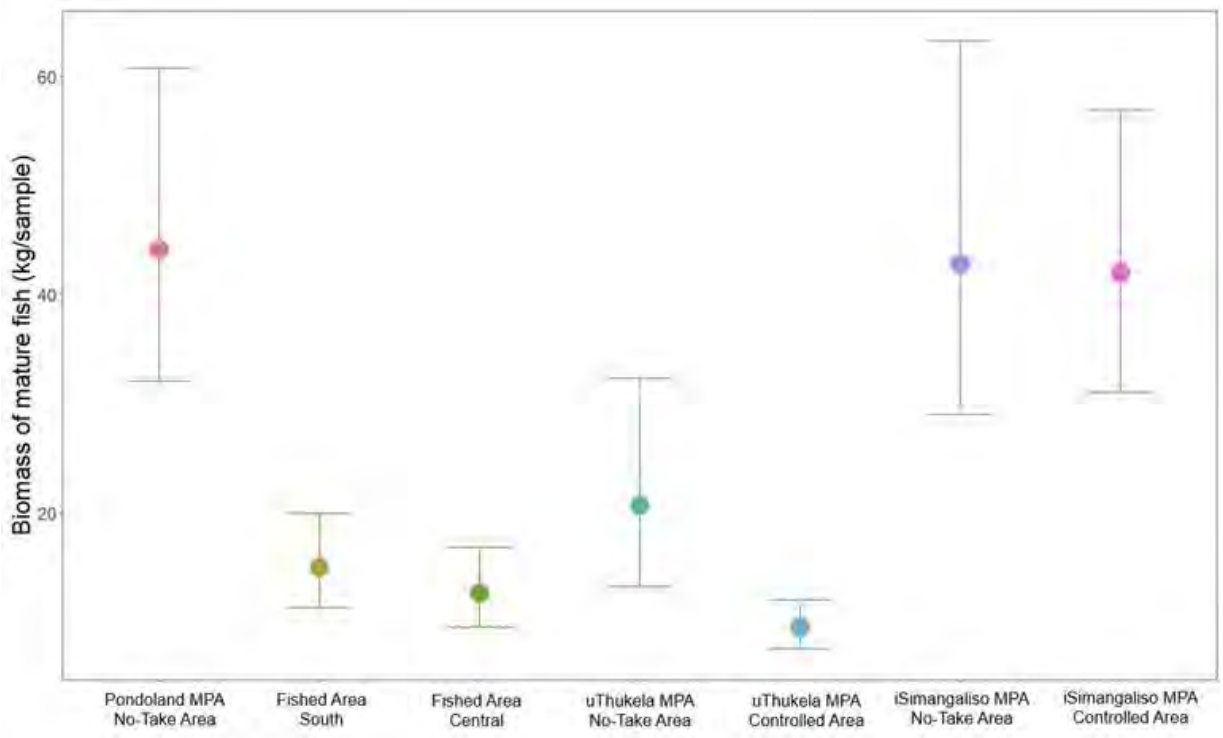

Figure 3.11: Prediction plot of m7, showing the effects of zonation within MPAs on the biomass of mature commercially important fish, with two areas outside MPAs for comparison. The predicted mean is indicated by points, and 95% confidence intervals are indicated by the lines above and below points.

In m8 (Figure 3.12), the Pondoland No-Take Area, uThukela No-Take Area, iSimangaliso No-Take Area, and iSimangaliso Controlled Area were not significantly different to each other and all contained a significantly higher abundance of mature fish than all other areas. The iSimangaliso Controlled Area contained the highest mean mature abundance of CIF, while the Central Fished Area contained the lowest mean abundance of mature CIF. The two Fished Areas and the uThukela Controlled Area were not significantly different to one another.

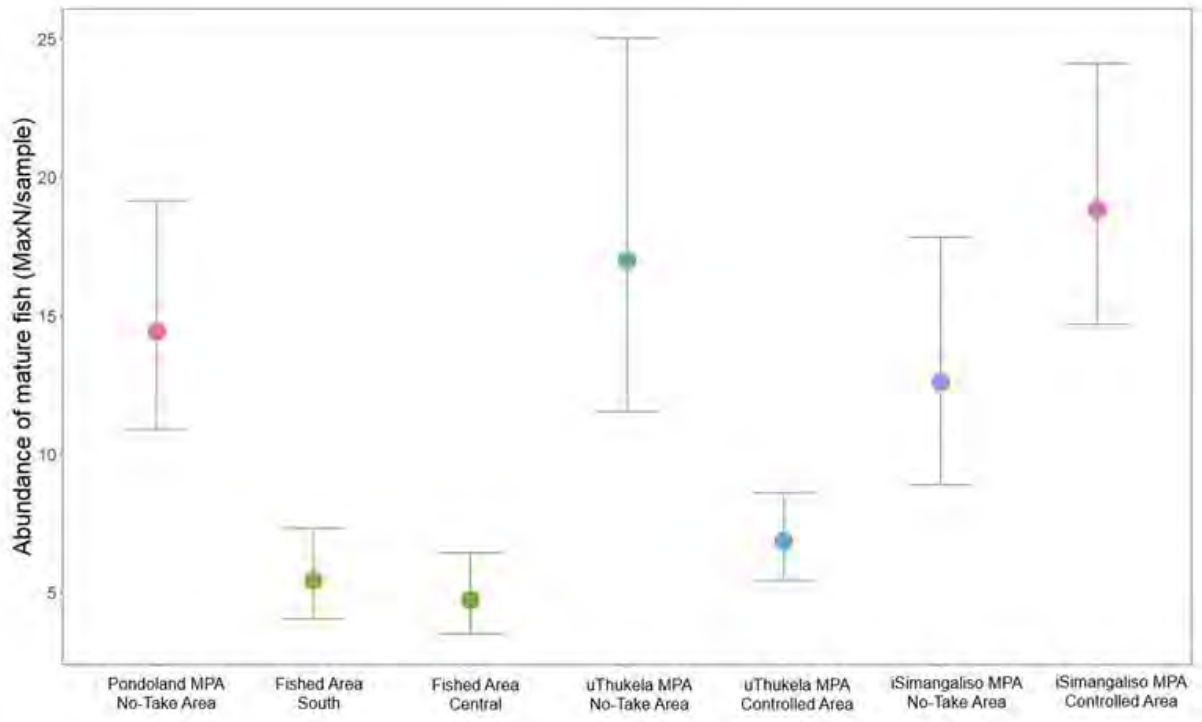

Figure 3.12: Prediction plot of m8, showing the effects of zonation within MPAs on the abundance of mature commercially important fish, with two areas outside MPAs for comparison. The predicted mean is indicated by points, and 95% confidence intervals are indicated by the lines above and below points.

Finally, in m9 (Figure 3.13), the iSimangaliso No-Take Area, uThukela No-Take Area, and Pondoland No-Take Area were not significantly different to one another. The No-Take Area in the iSimangaliso MPA contained a significantly lower proportion of immature fish than its Controlled Zone. The iSimangaliso Controlled Zone was not significantly different to the Pondoland No-Take Area or the uThukela No-Take Area, but also contained a lower proportion of immature fish than the uThukela Controlled Area and the Fished Areas in this study. The Southern and Central Fished Areas and the uThukela Controlled Area were not significantly different to one another. The two Fished Areas contained the highest mean proportion of immature fish, while the iSimangaliso No-Take Area contained the lowest (Figure 3.13).

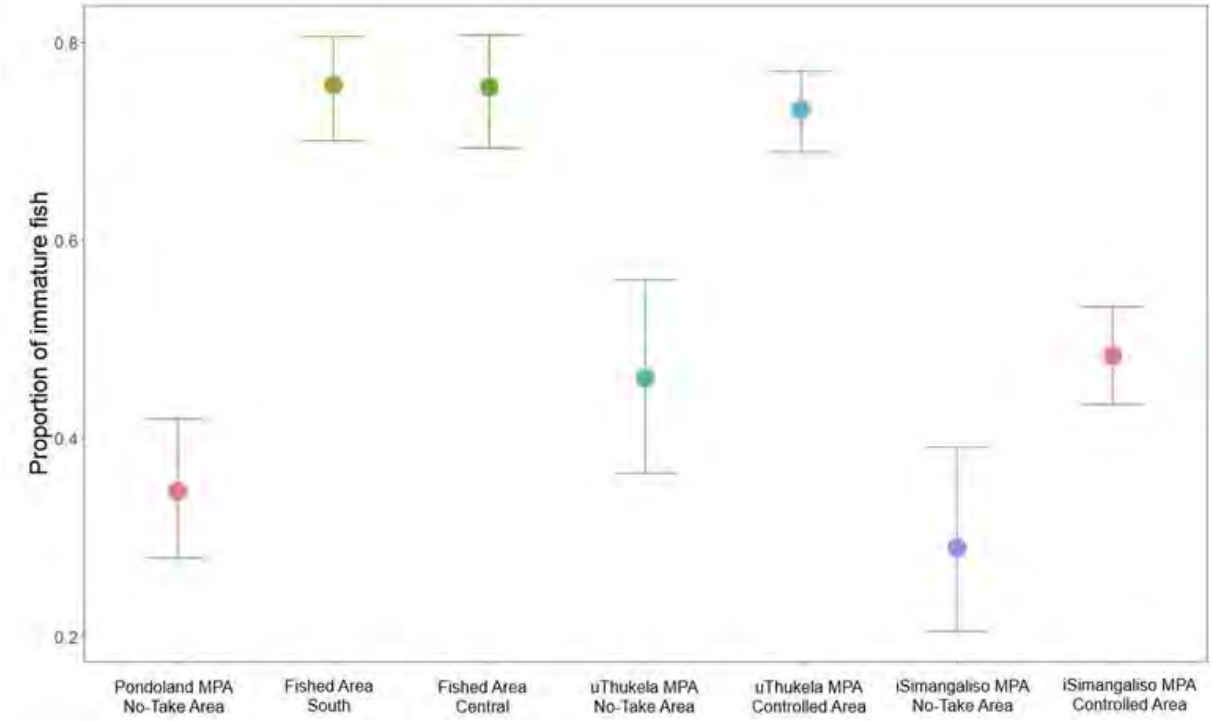

Figure 3.13: Prediction plot of m9, showing the effects of zonation within MPAs on the proportion of immature commercially important fish, with two areas outside MPAs for comparison. The predicted mean indicated by points and 95% confidence intervals are indicated by the lines above and below points.

3.7 DISCUSSION

The analyses conducted for this component have aimed to understand the ways that MPAs and their zonation impact the populations of CIF in KZN, using available stereo-BRUVs data. The analyses compared Fished Areas outside MPAs to areas inside MPAs and, within MPAs, areas under different spatial management strategies (zonation) to understand how CIF populations respond to each. As per the study undertaken by Edgar et al. (2014), MPAs are expected to have different levels of ecological effectiveness due to their respective NEOLI criteria. The results of these analyses have fulfilled the objectives of this chapter and show that MPAs in KZN are effectively contributing towards the management of CIF populations by conserving mature CIF. BOFFFFs are the most important breeding population, and MPAs which effectively protect these fish should positively impact fish populations (Harrison et al., 2012), which implies that there is a strong possibility that these MPAs benefit fisheries in the long term. In the MPA analysis, all MPAs contained a higher abundance of mature fish than Fished Areas. Additionally, both MPAs that scored higher in the assessment against NEOLI criteria conducted by Kirkman et al. (2021) contained a significantly lower proportion of immature fish and higher abundance of mature fish than both the Fished Areas and the younger and lower-scoring uThukela MPA. They also both contained a higher mature biomass of CIF than the uThukela MPA. Therefore, the outcomes of this study lend support to the use of the NEOLI criteria to conduct quick assessments of MPA effectiveness when there is no capacity for longer and more in-depth studies. These results also indicate that NEOLI criteria could be a useful tool for setting realistic expectations with stakeholders, particularly regarding the long time required before MPAs start becoming effective as a fisheries management tool and the other necessary conditions which must be maintained while MPAs are developing to ensure their effectiveness, particularly the need for No-Take Areas to be implemented and to remain in place. Overall, No-Take Areas outperformed other management strategies, with higher mature CIF biomass and lower proportions of immature fish than other management strategies. This can be interpreted as an indicator that these areas are working to ensure that MPAs fulfil their purpose of supporting sustainable fisheries management by effectively protecting breeding stocks. Finally, the Zone analyses showed that the type of zonation within MPAs was critical to their performance, as the areas which are zoned as No-Take Areas contained the most and biggest fish, as well as the lowest proportion of immature fish in each MPA, while Controlled Areas had vastly different effects on fish populations, depending on their regulations.

3.7.1 MPAs PROTECT THE BREEDING POPULATION

The importance of the biomass of mature fish cannot be overstated, as larger females, also known as BOFFFFs[5] play a disproportionately important role in fish stock recovery (Berkeley et al., 2004; Barneche et al., 2018). Hixon et al. (2014) showed that these fish generally produce many more (sometimes orders of magnitude more), and often larger eggs than their smaller counterparts do. Larger eggs lead to better fertilization and improved survival of larval fish. BOFFFFs are also more likely to survive periods of hardship that would kill smaller females, meaning that they can better withstand environmentally unfavourable years and lay eggs that are more likely to survive once these conditions pass. Furthermore, the offspring of BOFFFFs are genetically and physiologically fitter than those of smaller females in fished areas (Duncan et al., 2019). This is an important consideration in the era of climate change, habitat destruction, and rapid biodiversity loss that characterises the Anthropocene (Lewis & Maslin, 2015). In batch-spawning species, BOFFFFs tend to have longer spawning seasons, often having more spawning events and starting earlier than smaller females. They are also more willing to spawn in locations that smaller females would normally avoid (Hixon, Johnson & Sogard, 2014). These findings indicate that protecting BOFFFFs is one of the most important ways that MPAs can work towards the recovery of collapsed and overexploited fish stocks. This has been proven recently, when Marshall et al. (2019) included the hyperallometric reproductive output of fish in MPA modelling scenarios and found that one hectare of an effective MPA can contribute the same egg output as 3 – 25 hectares of unprotected marine space, depending on the fish species in question.

The results of this study show that the older MPAs (such as iSimangaliso and Pondoland) with higher NEOLI scores (according to the assessment by Kirkman et al., 2021) contain a higher abundance and biomass of mature CIF in their No-Take Areas than Fished Areas do, which is evidence that these MPAs work well to aid in the protection of larger adult fish. Given existing literature on the importance of BOFFFs, this can be understood as evidence that No-Take MPAs potentially contribute to sustainable fisheries management through spillover and seeding of eggs and larvae. The case of the younger uThukela MPA will be discussed in more detail later, but evidence indicates that the No-Take Area of this MPA may become an equally important fisheries management tool once it matures.

[5] Big Old Fat Fecund Female Fish

3.7.2 No-Take Areas are critical for MPA effectiveness

There is widespread agreement that No-Take MPA zonation is critical to truly successful MPAs (Maggs et al., 2013; Edgar et al., 2014; Sala & Giakoumi, 2018a). The evidence found in this research shows that these areas are contributing notably more to both the abundance and biomass of mature CIF than the adjacent Controlled or Fished Areas, except for the iSimangaliso MPA, which has a Controlled Area that does not allow bottom fishing and therefore acts in a similar way to the iSimangaliso No-Take Area for the demersal[6] species that are the focus of this research (Figure 3.11, Figure 3.12). Sala & Giakoumi (2018a), in their meta-analysis of global MPAs, found that No-Take Areas contain, on average, 670% more biomass of whole fish assemblages than fished areas do. The No-Take Areas assessed in their study also contained, on average, 343% more biomass than partially protected areas, comparable to the Controlled Areas in South African MPAs. This publication received some criticism, with Hilborn (2018) claiming that an earlier study, which found a 200% increase in biomass in a No-Take Area compared to a Fished Area, was more realistic (Lester et al., 2009). Sala & Giakoumi, however, responded with further evidence backing up their claim (Sala & Giakoumi, 2018b). Nevertheless, the bottom line is that well-enforced No-Take Areas have a significant positive impact on fish stocks by protecting fish so that they can grow and reproduce (Marshall et al., 2019). The results here align with existing literature, showing that No-Take Areas are effective (Figure 3.5, Figure 3.6, Figure 3.7), despite the lack of enforcement in South Africa (Kirkman et al., 2023), which severely constrains MPAs from reaching their full potential (Gill et al., 2017). These findings suggest that if an MPA contains “recovery of linefish stocks” in its gazetted purpose, then it must contain a No-Take Area.

No-Take Areas are also important for preserving the genetic integrity of CIF species. Fisheries Induced Evolution (FIE) has been confirmed in various CIF species globally, with in-situ experimental results showing that exploited fish stocks are evolutionarily driven to mature earlier and subsequently do not grow as large as they did prior to exploitation (Jørgensen et al., 2007; Heino, Díaz Pauli & Dieckmann, 2015). This means that CIF species slowly become less productive and less adaptable over time (Laugen et al., 2014). MPAs that protect large, old fish (such as the No-Take Areas investigated in this study) have been identified as a powerful conservation tool to combat the effects of FIE (Law, 2007). A study by Duncan et al. (2019) also found that No-Take Areas allowed more physiologically fit and climate-resilient

[6] Living on or near the seafloor, e.g. reef-dwelling species

genetics to thrive – a consideration that becomes increasingly important with the acknowledgement that we are living in the Anthropocene (Lewis & Maslin, 2015).

3.7.3 The value of Controlled Areas for commercially important fish

Although Controlled Areas afford some protection, their effect is variable depending on what fishing activities are allowed. This was made clear from the Zone analyses, which showed that Controlled Areas do not necessarily protect fish stocks. The uThukela Controlled Area, which allows bottom fishing, was not significantly different from Fished Areas in any of the three analyses (Figure 3.11, Figure 3.12, Figure 3.13). This is not surprising, as Controlled Areas are generally still fished (depending on activities permitted), which would remove the all-important BOFFFFs from the population first (Cooper et al., 2013; Barnett et al., 2017). The removal of mature fish from the CIF population by fishing is clearly shown in the analyses of the proportion of immature fish in this study, which showed that on average, approximately 70% of fish in the Fished Areas sampled were immature, as opposed to approximately 35% in the No-Take Areas, with the Controlled Areas containing a mean of approximately 60% immature CIF (Figure 3.7) which made them more similar to Fished Areas than to No-Take Areas. All areas that allow fishing (including Controlled Areas) consistently contained a higher proportion of immature fish than No-Take Areas in a similar environment, regardless of the type of analysis (Figure 3.7, Figure 3.13). In terms of adult biomass, adult abundance, and the proportion of immature CIF, the uThukela Controlled Areas, where bottom fishing is allowed, were more similar to the Fished Areas than to the No-Take Areas (Figure 3.11, Figure 3.12, Figure 3.13). This is because the CIF species identified for this research are mostly demersal species and no protection is offered to them in Controlled Areas that allow bottom fishing. However, the Controlled Areas in the iSimangaliso MPA (and a small area in the uThukela MPA) impact CIF in a similar way to No-Take Areas, as they only allow fishing for listed pelagic[7] gamefish species (these are known as Controlled Pelagic Linefishing Zones) and no bottom fishing is allowed. These Controlled Areas, therefore, provide direct protection to the demersal species of interest to this study, and it is largely for this reason that the overall results for Controlled Areas in the Management Analysis performed better than Fished Areas in terms of mature fish abundance (Figure 3.6).

Furthermore, the uThukela MPA contains one Controlled Area where only commercial linefishers are allowed to fish (effectively making this a Fished Area for CIF), another where only pelagic game fishing is

[7] Open ocean-dwelling species

allowed (which provides some protection to CIF, similarly to the Controlled Areas at iSimangaliso1), and yet another two areas where bottom fishing is allowed by both commercial and recreational boat-based fishers (effectively making them Fished Areas for CIF). These factors make it complex to properly measure and understand how Controlled zonation impacts CIF. Understanding this properly would require further analyses, comparing the different types of Controlled Areas to each other and grouping like with like. Nevertheless, considering that Controlled Areas in a South African context still provide biodiversity protection by prohibiting other forms of use (e.g. mining, trawling, longlining, etc.), these areas remain a useful tool for effective spatial management (Rassweiler, Costello & Siegel, 2012).

3.7.4 The relationship between mature abundance, mature biomass, and MPA age.

Mature abundance and mature biomass were used together to understand the effects of MPA zonation on mature CIF. Neither of these metrics on its own would have been able to pick up some of the more interesting results of this study, which can be found by comparing the analyses of zonation on mature abundance and mature biomass (Figure 3.8, Figure 3.9). There is a relatively low mature abundance but high mature biomass at the Pondoland and iSimangaliso No-Take Areas, and, conversely, a very high mature abundance but relatively low mature biomass in the uThukela No-Take Area. This pattern is likely related to the relative age of the respective MPAs. The iSimangaliso MPA is the oldest in KZN and in this study, with its first No-Take Area declared 47 years ago, in 1979 (Kirkman et al., 2023, supplementary materials: Appendix 1)[8]. The Pondoland MPA was declared 20 years ago, in 2004[9]. The uThukela MPA, in contrast, is only 4 years old[10] and was only two years old at the time of sampling.

The mature biomass of CIF can be expected to increase more slowly than mature fish abundance for various reasons. Fish can live for a long time, and females can take many years to reach the size necessary to be considered a “BOFFFF”. For example, black musselcracker, one of the species that was chosen for this study, has been found to live up to 45 years (Buxton & Clarke, 1989), which is almost as long as the oldest established portion of the iSimangaliso MPA. This means that it could take a long time for fish stocks inside No-Take MPAs to stabilise, and consequently, for MPAs to reach their full potential for the rehabilitation of fish stocks. Fishing alters not only the population structure of the target species, but also larger ecosystem processes. Prey release, the phenomenon by which smaller prey species dominate and

[8] No-Take Area was 37-40 years old at the time of sampling
[9] No-Take Area was 10-14 years old at the time of sampling
[10] Established in 2019

alter an ecosystem once their predator populations have been reduced by fishing (i.e. fished down to the point where normal trophic relationships are not maintained), has been well documented as a side effect of overfishing (Britten et al., 2014; Heyns-Veale et al., 2019, Mann et al. 2022). Predatory fish are often larger (Penney et. al., 1999), and will therefore contribute a higher biomass per fish than prey species would. The lower abundance but higher biomass found within older No-Take Areas in this study indicates that they contain fewer but significantly larger fish than No-Take Areas in younger MPAs. This could be interpreted as evidence that the effects of prey release due to fishing have been reversed, and normal trophic interactions have returned in the older No-Take Areas. The younger uThukela MPA has a very high mature abundance of CIF, but these fish, although mature, have not yet been protected from fishing for long enough to reach BOFFFF status, and it is, therefore, unlikely that normal trophic balance would have returned at the time of sampling. The results relating to the CIF population in the uThukela No-Take Area are therefore here interpreted as an indication that the population is recovering from fishing, but the pattern of low biomass and high abundance could indicate that the MPA is not yet fulfilling its full ecological potential as a haven for the protection of larger breeding fish and predatory fish. This is to be expected, as MPAs generally take a long time to become ecologically effective, with one meta-analysis finding that benefits to fisheries only started becoming obvious after a minimum of 30 years since implementation (Vandeperre et al., 2011). The evidence provided by this study (Figure 3.11, Figure 3.12, Figure 3.13) indicates that although the No-Take Area at uThukela is already working to protect CIF stocks, it should, with time, become more effective as these adult fish grow larger. Interestingly, the same pattern of higher abundance and relatively lower biomass is present to a lesser extent at the iSimangaliso Controlled Area, which could be an indication that the removal of predatory pelagic fish at these Controlled Areas is affecting the population structure. Further evidence for this is provided by the higher proportion of immature fish present in the iSimangaliso Controlled Area, in comparison to the No-Take Area of the same MPA.

3.7.5 The importance of the NEOLI attributes

The analyses conducted in this study showed clearly that No-Take Areas outperform other spatial management strategies (Figure 3.5, Figure 3.6, Figure 3.7). Additionally, the oldest No-Take Areas are performing the best: They contain a higher biomass of mature fish compared to younger No-Take Areas, and for both Pondoland and iSimangaliso, there is some evidence which supports the likelihood that normal trophic interactions may have been re-established inside their No-Take Areas (Figure 3.11, Figure 3.12, Figure 3.13). The MPA analysis showed most significant differences between the oldest and newest

MPAs, and between the oldest MPA and the Fished Areas, showing that the older, more mature MPAs are the most effective (Figure 3.8, Figure 3.9, Figure 3.10). In the MPA analysis, the higher proportion of immature fish in the iSimangaliso Controlled Area (Figure 3.10) increased the proportion of immature fish for the whole MPA, which meant that it contained a slightly higher mean proportion of immature fish than the Pondoland MPA, for which no Controlled Area samples were used in this study. The results of this analysis also lend support to the importance of large No-Take Areas, as the oldest MPA in this study (i.e., iSimangaliso) was also the largest MPA and had the biggest No-Take Areas. The relative effectiveness of the newer uThukela No-Take Area so soon after its declaration could also partially be due to its isolation, as well as its large size. The uThukela No-Take MPA is relatively isolated from the more popular launch sites at Durban and Richard´s Bay, and a combination of long travelling distances (~ 50km from the nearest launch site) with a need for near-perfect weather for reefs in this area to be fishable, probably contributed an element of natural protection to fish stocks in the area, long before the proclamation of the MPA occurred (Commercial linefishers, pers. comm). At the time of the data collection, the Pondoland No-Take Area was not yet 30 years old and, therefore, not expected to be maximally effective for protecting fish stocks (Vandeperre et al., 2011). However, the No-Take Area of this MPA is very isolated due to limited coastal development and lack of safe launch sites, which make it necessary for fishers to travel a long distance by boat to fish in (by poaching) or near it (Bruce Mann, ORI, pers. comm). Edgar et al. (2014) indicated that ten years is enough time for an MPA to be considered old, so this combination of geographic isolation/accessibility and an age of over 10 years old could explain why the Pondoland No-Take Area shows a similar pattern to the much older iSimangaliso MPA when comparing mature abundance with mature biomass, although the pattern is not as pronounced in the younger MPA. Pondoland MPA thus shows that a No-Take Area can become effective after a shorter timeframe than 30 years, provided it also benefits from other NEOLI attributes.

At the time of sampling, there were three other smaller MPAs within the larger study area. One of these, the Trafalgar MPA is restricted to relatively shallow depths that were not the focus of this study. The second MPA, namely the Aliwal Shoal MPA, was sampled before the offshore extension of the MPA took place in 2019. This meant that although sampling had been conducted in the area, at the time of sampling, the sampled area was not yet an MPA, and it was being actively fished. Data from the area was therefore classified as belonging to the Fished Area (South). The third protected area was at Protea Banks MPA. Prior to 2019, the high points of this extensive reef area were supposedly protected from bottom fishing by a gentleman's agreement. Fishers in the area (mostly launching from Shelly Beach) had agreed not to bottom fish on the pinnacles of this reef, so it was essentially a locally managed MPA that had not been

formally promulgated (B. Mann, ORI, pers. comm.). Data from mesophotic depths within the bounds of what is now designated as the Protea Banks MPA were included in the analyses, but they were categorised as belonging to the Fished Area (South) due to the lack of formal protection at the time of sampling. Interestingly, including the Protea Banks area as a fished site (within the "Fished Area South" category) did not have a measurable positive effect on the population of mature CIF in Fished Areas, although the "Fished Area South" did contain a slightly higher (but not significant) mean biomass and abundance of mature CIF than the "Fished Area Central", which consisted entirely of areas without such agreements in place (Figure 3.11, Figure 3.12). Anecdotal information suggests that the "gentleman´s agreement" on the Protea Banks reef was not respected by everyone, as bottom fishing still occurred, leading to infighting among fishers in the area (B. Mann, ORI, pers. comm). The story of Protea Banks is not really relevant to this study, but it provides some interesting context on the enforcement of MPAs. A follow-up study looking at fish populations after 2019 could allow researchers to see whether the formal declaration of the MPA has had any effect, especially considering that actual enforcement of this MPA´s rules on the water is almost non-existent (Kirkman et al., 2021). This could be useful to start understanding users´ values related to MPAs, which have an effect on compliance behaviour (Bennett & Dearden, 2014b), and could provide some understanding of what type and how much enforcement will be necessary to ensure the effectiveness of this MPA.

Adequate enforcement of and compliance with No-Take Area regulations is critical to the success of MPAs, as per findings by Edgar et al. (2014) and Gill et al. (2017). Kirkman et al. (2021) found that none of South Africa´s MPAs are very well enforced. Although the No-Take Areas are working, poaching still affects these MPAs, and ineffective enforcement would imply that they take a longer time to become effective for fisheries purposes and probably stay less effective than they have the potential to be in the long term. Enforcement of regulations and voluntary compliance complement one another, and it will be necessary to balance the two to maximise the effectiveness of MPAs in KZN, especially considering that capacity issues hinder enforcement throughout the country (Kirkman et al., 2023). With minimal enforcement capacity, it would make sense to understand the role of voluntary compliance with MPA rules better, so that resources can be used most effectively. Comparative data from Protea Banks could make a good case study for quantifying the current compliance situation in KZN from an ecological perspective, allowing management to plan enforcement more strategically.

3.7.6 The importance of immature fish for understanding the effectiveness of MPAs

This study did not focus on immature fish populations, due to the rationale already discussed. The analyses looking at the impacts of various spatial management strategies on the proportion of immature fish were intended only to complement evidence from analyses looking at mature fish biomass and abundance, and to clarify how fishing impacts CIF population structure. Results from these analyses indicate that there is generally a lower proportion of immature fish at mesophotic depths inside MPAs (particularly within No-Take Areas and more established MPAs) than in fished areas outside (Figure 3.7, Figure 3.10, Figure 3.13). Linefishing frequently removes the larger (i.e. mature), and bolder fish first, thus making the study of the proportion of immature fish populations important when assessing the ecological effectiveness of MPAs. This is particularly relevant considering that one of the main mechanisms by which MPAs are supposed to support fish stock recovery and the sustainable use of fish is through the spillover of young fish and eggs into neighbouring unprotected areas (Kenchington, Ward & Hegerl, 2003). Younger fish tend to inhabit shallower areas (Heyns-Veale et al., 2016), and this is well evidenced in this study, which showed that higher proportions of immature fish were correlated with shallower depth ranges (Appendix 1; Figure A 1. 3, Figure A 1. 6, Figure A 1. 9). Studies showing the movement of CIF in a Northward direction along the KZN coastline as they grow older (Mann, Daly, et al., 2022; Mann et al., 2023) also indicate that MPAs in the South could naturally be a haven for younger fish and therefore contain a higher proportion of immature CIF, making these areas particularly important nursery areas. The fact that this study focussed on mesophotic depths means that it is not well suited to understanding the impacts of MPAs on immature fish populations, and further research on the topic, using data from a wider depth range, would allow for more conclusive findings on how well MPAs are performing with regard to supporting immature fish populations.

3.7.7 Study design as a possible source of variation or error

This study uses existing data as a reference point from which to monitor the effectiveness of the MPA network in KZN. Baited Remote Underwater Stereo-Video Systems contribute some of the most cost-effective and robust data for MPA monitoring (Bernard, 2012), have been used in South Africa to monitor fish populations in MPAs since 2010, and will likely continue to be used in the future. Given this, it made sense to use existing stereo-BRUVs data for this comparative study. However, the growing dataset was not perfectly suited to this analysis, due to various constraints. The cost of data collection in MPAs in KZN is significant because of long travelling distances by land and sea, as well as the need for long field trips to allow for the many bad weather days which occur in KZN. Another important aspect to consider is that

when using stereo-BRUVs for monitoring, it takes a long time for raw video data to be processed before it is available for statistical analysis (Holmes et al., 2013). This means that even when resampling at a site has occurred, data is not immediately available, and this creates a long lag time for monitoring outcomes. For example, this study utilised data from before the Protea Banks and Aliwal Shoal MPAs were established/extended. No resampling had yet occurred at Aliwal Shoal, and although Protea Banks was resampled in 2022, these data had not yet been processed. As a result, this study could not provide insight into the effectiveness of all the current MPAs in the province. Clearly resampling and further research will be needed to effectively monitor all KZN MPAs. However, findings from this study related to the value of NEOLI attributes and the importance of No-Take Areas may still help to inform decision-making regarding the Protea Banks and Aliwal Shoal MPAs. The abovementioned constraints on sampling also mean that pragmatically it is nearly impossible to sample all sites in the same season for optimal comparability, with the implication that seasonal variation in fish size or location may impact the results of a study (Haupt et al., 2017). Repeat surveys and consistent monitoring using the same methods may allow seasonal variation to be understood better (Foster et al., 2020).

Additionally, it was only in 2019, with the completion of multibeam echo-sounder bathymetry mapping for reef systems in uThukela MPA (Wanda et al., 2023), that it became possible to plan sampling sites with a high level of accuracy. All sampling that occurred prior to 2019 relied solely on local knowledge provided to the researchers by fishers to inform site selection and randomised sampling design. The size of reefs was unknown, leading to many stereo-BRUVs landing on a sandy bottom and not the reef habitats of interest. Data used for this project therefore contains a lot of variation in terms of habitat (reef height, rugosity and depth), which likely has a significant effect on the results (Luckhurst & Luckhurst, 1978). Therefore, the difference in sampling approach between the uThukela and older stereo-BRUVs datasets would probably have had positive effects on the abundance and biomass estimates of fish in the uThukela MPA, which means that this MPA may be less effective than indicated by the findings of this research. However, the modelling process included habitat as an explanatory variable and an iterative process was followed whereby a random effect for sampling location and a spatial auto-correlation structure were added into the models and tested for their effect, and then either kept or removed from the model depending on the model optimisation outcome. The final “best-fit” statistical models all included a parametric term for habitat and a correlation structure, while m1, m3, m4 also included a random effect for location to account for this variation.

Survey design becomes incredibly important when the data will be reused to answer different types of questions (Hayes et al., 2019). The Stereo-BRUVs database at SAIAB consists of data which has been collected using the same survey design and sampling method at each MPA, with metadata available for future analyses, making it a useful resource for the long-term monitoring of MPAs in KZN (and elsewhere along the South African coast). However, there is a clear need for more sampling locations outside MPAs to be chosen and monitored if analyses such as the one in this study are to occur regularly, as many of the "fished sites" utilised for this study have now been incorporated into MPAs. At least four, but preferably more fished areas in between existing MPAs need to be sampled to ensure that the entire continuum of habitats along the KZN coast is sampled both inside and outside MPAs. Having data from more fished sampling sites available would allow researchers to better understand how MPAs affect the marine environment and how fish populations respond to protection (Foster, Hosack, et al., 2020). Ideally, MPA monitoring should sample in Fished Areas on either side of each MPA as heavily as they sample inside the MPA and within the differently zoned areas in each MPA. Since commercial linefishers tend to target the most abundant species (Penney et al., 1999), this would mean that reef areas both to the north (up-current) and south (down-current) of each MPA (within the same depth range and habitat type) should be sampled each time that the different MPA management zones are sampled. Each management area/zone and Fished Area should be sampled with at least 28 stereo-BRUVs deployments to enable changes in fish populations to be detected (De Vos et al., 2014).

3.7.8 STEREO-BRUVS AND IMMATURE FISH

One of the biases found in stereo-BRUVs data is related to the shoaling behaviour of juvenile fish, which is common even for species which are solitary as adults (Williams, Shertzer & Bacheler, 2022). This can affect the dataset, as the largest shoals measured at MaxN often contain many juvenile fish, which may bias the data toward estimating a higher proportion of immature fish than is actually present (Langlois et al., 2015). However, findings by Coghlan et al. (2017) showed that this effect is minimised in horizontal-facing stereo-BRUVs, as smaller fish which are chased away from the bait by larger fish often still appear in the background after being chased away, or will come back to the bait quickly, while larger fish often arrive early and stay in the field of view of the cameras for a long time, due to territorial behaviour. This means that large-bodied and small-bodied fish are all captured and the bias toward counting smaller fish is largely mitigated. This bias is further mitigated by taking multiple samples per reef complex, which allows for a better understanding of the population structure at that reef (Foster et al., 2020), and by ensuring that the sampling design targets habitats that are relevant to different size classes, for example

including mesophotic and shallow reef complexes (Heyns-Veale et al., 2016). A bias toward counting immature fish at MaxN means that there is a risk of falsely finding no difference between MPAs and outside areas, as smaller, more abundant fish are less likely to be impacted by fishing. If this bias is significant, only the smaller fish inside MPAs will be counted, while large fish will appear only rarely. The results of this study show clear differences in the mature fish populations between areas under different spatial management strategies, indicating that stereo-BRUVs can provide insight into the effectiveness of MPAs for mature fish as well as immature populations, despite a known bias to counting smaller fish.

3.7.9 A NOTE ON THE FUTURE OF MPAS IN SOUTH AFRICA

The MPAs in this study are clearly important to the protection and sustainable management of CIF, and it is clear that No-Take Areas that are large and remain in place for a long time are important to achieving this goal. It is well known that MPAs in South Africa (Kirkman et al., 2023) and globally (Gill et al., 2017) suffer from insufficient enforcement capacity. However, even with poor enforcement and a lack of resources, the old, large, No-Take MPAs that were assessed in this study showed strong positive outcomes, with evidence that isolation plays a role in allowing them to become effective more quickly. The newly expanded MPA network has been designed with the NEOLI attributes in mind, and the results of this study indicate that these attributes help to ensure that MPAs are effective. However, these results also show the immense potential of a well-managed MPA network, where enforcement is adequate and buy-in from resource users is absolute. If our MPAs were better enforced and compliance was high, they could become an even more powerful asset for fisheries management and could show tangible benefits to fisheries much faster. Considering that the linefishing sector in South Africa still places severe pressure on our fish stocks (Potts et al., 2020), it is necessary to ensure that MPAs work as efficiently as possible, to support the sustainable use of these species. Compliance is one of the most important factors affecting MPAs and has been associated with adequate enforcement as well as the inclusion of local resource users in decision-making processes (Arias et al., 2015). Even when enforcement is not adequate, buy-in from local resource users is an important factor influencing compliance, and in this regard, South Africa still has much work to do (Mann-Lang et al., 2021). An integrated approach whereby local stakeholders are provided with opportunities to self-police, contribute to effective enforcement, and are given an opportunity to participate in the decision-making processes, could go a long way towards improving the effectiveness of the MPA network in KZN for fulfilling its ecological purpose (Armitage et al., 2009; Cinner et al., 2012).

3.8 CONCLUSION

The results of this study clearly show the importance of No-Take Zonation for MPAs to attain their gazetted purpose of protecting and replenishing CIF stocks for fisheries sustainability. The fact that the NEOLI attributes have been incorporated in the MPA expansion seems to have already benefitted the MPA network, as shown by the increased relative success of older, larger and more isolated MPAs in this study. The MPA network in KZN shows strong evidence that MPAs, once established, are effective for protecting and contributing to the sustainable management of commercially important fish stocks, despite serious problems around a lack of enforcement which should be addressed alongside concerns about the inclusion of local stakeholders in decision-making processes, which will enhance the MPA network and allow it to reach its potential for enabling the sustainable use of CIF.

The MPA monitoring programme that is currently in place allows for a large amount of data to be analysed using three metrics (mature fish biomass, mature fish abundance and proportion of immature fish) to understand the population structure of fish communities. The use of more than one metric for assessing fish populations is beneficial, as it allows for a deeper understanding of the ecological processes taking place in these areas and may be able to act as an early warning system when MPAs are not developing in the expected way. The monitoring programme would benefit from better coverage of the marine space in KZN such that it has equal representation of comparative reefs inside and outside MPAs for more accurate conclusions to be drawn as to their successes or failures, which would allow for improved adaptive management. Monitoring over time and the repetition of analyses such as this one will be critical to understanding how the MPA network is functioning and where improvements to management can be made to ensure that the MPA network remains on track to attain its gazetted goals

CHAPTER 4

4 ABOUT THE FISHERS: PERCEPTIONS OF MPAS AMONG COMMERCIAL LINEFISHERS

4.1 REFLECTION

COMPLEXITY

/kəmplɛksɪti/

The state of having many different parts connected or related to each other in a complicated way.

(The Collins Online Dictionary, 2023)

REFLECTION:

The Rastafari deny all "-isms". They claim that one cannot say that everything is always one way or another, but rather, one should use intuition and experience to determine the validity of a belief or practice for oneself… A nod to the contextual nature of knowledge. The deep dive that I took into the various "-isms" of social research made me lean ever more toward agreeing with the Rastas´ rejection of them. All these worldviews hold some truth, yet none feel like an adequate, complete description of the way the world works. Life and truth are inherently complex, especially when working with people. We don´t have hard boundaries on our thinking, and trying to impose boundaries where there are none always leaves something out. It would be naïve to think that a process of boundary imposition could allow for a full understanding of the way things work. It doesn´t give the necessary respect to the big picture if we ask fishers only to speak on MPAs and ignore how our fisheries work, for example. The two things are one thing in their experience, and it would not do justice to their reality if those things were segregated. Fortunately, I learned that complexity is not just a word; it´s also a worldview. The only worldview I could align myself with would allow for the complexity of life and the importance of that which is not obvious and sometimes not tangible either. It was a relief that this worldview is essentially the philosophical underpinning for all social-ecological systems work. A small confirmation that my path is right for me.

4.2 INTRODUCTION

I have decided to write this chapter from the first-person perspective. This decision stems from my research into how things are done in the social sciences, where I quickly realised that most publications in this field were written in this way. Initially, my ecology-trained mind scoffed at the ego of placing oneself at the centre of one´s work, but later I understood that, if we really think about it, researcher objectivity is an impossible goal (Rosendahl et al., 2015), and being open about your background and ideology, i.e. making your positionality explicit, is the first step in helping your reader understand where you end up. Especially in social research, this is critical to producing something of value (Braun & Clarke, 2019). This realisation made me wonder if it made sense, then, to write the components of this thesis in the voice that the relevant institution has chosen for itself. According to Zhou & Hall (2018), it does. Each way of writing has its strengths and weaknesses. The etic, the objective outside perspective generally used for "hard sciences" like ecology, is useful when one is examining or searching for objective truths. However, it lacks the substantive value of the emic, the subjective inside perspective, which allows for the exploration of components of reality that, while still true, are more personal and experiential. The etic perspective, in contrast to the emic, does not allow for objectivity. Zhou & Hall (2018) explain the benefit of allowing both to contribute to the conversation:

> "By allowing academic writing, especially mixed methods writing, to be open to both the emic and etic perspectives, we begin to trouble the single perspective, the single gaze from which all academic discourse flow."

The benefit of the combination of voices, therefore, lies in the power of such an approach to explore reality from multiple points of view, rather than committing to a single way of discussing an issue. This approach aligns with the overall purpose of this project, which is to explore the issue of MPAs in KZN from multiple perspectives. A reflection on my positionality as a researcher (i.e. the way my identity influences the work I do) can be found in Chapter 7.

4.2.1 CHAPTER OVERVIEW

This chapter focuses on the social aspects of this project. The first portion consists of a review of literature relevant to the research and the methods that I have chosen. This is followed by the specific aim and research questions of this chapter, and then a description of the methods that I used. Finally, I share first the quantitative and then the qualitative results before discussing both sets of results and how they relate to the literature.

4.2.2 USING PERCEPTIONS TO ASSESS MARINE CONSERVATION OUTCOMES

Perceptions are defined by Bennett (2016) as:

> "The way an individual observes, understands, interprets and evaluates a referent object, action, experience, individual, policy, or outcome"

This means that perceptions are layered, arising from the observation of something occurring in the physical realm as well as the subsequent sense-making process, which relies on various influencing factors including personal knowledge and other elements of reality that, based on the person´s experience, might explain or influence the way they make sense of that observation. Perceptions research, therefore, makes sense as a way to uncover relationships within a Social-Ecological System (SES) which are not obvious to an observer who is generally situated outside the SES. I am an outsider with expertise in research, but I am not local to the area, nor am I an avid fisher, and it therefore makes sense to rely on the expertise of locals to help understand the dynamics of this system (Fazey et al., 2006). Research on perceptions is becoming more common in the field of marine conservation, due to the rich insight it provides into the development, delivery, and evaluation of conservation projects (Gelcich & O'Keeffe, 2016). More recently, it has been accepted that there is a need for a paradigm shift in the marine sector toward a better understanding of human behaviour in the context of Marine Protected Areas (MPAs) (Bergseth, 2018), and that research on perceptions is fundamental to finding successful pathways to achieve effective marine conservation (Jefferson et al., 2021).

4.2.2.1 THE IMPORTANCE OF UNDERSTANDING RELATIONSHIPS IN COMPLEX ADAPTIVE SYSTEMS (CAS)

Bennett (2016) found that perceptions research allows us to understand more about four important components of the SES in any conservation issue, namely the *social aspects* and *ecological outcomes* of conservation, the *legitimacy of governance*, and the *acceptability of conservation management*. These are elements that allow us to understand more about the nature of the relationship between the human

component and the rest of the SES. As a CAS, an SES is heavily influenced by the relationships that exist between subsystems (Preiser et al., 2018), and understanding these well is critical to finding pathways to marine conservation methods that are likely to succeed (Bennett et al., 2019; Jefferson et al., 2021). As has been discussed in the Introduction (Chapter 1), the way that people perceive conservation (in other words, their relationship with conservation) is especially important in the marine realm, where enforcement is often poor (Bennett & Dearden, 2014b; Gill et al., 2017; Kirkman et al., 2023) and compliance is dependent on positive perceptions of management, social impacts, and ecological effectiveness (Bennett et al., 2019).

4.2.2.2 Expert and experiential knowledge

Including perceptions research in the monitoring and assessment of conservation efforts is clearly necessary, but it also makes sense that the perceptions of different groups can have different value for decision-making, depending on whom they are coming from. This is related to the nature of knowledge and how experience shapes our knowledge of a system. Experiential knowledge, or knowledge gained from experience, can be broadly categorised into two types of knowledge, namely explicit and implicit knowledge (Davies, 2015). Explicit knowledge refers to that which is shared, while the implicit is that which is not shared in a conversation. Within our implicit knowledge, which is not shared, lies tacit knowledge - that which forms a part of our understanding of any given phenomenon, but cannot be shared or communicated explicitly, even if we wanted to. Other implicit knowledge could be expressed but is not. Knowledge gained from experience within a system can also be classified as either expert or non-expert knowledge (Fazey et al., 2006). Expert experiential knowledge is of the utmost value to inform decision-making, due to several features, which I summarise from (Fazey et al., 2006) below:

1. Experts have extensive experience from which their knowledge is drawn through many years of observation and reflection. This is enhanced when they are embedded in a system where they receive direct feedback on their actions.
2. Experts can aggregate knowledge in novel ways and are more likely to recognise emergent properties of a system. They can draw on this competency in ways that enhance their ability to make more accurate predictions without being able to explain how they do it. (Expert predictions are often only slightly less accurate than complex computer models, and they need minutes to make them, as opposed to days.)
3. Experts have an improved ability to adapt to new knowledge and make good decisions given a high level of uncertainty: They have adaptive expertise.

4. Expert knowledge is complex and cannot be reduced to facts and suppositions: It is more than memory and intelligence (tacit knowledge is significant in experts).
5. Expert knowledge is often highly localised in time and space.

These properties point to expert experiential knowledge as an important source of information in SES, which are constituted relationally, adaptive, radically open, and contextually determined. Their behaviour is generated by dynamic processes, and they have emergent qualities that arise through complex causality (Preiser et al., 2018). All of these properties of SES, as CAS, are complex for a non-expert to understand and work with but are much better understood by the experts who work within and navigate this complexity every day. The features of expert knowledge in fact respond almost directly to the features of SES (Table 4.1). Expert experiential knowledge, drawn from reliable sources and used in the correct way, can therefore play an important role in helping to navigate the complexity of SES faster and with a high degree of accuracy (Fazey et al., 2006).

Table 4.1: The features of expert knowledge (Fazey et al., 2006) which make it suitable for SES research, based on the properties of SES (Preiser et al., 2018), according to my understanding and interpretation of the literature above.

Property of SES as CAS	**Corresponding feature of expert experiential knowledge that makes it suitable for supporting SES research**
Constituted relationally	Drawn from extensive experience, observation and reflection, localised in the SES (experts understand the relationships in an SES because they have personally experienced them).
Adaptive	Adaptive expertise.
Radically open	Ability to adapt to and integrate new knowledge (if the system experiences a new entity / relationship, they can recognise it as such and see how this relates to the rest of the system).
Contextually determined	Localised in time and space (they understand the context; their knowledge is localised in the same way that a portion of the system is).
Behaviour generated by dynamic processes	Extensive experience in the SES, observing and reflecting on processes, means experts know more about the ways that these dynamic processes operate and interlink than non-experts do and can predict system behaviour more easily.
Emergent qualities arise through complex causality	Ability to recognise emergent properties and adapt accordingly.

The boat-based commercial linefishers whose perceptions are being explored in this chapter are experts in their field. Previous studies have shown that these fishers spend more days, and more time per day, on the ocean than any other group of linefishers, and they have a higher Catch per Unit Effort (CPUE) than any other linefishing sector in KZN (Dunlop & Mann, 2013; Dunlop, 2011). Their continued presence on the ocean and interaction with fish species means that their tacit and implicit knowledge of the ecology of the areas they fish is high. The fact that the MPAs in KZN are sometimes zoned in such a way that allows access for commercial linefishers to certain portions, but not others (i.e. within the uThukela MPA, Government Gazette, 2019), combined with relatively strict monitoring protocols (Dunlop, 2011) means that, by necessity, fishers in this sector have significant experience with and knowledge of the MPAs in the area. Furthermore, the decision in 2006 to issue commercial linefishing rights for a long term (i.e. for 7 years) before renewal, means that most commercial linefishing rights holders have more than the requisite 10 years of experience necessary to be considered an expert in one´s field, especially as many

fishers remain active in the sector for a long period of time (Dunlop, 2011; Fazey et al., 2006). The perceptions of commercial linefishers can, therefore, be classified as expert knowledge and obtaining this knowledge can be considered an impactful and efficient way to gain a better understanding of how the MPAs in KZN are currently succeeding or failing in their stated objectives, which include supporting and improving the management of the linefishery.

4.2.3 Fishers´ perceptions of MPAs globally

Although fishers' perceptions have only been valued relatively recently as a way to assess and understand the impacts of MPAs on local communities, the body of work is growing and resulting in a better understanding of the ways that MPAs and their governance benefit or disadvantage local people, both internationally (Bennett & Dearden, 2014b, 2014a; Fazey et al., 2006; Leleu et al., 2012; Ordoñez-Gauger et al., 2018; Weigel et al., 2014) and, to a more limited extent, in South Africa (Sowman & Sunde, 2018; Francolini et al., 2023). However, only a few studies focus specifically on the perceptions of commercial fishers, and Pita et al. (2011) could only find 16 articles on commercial fishers´ perceptions of and attitudes toward MPAs in a global review. Most published studies have focussed on the perceptions of recreational and/or artisanal fishers.

In their review, Pita et al. (2011) found that the research on commercial fishers´ perceptions focussed mostly on three topics, namely: governance issues related to MPAs, environmental issues related to MPAs, and the impact of MPAs on fishing activity. Perceptions of commercial fishers regarding MPAs varied widely, largely because MPA design and management can vary so much. However, there was general agreement between studies about certain issues, such as the fact that fishers do not believe that their knowledge is adequately integrated into the planning and management of MPAs through their involvement and participation in these processes. Interestingly, they found that MPAs which were implemented for the purpose of fishery management generally had more positive perceptions associated with them than those with only a conservation purpose. There was also a trend of No-Take Areas being regarded less favourably than areas which were controlled using gear restrictions or other management methods (but allowed fishing). Enforcement was often perceived not to be effective, and one study they reviewed found that the fishers believed that the main reason for the failure of MPAs to deliver on their goals was poor enforcement (Himes, 2003).

Research by Bennett et al. (2019), on the perceptions of MPA stakeholders more generally, found that perceptions of good governance, positive social impacts, and ecological effectiveness were correlated to

support for MPAs, but, interestingly, perceptions of good governance and positive social impacts were more strongly linked to supportive sentiments than perceptions of ecological effectiveness were. Similarly, Leleu et al. (2012) found that although fishers were aware of the ecological benefits of MPAs, they were not convinced that MPAs had any positive impacts on their own activities. They also found that fishers who had been fishing for longer had fewer positive perceptions of MPAs and were less likely to fish near their borders regularly than less experienced fishers. Pita et al., (2020) found that negative fisher perceptions of MPAs were related mostly to social impacts and individual interests and were not associated with catch rate. In their study, the perceptions of fishers about MPAs were slightly more negative 10 years after the implementation of the MPA than they were at the outset.

In South Africa, the research on MPA perceptions is limited and focuses mainly on the impacts on small-scale and subsistence fisheries (Sowman & Sunde, 2018; Francolini et al., 2023). Limited research in South Africa has focussed on the perceptions of commercial linefishers regarding MPAs (Sauer et al., 1997; Dunlop, 2011), and social science research has been identified as a gap in the South African MPA literature (Mann-Lang et al., 2021). Research by Sowman & Sunde (2018) identified five key social impacts that were attributed to MPAs by local communities along the South African coastline. These were: 1) Weakening of local governance rights and processes, 2) Loss of tenure rights and access to resources, 3) Loss of livelihoods, 4) Impact on culture and way of life, and 5) Increased conflict. Additionally, past exclusionary governance (i.e. apartheid) was identified as a major problem in South Africa, but this was more related to the impacts of MPAs on local small-scale and subsistence fishing communities than the commercial sector.

4.3 AIM AND RESEARCH QUESTIONS

4.3.1 AIM

Understand perceptions of Commercial Linefishing rights holders in KZN regarding the MPA network and its current governance, as well as how this may be improved in future.

4.3.2 RESEARCH QUESTIONS

1. What are the perceptions of the Commercial Linefishing Rights holders in KZN regarding MPAs and their governance and management?
2. How can management be improved to ensure better MPAs in the future?

Due to the way that my analysis has progressed, both research questions are addressed to some extent by each of the themes that I developed.

4.4 METHODS

The below figure (Figure 4.1) is a graphic representation of the methods which were used for this research chapter, in the context of the whole project. The methods for this chapter will be described further in the below sections.

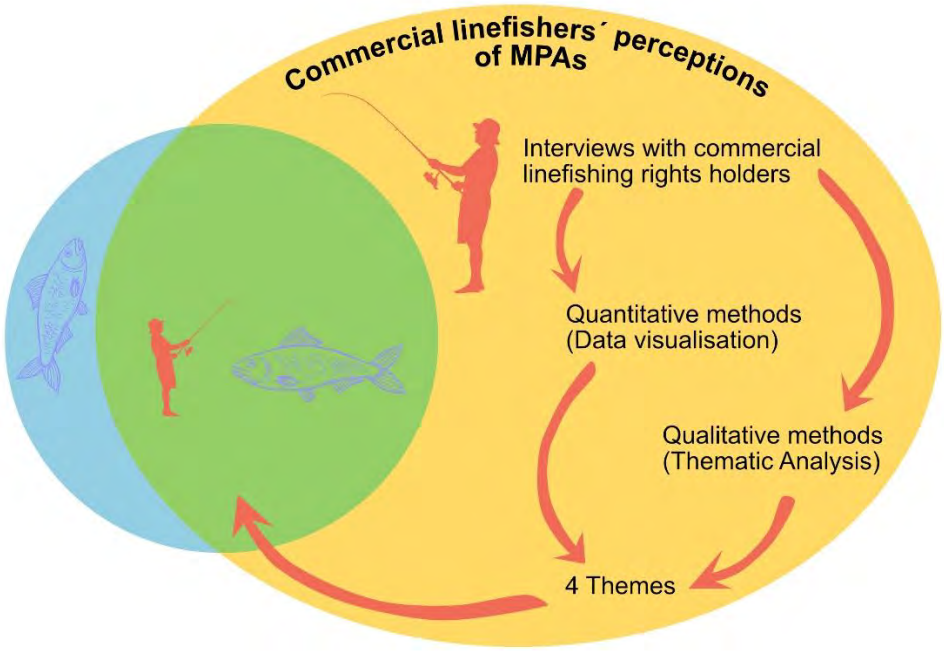

Figure 4.1: The methods for this chapter and its context in this research project (illustrated in Figure 2.1). The yellow oval on the right represents the social science research on which this chapter focuses and contains a brief overview of methods for this chapter. The blue circle on the left represents ecological research, conducted in the previous chapter (Figure 3.1), and the green overlapping area indicates the integration of social and ecological results for a social-ecological systems perspective, which will be explored in the following chapter (Figure 4.1).

4.4.1 INTERVIEWS

4.4.1.1 SAMPLING APPROACH

I chose to interview only the Commercial Linefishing rights holders in KZN, to ensure that I was speaking to experts within the study SES as far as possible, as fishers must prove their expertise in order to be granted commercial linefishing rights (Dunlop, 2011). I decided to try to interview all the commercial linefishers in KZN using snowball sampling, because they are a small group (n = 30) and are likely to know one another, which makes this method suitable for the purpose (Naderifar, Goli & Ghaljaie, 2017). I first asked the South African Department of Forestry, Fisheries and the Environment (DFFE) for a list of the currently active commercial linefishers in KZN. They obliged with a list including contact information. Dr Bruce Mann from the Oceanographic Research Institute (ORI), who has worked closely with Commercial Linefishers in KZN throughout his career, also assisted me with an introduction to some of the fishers using a WhatsApp group which he shared with me. This initial contact and introduction from a trusted source allowed me access to the community, and I proceeded with the recruitment of new interview participants using snowball sampling. I made first contact with fishers using WhatsApp, where I sent a message introducing myself and my project. If a fisher indicated that they were willing to speak to me, I set a date and time for the interview and offered to explain more about my work on a phone call if they felt it was necessary. During the interviews, I asked fishers if they knew about other Commercial Linefishers with active rights in their area who may be willing to speak to me, and who would not mind me making contact.

4.4.1.2 DESIGNING THE INTERVIEW

The data for this chapter was collected using an interview set of 27 questions (Appendix 2), which was developed using the supplementary materials of Bennett et al. (2019) for initial guidance. I chose to develop my interviews in this way due to the large body of work done by Bennett on the importance of perceptions research for conservation and MPAs specifically (Bennett & Dearden, 2014a,b; Bennett, 2016; Bennett et al., 2017, 2019), as well as a desire to ensure that the questions being asked were comparable to those used in other published research (Partelow, Jäger & Schlüter, 2021). This essentially ensures that the description of the SES that arises from this work will explore the most salient issues in MPA management according to current knowledge and it will also mean that these data can be compared to similar data in other parts of the world. This was important to me because biodiversity loss, climate change, and anthropogenic pressures are global problems that need the best conservation solutions possible, as quickly as possible (Soulé, 1985; Cowie, Bouchet & Fontaine, 2022). Comparability between research projects and management data contributes to this goal, as meta-analyses rely on comparable

indicators between sites (Fox et al., 2014). The Bennett et al. (2019) publication that guided the development of my interviews explores the same issues that I wanted to explore with my own project, namely local perceptions of governance (acceptability and legitimacy), social impacts, and the ecological effectiveness of MPAs. I adapted the questions from the household survey used by Bennett et al. (2019) so that my interview was more open-ended (see Appendix 1). This allowed me to conduct more qualitative analysis than was done for their study (which was designed for more quantitative analysis) but still ensured that my findings speak broadly to the four themes of Bennett´s work on perceptions.

4.4.1.3 Ethical considerations

Ethical approval for this research was granted by the Rhodes University Ethical Standards Committee (Appendix A2.6.1 Ethical approval for human research & A 2.6.2 Ethical clearance extension letter for human research, Approval number: 2022-5931-7221). The Rhodes University Ethical Standards Committee requires all students to explore and clarify any risks involved with the research, and for ethical approval for studies involving humans, requires a commitment to ensuring the privacy and anonymity of all participants (Rhodes University Ethical Standards Committee, 2014). This research was identified as having a low risk to participants through the ethical approval process.

Prior to starting the interviews, the fishers were provided with a brief description of my project, including how their data would be used. I shared a consent form with each fisher, which is attached in Appendix 2. With consent granted, I recorded all the interviews and also had a notebook where I took physical notes of anything of interest that was said before, during and after the interviews. Interviews were recorded on Otter.ai (Otter.ai, 2022), an application which simultaneously records and transcribes audio, using Artificial Intelligence (AI). After initial recording and transcription using Otter.ai, Express Scribe (NCH Software Pty Ltd., 2024) was used to correct any mistranscription done in the Otter app, as well as to remove any information which may identify individual fishers, for the purpose of anonymity.

4.4.2 Data analysis

I analysed the data for this chapter using mixed methods, including both qualitative and quantitative analysis. I analysed quantitative data first to provide myself with an overview of what perceptions were held strongly within the community before I started conducting qualitative analysis (Franzosi, 2008; Newing et al., 2011).

4.4.2.1 Quantitative data analysis

In order to visualise descriptive statistics, I first carried out quantitative content analysis. Any data which was easily extractible from the interviews was extracted; for example, when an interview question asked a "Yes / No" question or asked the fisher to rate a statement on a rating scale. These data were captured onto a spreadsheet (Microsoft, 2023), and pie charts were made based on the results for each question. Fishers did not always believe that either yes or no was a complete answer, sometimes saying "yes and no". These answers were accepted with a request for further explanation of why they say this. In such cases, a category in the pie chart was created for "yes and no" answers, and their reasoning was included as qualitative data. Where fishers refrained from answering a question, an "unassigned" category was created to ensure that each pie chart took into account the entire population of fishers who were interviewed. These were analysed visually, with percentages included in the pie charts for easy interpretation. For pragmatic reasons, I also made Sankey diagrams of all my code categories in Atlas.ti. Although Sankey diagrams are usually used to show the flow of information or materials (Schmidt, 2008), in this case, they allowed me to see how sub-categories fed into higher-level categories and which of these sub-categories contributed the most to the code density of a given higher-level category. These diagrams made pragmatic sense for data exploration because the Atlas.ti software, which I had used for all the coding, has this tool available. Being able to visualise how the code density within each sub-category contributed to a larger category in this way allowed me to understand which issues were mentioned most often in the dataset. More ubiquitous topics were interpreted as being more salient to the commercial linefishing community, and these two ways of visualising data quantitatively gave me a useful overview which I could lean on for qualitative analysis (Newing et al., 2011).

4.4.2.2 Qualitative data analysis

4.4.2.2.1 Approach to coding and analysis

While doing methodical research for the analysis of this component, I realised that there are many different ways to conduct Thematic Analysis (TA). For pragmatic reasons, I chose to use a modified codebook approach (Braun & Clarke, 2019): I built a codebook (Appendix 3) in which I indicated under which conditions codes were applied. My approach to the analysis itself resembled that of Reflexive TA (Braun & Clarke, 2019; Byrne, 2022), in that the analysis was an outcome of my interpretation of: 1. The data itself; 2. The theoretical assumptions of my analysis; and 3. My own analytical skill (Byrne, 2022). However, my approach differed from pure Reflexive TA in that I included the construction of a codebook and some quantitative analysis in my initial exploration of data and my approach was informed through a

process-relational philosophical stance rather than constructionism, which is the typical approach of Reflexive TA (Braun & Clarke, 2019). I complimented this by drawing on the work of Bazeley (2009) and Newing et al. (2011) to guide my process from a pragmatic perspective (Braun & Clarke, 2012, 2013, 2019, 2021).

Byrne´s (2022) description of the Reflexive TA process allowed me to engage well with questions about my own theoretical assumptions, which are necessary to describe to ensure good TA (Braun & Clarke, 2019). He describes four continua along which one´s theoretical assumptions should be made explicit, namely epistemology, orientation to data (critical to experiential), approach to analysis (inductive to deductive), and approach to coding (semantic to latent). I have already discussed my epistemological and ontological stance in the methodology chapter (Chapter 2). My reflections on further assumptions are available in Appendix 4. If a fisher brought up a topic multiple times in the conversation, it would be coded for multiple times. Code density in this study is therefore a result of how often something is discussed and not how many fishers discussed a topic.

4.4.2.2.2 Language and terminology for the qualitative analysis

There is no agreement in qualitative data analysis about the meanings of the words “category”, “theme”, and “concept”, and these are often used interchangeably (Bazeley, 2009), while the “code” is an important term that seldom receives a definition in the literature, as it has a meaning that is generally agreed upon. I have defined how I used these terms in Table 4.2. The hierarchy of terms for the qualitative grouping of evidence for this thesis will be: Code –> Category –> Concept –> Theme. The code, as the most basic/primary unit of analysis, contains only a description of the direct evidence in the text, while the final themes that are developed arise from the “describe – compare – relate” process of Bazeley (2009), and are much more nuanced, relying on evidence from interviews and other relevant information sources, including existing literature and the implicit knowledge that I gained from my experience in the field.

Table 4.2: The intended meaning of terms which are sometimes conflated in qualitative analyses.

Term	**Intended meaning**
Code	A term or short description of evidence identified directly from the text (Byrne, 2022).
Category	A descriptive grouping of codes (Bazeley, 2009). Sub-categories have the same definition, but each category could contain a few sub-categories that feed into it.
Concept	A more abstract level of coding / grouping of codes and categories (Bazeley, 2009).
Theme	A pattern of shared meaning underpinned by a shared concept (Braun & Clarke, 2019) and arising from the describe – compare – relate process of Bazeley (2009). The highest order of meaning and interpretation.

4.4.2.2.3 Analytical process

Transcription and quantitative data analysis ensured that I was familiar with the data by the time qualitative analysis started. I followed the method described by Bazeley (2009); describing themes from the data, comparing data from different contexts or interviews to each other, and then trying to understand how these relate to each other and what this means on a broader, systemic scale.

I used inductive and deductive coding on Atlas.ti software (ATLAS.ti Scientific Software Development GmbH, 2024). For deductive coding, I created categories for information that I was broadly interested in before coding. I then started coding the interviews inductively, creating a new code every time a new issue relevant to a category I had identified was discussed. Codes were labelled according to the meaning that was conveyed by the coded text. During and after the coding process, I revisited my codes to minimise the number of codes per category without removing complexity and nuance from the dataset. This process meant that there were about three levels of code categories and sub-categories when I started the more interpretive concept and theme-building process.

Sankey Diagrams, described above in the quantitative methods, were used in Atlas.ti for a first look at how code sub-categories contributed to main categories. I then used Affinity Designer (Serif (Europe) Ltd, 2024), an illustration software, to manually work with codes. I made a large document and then created a moveable block for each code, which was colour-coded according to its category. I used this to group codes, creating a mental model of the current governance system. This allowed me to reflect on potential weak points in governance and management that could be causing the fishers to experience the problems that they shared with me (Appendix A2.3: Code Book).

Another analytical method that I used was to create a table containing my research questions and the themes that I had identified to answer them, with relevant quotes providing evidence for themes. This was useful because it made me realise that the way I was sorting through the ideas in the interviews was too positivistic, and after engaging with this for a while I chose instead to answer the research questions with more holistic themes that could answer both research questions simultaneously and were more focussed on core issues. This minimised repetition and allowed me to focus on what the fishers were trying to convey rather than on my own desired outcomes for the work. For this final stage of theme development, I chose to allow a few concepts to feed into each theme, which would take the form of a statement conveying my complexity-based understanding of a dominant issue. This approach meant that some of the concepts were used in the development of more than one theme, but also that themes were

more accurate to the complexity of the SES than themes developed from a single concept could have been.

4.4.2.2.4 Workshops with fishers

After finalising themes from the analysis of social data and the results of statistical analysis for ecological data, I held two workshops with the commercial linefishers in KZN. Dr Bruce Mann (ORI) came with and helped to facilitate the workshops, as he has a lifetime of experience in the linefishing sector, both as a fisher and a researcher. Workshops were not seen as an opportunity for data collection, but rather served as a way to share the results of this project with fishers and confirm that they agreed with the outcomes of my analysis of interview data. The first workshop was held in Rocky Bay, just south of Durban, and the second was held in Richard´s Bay, north of Durban. This made sure that all the commercial linefishers in the province could attend. Workshops were formatted as an open space for dialogue, encouraging engagement from fishers. I first provided feedback on ecological findings, then we had a discussion on these results, before I shared my findings from the social research, which were also discussed. I had some guiding questions for the final discussion session, which were intended to help with the development of the Theory of Change for the final chapter, but these were not always answered and we allowed the discussion to flow according to the interests of the fishers. This gave me a sense of what issues were important to the fishers. Dr Mann´s inputs were key here as his historical knowledge of fisheries management meant that he could engage with fishers about the context and history of MPA governance and management over a longer timeframe than I could. I learned a lot from being in these discussions, which I incorporated into the production of the Theory of Change in Chapter 5. One thing that I noticed is how eager fishers were to engage with research and researchers: In both workshops, the attendance was double the number of fishers who had RSVP´d, despite both workshop days also being good fishing days. I also had various requests from recreational fishers who wanted to join the workshops. We decided to decline recreational fishers´ requests to attend, as we had decided to keep the workshops small and wanted commercial fishers to be able to share their perspectives freely without friction with other fishers in different sectors. Fishers in both workshops expressed a desire to have more opportunities to engage with research and help researchers to understand the context of their research better, and they were generally frustrated by inefficiencies in the governance and management systems in place for MPAs and fisheries more generally, especially related to the lack of enforcement on recreational fishers. They also reiterated a need they had expressed in the interviews for better communication, collaboration and cooperation between fishers, Ezemvelo KwaZulu-Natal Wildlife (EKZNW), and the Department of Forestry, Fisheries, and the Environment (DFFE).

4.4.2.3 USE OF QUOTES

Quotes have been used to illustrate the points made by fishers in interviews, and to maintain their voice in the outcomes of this work. I chose to label quotes such that each quote is numbered according to the following formula: Q4.x; where "Q" indicates that this is a quote label, 4 is the chapter number and x is the number of the quote in this chapter. The first quote will therefore be "Q4.1", the second "Q4.2", etc. Quotes were edited slightly to ensure that the meaning conveyed by fishers was clear to anyone who might read it, while maintaining the voice of the fisher. This sometimes included translating something that was said in Afrikaans, or adding some contextual information from the conversation or other relevant contextual information that may allow the reader to engage fully with the intended meaning. Edits to quotes are indicated in square brackets within the quote.

4.5 RESULTS

4.5.1 RESEARCH PARTICIPANTS

I interviewed 22 fishers in total, of which 12 were operating in the area north of Durban (North coast) (55%), two were in Durban itself (9%), and 8 were operating south of Durban (South coast) (36%) (Figure 1.2, Introduction chapter). I knew of an additional four fishers operating on the South coast and an additional three who were operating on the North coast, making a total of 29 commercial linefishing rights holders who were either made known to me by word of mouth or who had been contactable and had responded. This indicates that there are more fishers operating on the North coast, and the distribution of my interviews was therefore fairly representative, unless there were additional fishers in the south of whom I was not aware. This is a real possibility given the disconnect that I noticed between government data and field data, details of which can be found in Table 4.3.

Table 4.3: Variation between DFFE data and field data

Category	Number
Total fishers on DFFE list	30
Total fishers known to me	29
Fishers on DFFE list, also known to me	25
Fishers on DFFE list but no confirmation of existence in the field	5
Fishers not on DFFE list but known to me	4
Contact information on DFFE list failed	3
On DFFE list but actually a fisheries lawyer´s contact number	1
Fishers claiming active rights, not on DFFE list	3
Fishers waiting for rights renewal	1

4.5.2 Overview of fishers´ perceptions: Content Analysis

The pie charts in Figure 4.2 and Figure 4.3 show the results of the quantitative analysis of the perceptions shared with me. These results were helpful in guiding my thought process and interpretation of the data, as they provided a basic understanding of the level of consensus between fishers on certain issues. For example, 46% of fishers indicated that MPAs have not altered their relationship to the sea (Figure 4.2), most fishers in this sample believe that fish populations in the ocean are decreasing (59%, Figure 4.3), and all of them believe that fish populations need to be managed (100%, Figure 4.2). Interestingly, the fishers I spoke to also largely believe that MPAs are a good tool for managing fish stocks (73%, Figure 4.2), and 69% of them believe that their fishing community is supportive of MPAs to some extent (Figure 4.3). These results indicated to me that, generally, the problem is not that fishers do not understand the purpose of MPAs, nor that they are opposed to having them. Rather, they mainly have a problem with the way that MPAs are planned and managed. The fishers largely agreed that enforcement of MPA rules is not conducted fairly (Figure 4.2), and that neither the distribution of MPA impacts on different ocean user groups (Figure 4.2), nor the distribution of impacts along the coastline (Figure 4.2) is fair. They mostly believe that their fishing rights (Figure 4.3) and their livelihood needs (Figure 4.3) are not taken into account in MPA planning and management, and none indicated that their involvement in the MPA consultation processes had been meaningful to them (Figure 4.3). They also largely agreed that there are no mechanisms by which they can engage with the MPA management or governance authorities (DFFE or Ezemvelo KZN Wildlife - EKZNW) when they have an issue that needs to be addressed (Figure 4.2). Appendix 2 (Appendix A2.5 Sankey diagrams) contains the Sankey diagrams which resulted from the

quantitative analysis of code densities. These diagrams only contain the sub-categories and categories that I had applied to codes.

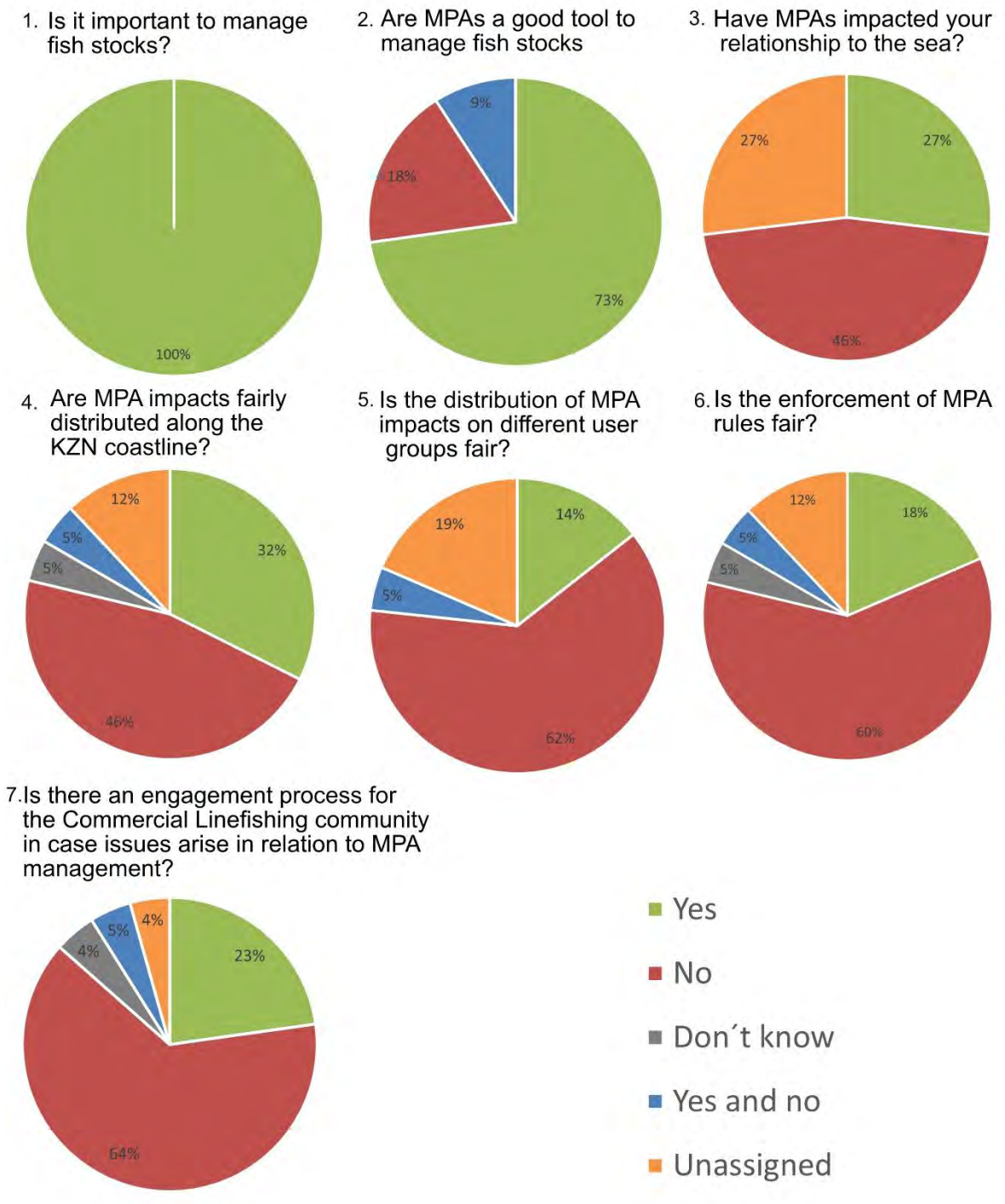

Figure 4.2: Pie charts showing fishers´ responses to Yes / No questions from the interviews. Note that more categories were created when fishers did not conform to Yes / No answers, to capture the diversity of their perceptions as accurately as possible. The "unassigned" category accounts for the number of fishers who refrained from answering a question. The sample size for this data was 22.

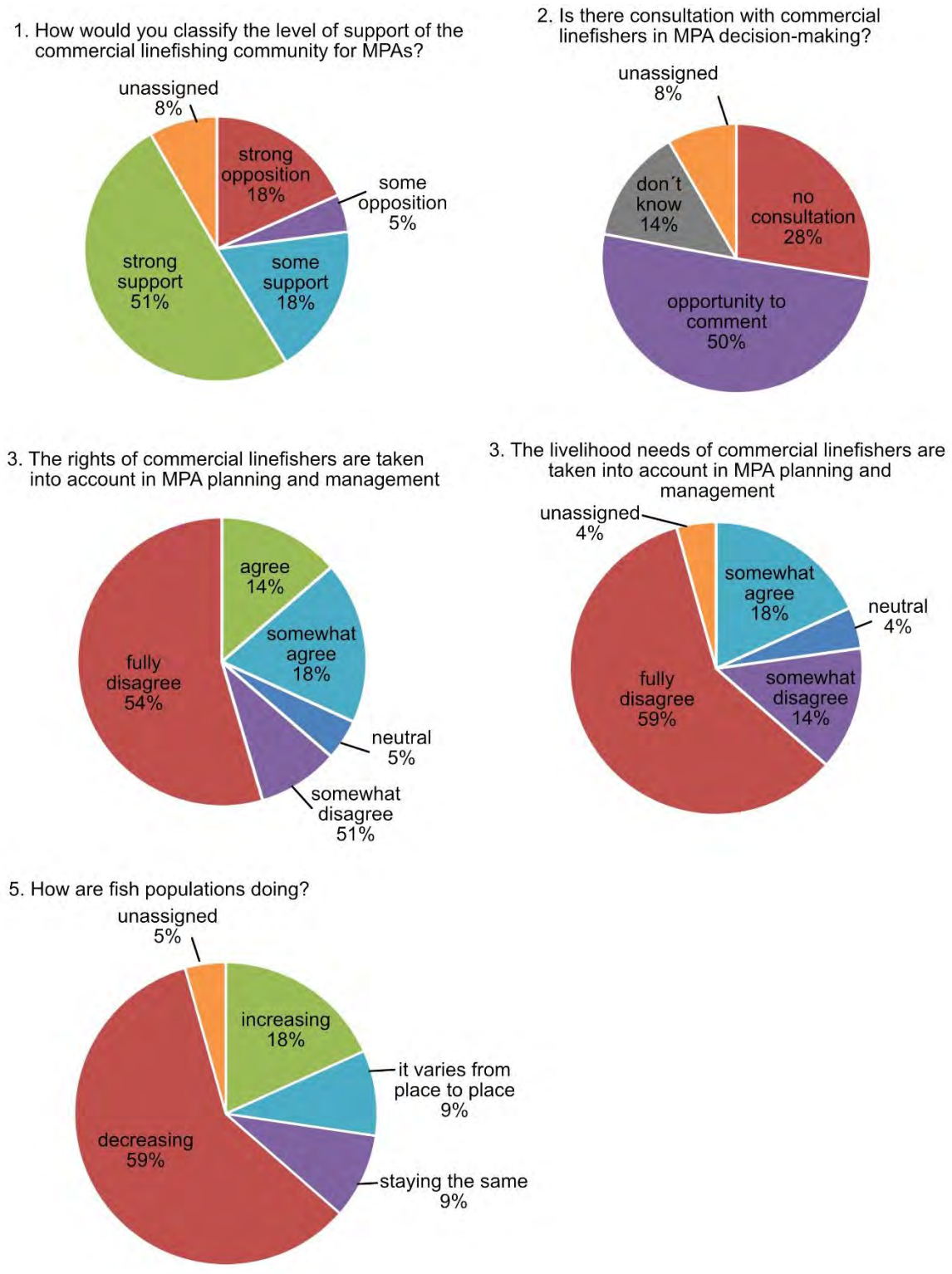

Figure 4.3: Pie charts indicating commercial linefishers´ responses to questions which were answered either according to predefined answers or on a Likert rating scale, with 1 generally being the most negative answer and 5 the most positive answer. The sample size for this data was 22.

4.5.3 QUALITATIVE RESULTS

The fishers shared a lot of specific information, which I think is important for understanding the impacts of the MPAs, their management and their governance on the commercial linefishing sector and commercially important fish (CIF) populations. Primarily, the interviews made explicit a wealth of social-ecological knowledge surrounding fish species and populations, the tensions and synergies among marine stakeholders, and institutional strengths and weaknesses surrounding MPAs in KZN and South Africa more broadly. This allowed me to develop an understanding of the relationships and dynamics in this social-ecological system that would be invaluable to anyone in the position to make and implement decisions regarding the system.

Although I could not capture all this complexity within the constraints of this thesis, through the iterative coding process described above (section 4.4.2.2.1) I developed four overarching themes which provide an overview of the core issues as they were discussed with me. These are:

1. Fishers believe that well-managed MPAs are effective and necessary for fisheries sustainability.
2. Monitoring and enforcement of fisheries and MPA regulations are poor and must be improved.
3. A poor relationship exists between fisheries management, MPA management and commercial linefishers that hinders the effectiveness of MPAs.
4. A lack of diverse sources of reliable information leads to misguided decision-making and long-term unsustainability of MPAs and fishery management.

These themes overlap and feed into one another, as is typical for the flow of information in Complex Adaptive Systems. I discuss the themes in more detail below.

THEME 1: FISHERS BELIEVE THAT WELL-MANAGED MARINE PROTECTED AREAS ARE EFFECTIVE AND NECESSARY FOR FISHERIES SUSTAINABILITY

As has been displayed by the quantitative results above (Figure 4.2 and Figure 4.3), the fishers often indicated that MPAs are potentially a good tool for managing fish stocks, as long as they are well-managed in accordance with this purpose. Some quotes highlight this sentiment:

Q 4:1

"I don´t think anyone opposes [MPAs]. I think everyone agrees that they are very good for the fishing. I mean, we need breeding areas. That is a given, it has to happen." – Fisher 9

Q 4:2

"I think the support for effective MPAs you'd find is strong because it's evidence-based…. We've all seen that. I mean, Pondoland MPA works; if you speak to any fisherman that has gone up to [iSimangaliso], everyone's impressed to see the health of the fish in those areas." – Fisher 1

The fishers spoke most favourably about two of the oldest MPAs in the region (namely iSimangaliso and Pondoland), often talking about how the Pondoland MPA especially had aided in the recovery of scotsman (*Polysteganus praeorbitalis*) populations. This perception was held particularly strongly by Fisher 14, who often fished in the Controlled Area of the Pondoland MPA, and also claimed that the black musselcracker population was much higher in and adjacent to the MPA. He repeated this belief a few times during the interview, specifically when referring to the importance of effective No-Take Areas. His opinion was that the Pondoland MPA is especially effective due to its geographical isolation (lack of safe launch sites in proximity to the No-Take Area), as well as its simple zonation, which means that citizens on shore can easily spot and report vessels suspected of poaching. Newer MPAs were generally not regarded as positively, and many fishers shared that they did not understand why these had been proclaimed, given the lack of capacity to enforce them:

Q 4:3

"They just bring in new laws, new laws and new laws and nobody enforces the laws. And you'll hear this from all of the guys here. They're gonna tell you the same old story, even though you're not asking it" – Fisher13

This theme is especially well evidenced using the code density of fishers´ suggestions to improve the sustainability of MPAs. The top three codes that were applied to their suggestions were, from highest to lowest density: "stricter enforcement", "fishing inside No-Take Area", and "better monitoring". Fishers´ desire for MPAs to be well managed is best evidenced by the fact that "stricter enforcement" and "better monitoring" were among the top three most common suggestions. "Fishing inside No-Take Area" was applied when fishers indicated that they would like special permission for their sector to fish inside No-

Take Areas. This indirectly shows that fishers believe that No-Take Areas are effectively protecting fish, as they know that the big fish they want to catch are inside the No-Take Area.

Q 4:4

"*But, again, lack of enforcement. That's our biggest biggest problem. Lack of enforcement." – Fisher13*

THEME 2: MONITORING AND ENFORCEMENT OF FISHERIES AND MPA REGULATIONS ARE POOR AND MUST BE IMPROVED

Q 4:5

"That´s why I say we´ve got very poor service from [DFFE]. Because they aren't visible for starters. You don't see them." – Fisher 2

This is a typical example of the way that fishers felt and spoke about DFFE and the lack of both fisheries and MPA enforcement, along the entire coastline. Commercial linefishers did not feel that there was sufficient enforcement of regulations, and most of them believed that the recreational fishery, in particular, was having a huge impact on their sector due to unfair implementation of rules, which focused mostly on the commercial sector simply because they are easier to monitor (All fishers except Fisher 1 and Fisher 15). Commercial fishers must, according to their permit conditions, have a functional Vessel Monitoring System (VMS) on their boat, which is activated when they go to sea and allows the DFFE to know their location while they are at sea and will create a "fishing" pin if the boat stays in one location for more than one minute. This permit condition is not applicable to recreational boat-based linefishers who, commercials believe, feel comfortable poaching due to the lack of monitoring and enforcement on their sector (Fisher 9). The only other type of monitoring that is conducted is boat checks, which happen very irregularly and often aren´t successful at catching poachers because they alert others, who will then dump all their illegally caught fish so as not to get into trouble (Fishers 11, 12 and 13). Corruption was also mentioned as a contributing factor:

Q 4:6

"We´re seeing [poachers on the water], we pass them.. [and we know they are catching more fish than they are allowed to]. And it's a jol [slang -like a party]. They´ll catch 300-400 kilos and they'll go back into the harbour but some of the guys will have connections in the water police and with them, they'll just rush into the harbour, go [and offload] their boat and go home, so ya, it's a free for all. They'll be in the loop, you know." - Fisher3

Q 4:7

"For example, I know two [commercial] guys that have been caught recently with seventy-fours… But I know in my heart of hearts, there´s guys [recreationals] that totally live off [catching] seventy-four throughout the year. They fish for it for a living… They'll come back with 300 to 400 kilos of it. Not once or twice a year, like 30 [to] 40 times a year, but…it's not regulated and the scientists don't know because no one will talk about it!" – Fisher3

Q 4:8

"And [in the Controlled Commercial Area], only commercials are allowed to fish, non-commercials [recreationals] are not allowed to fish, but they are there. There are more non-commercials coming and fishing there than commercials" – Fisher4

Q 4:9

"We´re monitored by the VMSs on our vessels. (But) the recreational guys are going there and just doing … whatever they want. There´s not enough law enforcement [on] the ocean itself, for the MPAs. Because vessels are there, fishing, illegally. Guys with no licenses, no VMSs." – Fisher 5

Some fishers stated that enforcement on commercials should also be improved, and this was well evidenced when one commercial linefisher mentioned that he sometimes stops to fish inside the No-Take Area of his nearest MPA. He shared that he does not want to break the rules but sometimes feels that he does not have alternative options due to the economic impact of the MPA on his fishing – which he claims has caused him to lose about 50% of his profit margin since its inception. Other fishers claimed similar losses due to the implementation of MPAs, either directly due to direct loss of fishing grounds (Fishers 3-6,9 - 12,17 -21) or indirectly due to increased travelling distance and hence fuel consumption or other expenses (Fishers 3,7,8,12,13,16 - 18,20), while others claimed not to be impacted too much, except for some inconvenience (Fisher 1). Many claimed that the way that enforcement is currently conducted does

not make sense given the realities of fishing. They mentioned that the fisheries control officers (FCOs) who have been in place since the DFFE took over fisheries management along the KZN coast (see Kramer et al., 2017 for explanation) are largely naïve and do not make logical choices in the way that they choose to enforce rules – leading commercial fishers to feel that they are being victimized unfairly (Fishers 1,3,7,9,11,13,14,16 - 18,21).

The lack of enforcement of MPA rules is compounded by a general lack of adequate enforcement of fisheries regulations, which enables a huge illegal fish market. The illegal activities of recreational fishers are not limited to catching more fish than they are allowed to. They are also fishing in places where they are not allowed to fish (including within No-Take Areas), and fishing for prohibited species such as seventy-four (All fishers). The sale of fish caught by recreational boat fishers is rampant, and a booming informal market for fish is causing economic stress for commercial fishers (Fishers 3, 6 - 13, 15 - 21). This is because recreational fishers can afford to sell fish at what commercials consider to be cost price, and in so doing they flood the market and reduce the price of fish. Recreational fishers generally go out on smaller boats (including sea kayaks) and do not employ staff, nor do they need to buy as much bait and equipment or pay the hefty fishing levies that the commercials pay. Recreational fishers generally fish for fun and selling fish illegally is often just a means of recovering some of the costs of their rather expensive hobby. Recreational fishermen that sell their fish illegally are often called "sham-amateurs" and they are in direct competition with legitimate commercial fishers. The following quotes highlight this aspect:

Q 4:10

"Okay, [a fish shop] was advertising slingers for R59.99/kg. Okay, that was the fish that we sell for R60/kg. How can they advertise a fish at R59/kg when we sell it to a buyer [at bulk price] for R60/kg? It can only come from one place. And we are commercials, we out there to make money [to support our livelihoods]... So all of us have a benchmark of what we caught, and we´re all about the same. So she [the fish buyer] is saying oh, but… you need to give me a discount on the fish. I said I can't! I said it´s R60/kg! She says, okay, but I want to show you something. She sent me a screenshot of [the fish shop price], R59.99/kg. Now you ask yourself, but how is it possible? And it's …KZN fish! That fish is coming from recreationals!" – Fisher 21

Many commercials stated that they now have to sell their fish inland, as the fish shops and restaurants locally are all fully supplied with recreationally caught fish and they are often unwilling to pay the higher price for legal, commercially caught fish (e.g.: Fisher 13, fisher 21). Enforcement along the value chain

(paper trail) is poor, and it is common practice for fishmongers to buy fish illegally from recreational fishermen and issue a fake invoice, in case a check is conducted in the following months (Fisher 3, fisher 13, fisher 22). The competition from the recreational fishery is a huge problem for commercial fishers, as it is compromising their economic viability.

This lack of enforcement not only impacts commercial fishers financially, but also impacts fish stocks. Species which have been banned from all types of fishing and should be recovering from previous overexploitation, such as seventy-four, are still being targeted illegally on quite a large scale by recreational fishers, meaning that the recovery of their stocks is much slower and commercial fishers remain banned from fishing for such species for a longer time. Other sensitive species which are still commercially fished, such as geelbek and dusky kob are also being overexploited by recreational fishers, particularly at night by boats fishing on the spawning aggregations of these species. This is putting these species under increased threat of complete stock collapse and potential closure of the fishery for both recreational and commercial fishers alike:

Q 4:11

"Remember, there's only 30 of us (commercials) from the Natal [KZN] coastline… There´ll be 200 [recreational] boats from Durban area fishing [near Ballito], and everybody's doing the same thing… like last month I know [of] just two catches [of geelbek], off two [recreational] boats in one night, was 1.6 tonnes. Two boats, two [poachers]. You understand what I'm trying to say? And then… a [commercial] guy gets caught with one seventy-four… and they want to throw [him in jail]! No, it doesn't justify, when another guy [recreational fisher] will actually [illegally] target [seventy-four] every single day that he can."
- Fisher3

These issues have led to a sentiment that the Commercial Linefishing sector is a dying sector which will not be around for much longer (Fisher16). Many of the fishers did not believe that the consequences of violations for the recreational sector were severe enough, nor that the matter gets taken further when poaching is reported:

Q 4:12

"They got nothing to lose. They're not being threatened by the Department. If you don't do this, …we´ll give you a fine, if you don't do this we´ll ban you for a year or so... To be quite honest, it would pay me to not even have a [commercial] licence, and to rather poach. I would make more money…" – Fisher 3

Q 4:13

"…We can phone the [DFFE] guys at night and say, hey, this boat came from [a given] beach. You go there a certain time and you will catch him. Nothing happens. Nothing ever happens!" – Fisher 8

Theme 3: A poor relationship between fisheries management, MPA management and commercial linefishers hinders the effectiveness of MPAs

The commercial linefishers whom I spoke with often shared that they had tried to engage with the DFFE regarding the planning, management, monitoring, and enforcement of the MPAs in KZN, but had made no headway, resulting in the ubiquitous belief that their contributions had not been valued nor truly heard (Fishers 3,4,8,10,11,13,21,22 on reporting poaching, all fishers to some extent on stakeholder engagement). Most fishers had subsequently stopped trying to engage with the department, and some claimed that their attempts at engagement had only made their relationship with other fishers worse (fisher 13), without bringing any positive change for their sector:

Q 4:14

"You know, when it comes to commercial fishermen, I think there's always gonna be limited…trust, because we, in the past, have given lots of information to [DFFE] officials which they haven't really followed. They haven't done anything about it. So, there's always going to be a question… when it comes to sharing this kind of information. I mean, whether they're going to actually act on it or not." – Fisher 22

The ways that fishers had tried to engage included reporting poaching incidents, attending various meetings about MPAs and fisheries, attending stakeholder engagement processes before the new MPAs were declared, and engaging with the DFFE through their Commercial Linefishers association with suggestions to improve the management of Commercial Linefishing in KZN (All fishers). Apparently, the

fishers did not believe that any of their input was valued nor acted upon by the DFFE (Figure 4.3). The only interaction which fishers mentioned to me as being a successful engagement with the department was a court case where the commercial linefishers had challenged the department and won, allowing them to continue fishing at night in the controlled areas of certain MPAs (i.e. Aliwal Shoal and uThukela). To me, the fact that the court case was regularly brought up as an example of "successful engagement" with the Department, indicates that there are no formalised pathways for the fishers to share their expert knowledge of the system and have it adequately valued. Many fishers shared this perception (Fishers 1,9,13,16,20,22).

Other than the court case, some fishers mentioned that they had attended stakeholder engagements for the planning of new MPAs. Not one fisher indicated that these engagements had been meaningful, mostly believing that the meetings were a "tick-box" exercise more than anything else (Figure 4.3, fishers 1, 2, 4, 8, 21). Some fishers were quite upset, as they had put a lot of thought and effort into these meetings and shared a lot of information, only to have the agreement they thought they had reached by the end of the meeting totally disregarded when the MPAs were proclaimed. They received no communication afterwards explaining why these changes had been made to the agreed-upon regulations (Fisher 13, fisher 19).

A lack of adequate communication is further evidenced by the fact that many fishers suggested improving the strength of communication between the DFFE, EKZNW, and the fishers in some form or other (Fishers 1,6,7,9,11-14,16-19,21,22). Suggestions included that the department should provide them with feedback on their catch returns and become more responsive to their poaching tip-offs. They also felt that a more thorough consultation process where their suggestions and knowledge were interrogated more openly would lead to better outcomes. When I asked about the level of trust between MPA management and fishers, I mostly received a response similar to:

Q 4:15

"No. No communication, no trust. No trust, no communication. Zero, nothing." – Fisher 6

However, despite a lack of effective communication channels between themselves and the DFFE, the commercial fishers often indicated that they would be open to working with the department to improve enforcement and share their expert knowledge on the SES:

Q 4:16

"I think what is very important is to maybe up [the level of cooperation], that you give… those commercial guys a certain amount of authority to…protect those areas, because if [DFFE] don't have the finances to do that, what is the second best? It's not a case of [giving all enforcing power to the commercials], I mean, just give us certain authority to …go up to them [boats fishing illegally in No-Take Areas], take photos, and know that there will be consequences. I mean, … that's supporting the enforcement of the MPAs." – Fisher 11

Q 4:17

"It´s just …a lot of decisions are made and areas are different. So a lot of legislation towards us as commercial fishermen are based on trawlers. " – Fisher 10

Q 4:18

"You know, it's just a pity that the department doesn't work with us. Just a pity." – Fisher 21

What the fishers really desired, therefore, was a reciprocal relationship between themselves and the DFFE, whereby their knowledge is valued in the decision-making process and knowledge sharing occurs bidirectionally. A sore point relevant to this that came up often was the fact that the DFFE has demanded catch returns from commercial fishers (i.e. submission of catch returns is a mandatory requirement), but has never set up a system of sharing information and research results from their catch returns (Fishers 5 - 7, 11, 13, 15 - 17, 21). One interview question asked was where fishers go for research and scientific information about fish stocks, to which many replied "Bruce Mann" – the name of a researcher working with ORI, who had taken a personal interest in linefishing and who has consistently made an effort to ensure that fishers can find scientific information if they need it. Other fishers, such as Fisher16, indicated that they had maintained a personal database of their own catch returns so that they could engage with these issues independently.

Theme 4: A lack of diverse sources of information leads to misguided decision-making and long-term unsustainability in MPA and fishery management

The fishers´ desire to expand engagement with regard to management and decision-making for MPAs was not limited to their own sector: Many of them believed that decision-making should rely on a broader

dataset than what is currently used (Fisher 10, 11, 13, 16, 18, 20, 21). Fisher1, in particular, indicated a hesitancy to believe the outcomes of current fisheries research because he believed that it was conducted in a way that could not capture the complexity of the whole system. Similarly, a few of the fishers mentioned above claimed that researchers did not spend enough time in the field and that research could easily be biased by seasonal and general ecological effects, which would impact results in a study with limited sampling. Many believe that the most accurate research would be that which requires the researcher to be in the field regularly, seeing and interacting with the SES they are researching, and that experts who interact with the system every day are not provided with an adequate opportunity to share their knowledge.

Evidence provided to support their narrative included the age-old issue of falsified catch returns:

Q 4:19

"I saw a statistic released on …[a] launch site, based on catch [returns] from recreational fishermen, every time [they beached] they´d …have to fill in the amount of fish that they've landed… The study was done all punched - all the numbers were punched - they released the statistics saying that I think it was 98% of the fish caught from [the] launch site was mackerel. Now …it's obviously not the case. (laughs) But based on numbers, maybe it is, I don't know, but it's seriously skewed. I think they said something like four slinger had been caught!" – Fisher 1

In addition, some commercial fishers felt that research was focussing on old information that is no longer current or relevant:

Q 4:20

"I think, ORI [Oceanographic Research Institute] is doing a fair job with the tagging programme in the Pondoland MPA and a few [other] studies coming through, but I think there's a serious lack of fisheries scientists in South Africa that are looking at the species of fish that are targeted by commercial linefishermen these days. They've been caught up on old populations of fish that have long since vanished and will never return, and they're not looking at the fish that we are focusing on catching now." – Fisher 1

Fishers were also concerned about issues which they believed were serious but not receiving any research attention, which they discussed often (Fishers 1 – 12 & 14 - 21). These included the impact of pollution on MPAs in the south from various sources (but often including the SAPPI SAICCOR factory at Umkomaas), the increasing number of sharks which take fish off their lines (depredation), the increasing population of

seventy-four, and changing weather patterns, which some believe is related to climate change. In the northern part of the province, there was also a concern about the stock status of dusky kob, a species which is no longer commercially viable due to restrictions, but which some commercials believed is hard hit by recreational poaching and needs a higher level of protection to avoid total stock collapse (Fishers 2, 9, 15).

Their concern about the seventy-four population is the result of some interesting dynamics. When the species was completely banned from fishing, it was apparently stated that this would remain in place for 10 years (see Mann, 2007)), after which it was assumed the ban would be lifted (Fishers 11, 12, 17). Since the implementation of the ban, commercial catch returns have not had a section where fishers could report on how many of these fish they had caught and released back into the ocean (Fishers 18, 19). Many claim that they now spend a significant proportion of their fishing time releasing seventy-four back into the ocean, especially on deeper reefs, where fish tend to suffer from barotrauma. Barotrauma is an often fatal fish injury that occurs when a fish´s swim bladder inflates as the pressure reduces while it is being pulled up from depth (Kerwath, Wilke & Götz, 2013), causing the fish to float on the surface unless it is released in a specific way, which can be time-consuming. Fishers claim that seventy-four populations are doing so well that they can no longer afford the time that it takes to carefully release all the seventy-four they accidentally catch, and often end up leaving perfectly good fish to float away on the surface and die:

Q 4:21

"When I started fishing in 1978, I was a youngster. It was 1982, [incorrect, actually 1998] they banned the [catching of] seventy-four for 10 years. So in reality in the early 90´s [actually by 2008], seventyfour was supposed to be unbanned. Well, ma'am, I'm 61 years old now and the seventy-four [ban] is still here. But [the ban does] more damage to the ecosystem for the seventy-four. The people are catching it. And that fish you cannot put back. " – Fisher 17

Q 4:22

"You'll catch 10 or 20 (seventy-four) in one down. Now you have 10 or 20 of these big fish. So what do you do? You just leave them and you move [away]. So you're not actually helping the stock, you're actually killing the stock. We´re actually throwing away food you could have used." – Fisher 9

Q 4:23

"The ban on catching seventy-four and red steenbras has definitely helped [these] fish stocks to come [back]. Now they´re overpopulated! [But], they´re still continuing with the ban and not allowing us to catch them." – Fisher 4

The problem of requiring more diverse information for decision-making was not only limited to a desire from the commercials to be more intimately involved in information sharing. It extends to the ways that enforcement and governance decisions are being made as well:

Q 4:24

"We've got poaching on an unprecedented scale happening here in KZN. So I think the first thing is they need to address the issues with charter boats (and) the recreational boats, you can see like with the amount of fish we´re allowed to catch. It's very easy to go to a club, check their boating [launch] records and see. If a boat is launching more than once a week, alarm bells should be ringing….What are they doing, fishing 2, 3, 4 times a week? …That's the first thing. And then the biggest problem is, these guys are now going to restaurants and so forth and selling their catches [illegally], which is creating even bigger problems for the industry as a whole… [Fisheries officers] should be …going to restaurants and so forth" – Fisher 22

4.6 Discussion

4.6.1 The history of fishery and MPA management in KZN and implications for results

During the interviews, I quickly realised that the fishers do not separate MPA management from fisheries management in KZN. This is largely because of the history of fisheries and MPA management in South Africa, particularly in KZN. Initially, the MPAs and all marine and coastal enforcement in KZN were managed by Ezemvelo KZN Wildlife (EKZNW) in terms of a contract with the national Fisheries Department within DFFE. This was, apparently, quite effective (Kramer et al., 2017). In 2016, however, the contract between the Fisheries Department and EKZNW was terminated, and national Fisheries Control Officers (FCOs) took over fisheries management in the province. Unfortunately, the management solution provided by the Fisheries Department resulted in a limited number of FCOs being moved between provinces for short periods of time (2-4 weeks), which resulted in turn in the FCOs making poorly informed management decisions, not being fully aware of the fishing regulations in KZN nor of the fish species found there (BQ Mann, pers. comm.). This change in responsibility also meant that the level of fisheries enforcement decreased drastically, from a situation where about 80 EKZNW field rangers patrolled the coast in 15 zones across the province, to a situation where a total of about 10 FCOs were tasked with the responsibility for managing the whole KZN coast. Unsurprisingly, this situation resulted in an increase in illegal fishing activity along the KZN coast (Mann & Mann-Lang 2020).

Following the implementation of the new or extended MPAs in KZN in August 2019 (i.e. uThukela, Aliwal Shoal and Protea MPAs), a contract was signed between DFFE: Department of Oceans and Coast (O&C) and EKZNW delegating authority to EKZNW to manage the KZN MPAs on behalf of national government. In the case of the iSimangaliso MPA, which is a World Heritage Site, EKZNW undertakes conservation management of the MPA in partnership with the iSimangaliso Wetland Park Authority. This division of labour has led to uncertainty in terms of jurisdiction and who is responsible for the implementation of fisheries and MPA regulations in the province, particularly amongst the fishers themselves. It is clear how this instability and uncertainty regarding the management and enforcement of fisheries and MPAs in the province would have resulted in an increase in lawlessness on the ocean. It would also help to explain fishers´ lack of trust and their scepticism regarding the acceptability and legitimacy of management decision-making, which was ubiquitous in the interviews.

4.6.2 MPA EFFECTIVENESS

Götz et al. (2013) indicate in their framework for assessing the ecological effectiveness of MPAs that the first step is to determine whether or not fishing intensity is less inside MPAs than outside. If this is not known, the assessment becomes automatically flawed. Interestingly, in their meta-analysis on the effectiveness of South African MPAs, Kirkman et al. (2021) indicated that most studies conducted here relied on a tacit assumption of lower fishing effort inside MPAs than outside, with few quantified studies available to provide evidence for such an assumption. Given the commercial linefishers´ concern regarding illegal fishing pressure both inside and outside MPAs, it is possible that this assumption does not always hold true, and our MPAs may, therefore, be less ecologically effective than they could be. According to Sander et al. (2014), rights-based management of fisheries only works when there is clear ownership of rights, as well as a capacity for rights-holders to contribute to law enforcement themselves, or at least report violations to an enforcing agent who will ensure that prosecution occurs in a court of law. The legal environment must also be such that the consequence of breaking the law is severe enough to deter potential rule-breakers. Without both a clear definition of rights and the adequate prosecution of violations, fish stocks are bound to the "tragedy of the commons" as if they are completely unregulated (Sander et al., 2014). Given the relevant knowledge shared by fishers in this study, the South African linefishery SES may be in this latter situation, as many indicated that neither of these conditions is being met. Concerns about monitoring and enforcement effectiveness in South Africa are echoed widely in the South African fisheries and MPA literature (Sundström, 2012; Cochrane, Eggers & Sauer, 2020; Kirkman et al., 2023).

Illegal fishing is mostly unreported (i.e. Illegal, Unreported and Unregulated [IUU] fishing), meaning that with high levels of poaching, government stock assessments are likely to overestimate fish populations, which can lead to unsustainable decision-making regarding fishing quotas, thereby increasing the potential for stock collapse (Agnew et al., 2009). The commercial fishers´ knowledge of and regular encounters with illegal fishing and illegal fishing practices, could provide a powerful indicator of the scale of the problem in KZN, if their relationship with the DFFE and EKZNW was improved to the point where reports of poaching were taken seriously and included as a metric in assessing fish stocks and MPA effectiveness. Commercial linefishers have an inherent interest in preserving the resource on which their livelihoods depend and, therefore, it would benefit them to participate in such data collection and associated activities. They have conveyed here a desire to contribute to such efforts if given the platform to do so.

Fisher14´s observation of scotsman and black musselcracker populations increasing adjacent to the Pondoland No-Take Area was accurate, as confirmed by Maggs et al. (2013) and again by Mann et al. (2022) in their assessment of the impact of the Pondoland No-Take Area on reef fish populations. The strong support among fishers for the iSimangaliso and Pondoland MPAs probably originated from their ecological effectiveness, which can be inferred from the fact that they are two of the four highest-scoring MPAs in South Africa for the NEOLI criteria, which were discussed in Chapter 1 (section 1.3.1) and Chapter 3 (section3.7.5) in detail (Kirkman et al., 2021). Fishers also stated that they had experienced the effectiveness of these MPAs themselves, while on recreational fishing trips or fishing along the No-Take Area borders. While in part informed by talks and popular publications from researchers, this agreement between fishers´ perceptions and ecological research (which was not limited to but rather well-evidenced by Fisher14´s contribution in this case) provides further support for fishers´ expertise and the desirability of including their knowledge more in decision-making processes.

4.6.3 Implications for governance and management of MPAs

4.6.3.1 Mental models and compliance

The results of this study indicated primarily that, according to the perceptions of Commercial Linefishers in KZN, the current system of fisheries and MPA governance and management is neither adequately informed nor adequately capacitated to successfully ensure the sustainable use of linefish resources in the province. This is a critical failing, considering the findings of Bennett et al. (2019) regarding the importance of positive perceptions of governance (legitimacy and acceptability), social outcomes and ecological effectiveness for compliance behaviour in MPAs. The pattern of decreased compliance correlating to negative perceptions is supported here by the poaching admission of one of the fishers and comments by others, which indicate that even among the well-monitored commercial fishers, compliance is not as strong as it should be. The rampant poaching by recreational fishers may be an indication that a similar perception of MPA governance and management is held by their group. Perceptions are not a direct measure of compliance but can rather be understood as an overview of a person´s interpretation of and personal commitment to a set of values, beliefs and norms.

In his framework for “knowledge ecology for hyper-turbulent organisational environments”, Malhotra (2002) describes compliance as rule-abiding behaviour which results either from a desire to receive some reward or to avoid punishment. He explains that in a complex organisational environment, such as the one found in fisheries management, the control of behaviour is more effectively achieved through

encouraging personal commitment to a set of beliefs, norms and values, than through compliance. He defines this commitment as:

> *"Internalisation of management-derived and sanctioned beliefs, norms and values, in the sense that they become part of the core of the individual´s perceptual world."* - Malhotra (2002)

This form of control is much more effective than control via compliance because it results in self-control, self-regulation (self-policing) and self-adaptation, which require less oversight and normalise "correct behaviour". In an enforcement environment that is severely constrained by a lack of capacity, such as that found throughout MPAs in South Africa (Kirkman et al., 2023), this outcome is highly desirable, and it may benefit fisheries to shift towards commitment-based control in their management strategy for MPAs. This study has laid a baseline from which to monitor commercial linefishers´ personal commitment to MPAs and their associated mental models. Although fishers have a negative perception of governance and management in MPA´s, Theme 1: Fishers believe that well-managed Marine Protected Areas are effective and necessary for fisheries sustainability) showed that there is an alignment in the mental models of the fishers and that of governance and management. MPAs are perceived as effective and necessary by both parties, provided that management is conducted in a way that makes sense to the fishers. This is an important leverage point that can be used to improve upon relationships and build an MPA system that is acceptable and desirable to the commercial linefishers in KZN, thereby gaining important allies for effective fisheries management.

4.6.3.2 Toward "Loose-tight" knowledge management using perceptions for MPAs

Bennett (2016) found that perceptions such as those shared in this study can be a powerful tool for adaptive management processes, as they provide insight from the ground regarding implementation and planning, in a faster timeframe than traditional research methods do. Again, this is backed up by Fisher 1´s quote (page 28) citing the lag between research and the fishers´ day-to-day reality. Including expert perceptions as evidence in assessing MPA management and governance may allow for a more efficient flow of information within the MPA SES due to the shorter timeframes needed to collect and use this information compared to even the fastest research or environmental modelling processes (Fazey et al., 2006). Malhotra (2002) indicates in his framework that a "loose-tight" system of knowledge management is required by organisations which work in a complex problem space. These systems are loose in that they allow for underlying assumptions and best practices to be regularly and collectively revisited, enabling the creation of a shared mental model of beliefs, norms, and values that govern the system. On the other

hand, these systems are tight in that they have efficient flows of information, so that everyone has the same information available to form their opinions on a topic. This allows regular and efficient re-evaluation of assumptions and best practices while capturing the diversity of mental models that exist within the organisation (in this case, the SES is viewed as the "organisation"). Including perceptions as a legitimate source of information for MPA management and governance decision-making would therefore constitute a step toward creating a loose-tight system for knowledge management in the MPA SES, as it would add to both the looseness (through increased diversity of knowledge inputs) and the tightness (through increased efficiency of information flow) of the system. A loose-tight system of knowledge management also contributes to double- and triple-loop learning (Argyris, 1991), as it specifically emphasizes a process of unlearning and relearning, wherein space is created to discuss how mental models around management, as well as the solutions that are currently in place, may be a source of problems in their own right (Malhotra, 2002). This type of introspection is called reflexivity in the transdisciplinary research space (McLoughlin, Thoms & Parsons, 2020). Reflexivity allows for a depth of insight that is critical to transdisciplinary-aligned research (Sellberg et al., 2021), which has been highlighted in the South African Marine and Antarctic Research Strategy as being critical to the way forward for South African fisheries research and comes recommended in the latest National Biodiversity Assessment (RSA, 2016; Sink et al., 2019).

4.6.3.3 Planning, governance and co-management

Nkhata & McCool (2012) view the processes of protected area governance and management as two hierarchically linked social sub-systems whose combined function is to regulate and facilitate the public´s access to common resources. They argue that when protected area governance and management become unlinked from one another, societal demands cannot be perceived nor responded to quickly enough, leading to a situation where the way that a protected area is managed is not in alignment with the public´s interests. Existing research related to South African MPAs, such as that conducted by Sowman & Sunde (2018) and Mann-Lang et al. (2021) indicate that, to a large extent, this is occurring here. The results of this study also support this narrative, as many of the issues discussed by fishers in this project have been related to perceived issues with the way that our MPAs are managed, more than their existence or even their direct impacts on fishing behaviour (which are nonetheless severe). The solutions proposed by fishers here include a need for more diverse sources of information (Theme 4), improving the relationship between the MPA authorities (DFFE/EKZNW) and fishers (Theme 3), and improving the monitoring and enforcement of MPAs (Theme 2). Fishers also indicated that they desire better communication from the

department about research, and that they would like to have their expert opinions valued. They would also be open to collaborating for improved enforcement, given the known lack of capacity in DFFE/EKZNW to adequately enforce MPA rules. All of these points raised by fishers support the need for a shift towards loose-tight knowledge management systems in the MPA SES. These points can furthermore be combined into a single message: Fishers would like to be more involved in the management of MPAs that are intended to help protect their livelihoods. Their value as expert knowledge holders is also supported by the fact that their perceptions of what would help to improve the system, align almost perfectly with research such as that done by Sander et al. (2014) on the necessary conditions for effective MPA management.

Collaborative management arrangements such as those suggested here are also known as co-management (Cinner et al., 2012), and various models of this type have been implemented globally. Co-management structures range from partnership arrangements where stakeholders are asked to express their views and opinions on possible new regulations, to arrangements where stakeholders have the right to design, implement and enforce rules related to natural resources, with the government only playing a consultative role (Hauck & Sowman, 2001). This type of reciprocal relationship between expert knowledge holders and governance is something that has been widely researched and has been linked directly to effective rights-based management in fisheries, leading to better financial outcomes for fishers as well as a more positive perception of conservation efforts (Solomon, Jacobson & Liu, 2012). Co-management of our marine environment has been advocated for in South African policies and legislation since 2000, with the release of the White Paper for Sustainable Coastal Development in South Africa (RSA, 2000). However, it is important to understand that such co-management arrangements are not a panacea to solve all MPA and fisheries management problems, and they only tend to work under a specific set of conditions, as described by Pomeroy & Williams (1994) and Armitage et al. (2009).

According to the framework provided by Nkhata & McCool (2012), planning should be viewed as a mid-scale and continuous process occurring throughout the adaptive management lifecycle of a protected area. Figure 4.4 shows their framework, which I have built upon using insights from this research project to make the conceptualisation of governance and management activities more explicit. They define planning as a "collective, iterative, and adaptive process of facilitating opportunities for dialogue" that leads to a shared understanding both within and between the management and governance sub-systems, enabling action to be taken in a constructive and agreed-upon fashion. Governance is not only about managing the relationship of the government with civil society. In the context of protected areas, it is

rather viewed by Nkhata & McCool (2012) ideally as a social process that mediates the relationship between society and a protected area agency and its constituencies. This process should allow society and the managing bodies to articulate interests, exercise rights, overcome differences, and meet their social obligations. Management, on the other hand, is seen as a process of implementation and direct action on the grounds of the public interests that are negotiated during governance actions (Nkhata & Breen, 2010). A more local definition by Kirkman et al. (2023) sees governance as relating to the way that policies, institutions, and processes interact to determine how decisions are made, who is involved in decision-making, and who is responsible for the implementation of management actions, including the production of institutional and legislative frameworks on which management is based. Management is here also defined as relating to the practical implementation, planning, and monitoring that takes place in order to action the decisions made at the governance level. Governance processes, according to both definitions, should include the government, but not be limited to the government only: A variety of stakeholders should be regularly and consistently involved in governance processes. Social belief systems, mental models, values and preferences should be adequately understood and agreed upon before policies, laws, and regulations are formed, to ensure that the decisions made during the implementation phase are responsive to the needs of society. Management, on the other hand, should ensure that protected areas are adequately enforced, that there is sufficient research conducted to understand the impacts of actions taken, and more generally, that society´s vision for the governance of common resources is realised.

Communication has been identified in this study as an important component of management, as fishers indicated that without efficient flows of information in both directions (fishers –> management and management –> fishers), trust is corroded. Trust has been identified as a key contributor to perceptions of legitimacy, which is defined as the perception of political action as right and just by stakeholders (Dehens & Fanning, 2018). Bennett et al. (2019) found that perceptions of legitimacy are correlated to law-abiding behaviour in MPAs and therefore, building trust in management through clear and regular communication with stakeholders, such as fishers who rely on the ocean for a living, is an important part of management. Such communication improvements are desired by the fishers and would contribute to building the ideal loose-tight knowledge management system for MPAs in KZN.

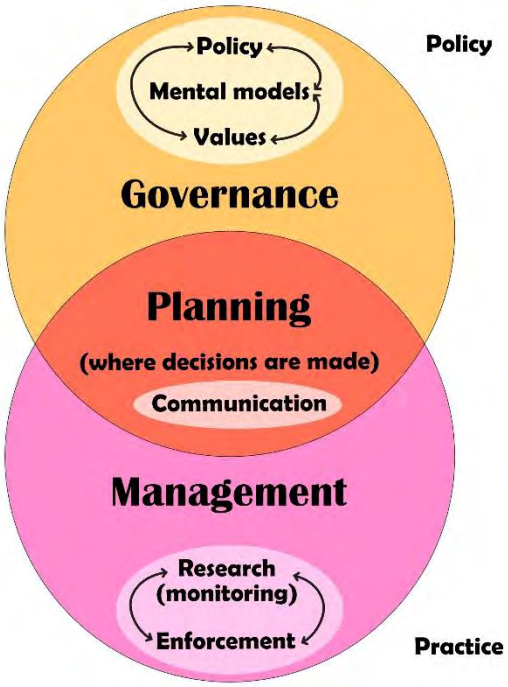

Figure 4.4: A framework for the coupling of management and governance processes through planning, adapted from Nkhata & McCool (2012). Governance is a process of ensuring that societal values and mental models are adequately incorporated into policy and other legal frameworks, while management is a process of implementation of agreed-upon protected area goals, through enforcement, research, and bidirectional communication with stakeholders regarding research outputs and enforcement. Planning processes are where governance and management meet to ensure that the two subsystems are adequately linked and respond to societal demands from protected areas. Adaptations to the framework are in lighter-coloured circles within the larger spheres, which depict the original framework.

4.7 CONCLUSION

Figure 4.4 above shows an adapted version of the framework produced by Nkhata & McCool (2012) for the coupling of management with governance through planning, which I build upon using insights from fishers provided during this study. I propose that an effective management system for the MPAs in KZN could utilise a framework similar to this one, allowing space for experts, such as the commercial linefishers, to be included in various components of management processes, through a co-management agreement, as well as governance processes, through stakeholder engagement. Fishers already contribute significantly to fisheries research through their catch returns. This study has found that they would like to contribute further by engaging more with the enforcement of MPA rules and that they desire stronger

communication channels between themselves and MPA management bodies so that their perceptions may be heard and valued correctly. Fishers already share a perception with the policy and governance sphere that MPAs are important and necessary, and furthermore believe that they should be managed well (Theme 1). Their desire for and willingness to contribute to a loose-tight knowledge management system is well evidenced in this chapter, and it may be argued that with some political will, the management of MPAs could become much more effective from a SES perspective, thereby protecting fishers´ livelihoods and fish stocks more effectively. Fishers have shared expertise and on-the-ground knowledge that may allow for better resilience through an improved capacity to respond to disturbances or changes in the SES within the necessary timeframes for adaptive management to be considered successful (Nkhata & McCool, 2012). Moving from an uncoupled system of governance and management to a properly coupled system is no easy task, but it is clearly a necessity for ensuring the sustainability of the MPA network in KZN. I believe that there is sufficient evidence of commercial linefishing rights holders´ expertise, to say that the commercial linefishing sector should be included in planning and management processes for MPAs in KZN as soon as possible. This will help to ensure that the MPAs attain their stated goal of ensuring the recovery and sustainable use of linefish species in the province, while simultaneously responding to South African policy requiring a move toward co-management and a more transdisciplianry-aligned way of working in research and practice.

A practical example of how this could be achieved on the ground would firstly require commercial fishers in KZN to become organised and to select trusted representatives who could speak on their behalf. Secondly, such commercial fisher representatives would need to become recognised as key stakeholders in the MPA Management Fora that will be set up as part of the Management Plan for each MPA in KZN (Bruce Mann, ORI, pers.comm.). Thirdly, the management agency responsible for the management of each MPA (in this case EKZNW), would need to accept advice provided by commercial fishers and be willing to find practical solutions to solve management problems. This may involve the establishment of partnerships that enable self-policing and quick and decisive responses to tip-offs about illegal fishing. The practical considerations and a potential roadmap toward a system that responds to the results of this research are explored further in the next chapter, which will consider ecological and social evidence to envision a holistic approach to management and governance for the whole SES.

CHAPTER 5

5 A THEORY OF CHANGE FOR HOLISTIC MPA GOVERNANCE AND MANAGEMENT

5.1 REFLECTION

CONSILIENCE
/ kənˈsɪlɪəns/

Agreement between inductions drawn from different sets of data or from different academic disciplines (The Collins Online Dictionary, 2023)

REFLECTION:

Consilience is an interesting term that I came across while trying to understand transdisciplinarity. Edward O. Wilson wrote a book on the subject in 1998, where he discussed the need to find consilience between science and social sciences to understand the systems we live in. I´m divided on this: On one hand, I believe that we must search for truth, and truth will always be what it is, so looking for consilience seems like a good way to find it. If you´re looking for grand truths… But, on the other hand, I don´t think that´s what I´m looking for. If it was, the only meaningful result of this project would be that MPAs work. That´s something ecological and social research agree upon. But there´s much more that has come out of this work. There´s so much that the combination of disciplines can add to our understanding of the dynamics at play in the system. Ecological research can answer some of the big questions the fishermen are asking, like: "How about, we move MPAs around? Wouldn´t that be grand?" - Well, no, sir, that would not be grand because then all your big fish genetics would disappear, and the fish populations would not recover as quickly, and your grandchildren probably wouldn´t be able to fish for a living, even if they wanted to. And the social sciences do the same for ecology: A marine scientist could say: "Well, would you look at that, our MPAs are doing a sterling job!" To which, one might respond: "No, ma'am. They´re OK, but they´re hanging on by a thread. People are fishing in our No-Take Areas every day, and nothing is being done about it!" What a wonderful conversation we can now have! And it´s not about consilience, it´s a collage: It´s about finding different bits of what´s there and sticking it together to see more of the whole system, and then using the collage to find pathways that lead to coexistence.

5.2 PURPOSE AND METHODS OF THIS CHAPTER

This chapter aims to use the integrated results of the previous two chapters (Chapter 3: about the fish, and Chapter 4: about the fishers´ perceptions) to investigate options for improving the sustainability of the Marine Protected Area (MPA) network in KwaZulu-Natal (KZN) from a social-ecological perspective. Bergmann et al. (2012) indicate that one method for integrating knowledge from different disciplines is through the production of a boundary object, described as an interface where actors from different disciplines can meet and communicate without prior effort to translate and describe concepts. They further clarify that a product or a set of guidelines can fulfil the role of a boundary object. Berkes & Franz (2025, p.124) describe the value of categorising information in complex systems to simplify the problem solving process and ease management decision-making processes (their position is described in more detail in section 1.3.4). Given this stance, I have decided to use the production of a boundary object, in the form of a Theory of Change (ToC) for MPAs in KZN, to demonstrate how the knowledge from the social and ecological research in previous chapters can be used together, as a baseline from which to plan management and governance activities that are committed to the sustainability of the entire SES.

Theory of Change is a method for describing a series of interventions that are expected to result in the achievement of a goal, while making explicit any assumptions about how or why these interventions are expected to work (Taplin et al., 2013; Mayne, 2017). Some key terminology relating to this method is described in Table 5.1.

Table 5.1: A description of terminology relating to Theory of Change (Taplin et al., 2013; Mayne, 2017).

Term	Meaning
Outcome pathway	A series of building blocks that are ordered and connected through a causal chain. Outcomes represent a changed condition in the system, and an outcome placed above another relies on the achievement of the below outcome before it can be realised.
Indicators	A measurable and observable phenomenon that can be used to measure the achievement of an outcome.
Interventions	Activities or programmes that are recommended for implementation, to allow an outcome to be achieved.
Rationales	Explanations of why an outcome is deemed important, why it is dependant on other outcomes below it, and how the suggested interventions are expected to work toward the achievement of the outcome.
Assumptions	These are the assumptions that are implicit in the outcome pathway, and are clarified as a way to elaborate why an outcome pathway is expected to work toward the achievement of a goal.
Narrative	The narrative is the written component of a Theory of Change, which describes in detail the Indicators, Interventions, Rationales, and Assumptions that contribute to the ToC.

Figure 5.1 below depicts the process and methods used for this chapter. Importantly, the "integration and interpretation from a process-relational perspective" is a cognitive process (Burger & Kamber, 2003), while the "Social-Ecological Systems (SES) perspective regarding MPA sustainability" refers to knowledge and consists partially of tacit knowledge, gained through my interactions with the fishers (Dampney, Busch & Richards, 2002). Both of these steps, therefore, rely on elements that cannot be properly displayed or easily described. However, if this thesis has been effective, the reader should, at this point, be able to independently integrate the available knowledge and thus have a fuller understanding of the focal SES available to them, despite lacking the tacit and experiential knowledge I benefit from. Nevertheless, I describe the salient points relevant to my grasp of the SES, to underscore my reasoning for choosing the pathway described in the ToC. The SES perspective is then explored in more depth, using the ToC as a boundary object upon which the rest of this discussion is based.

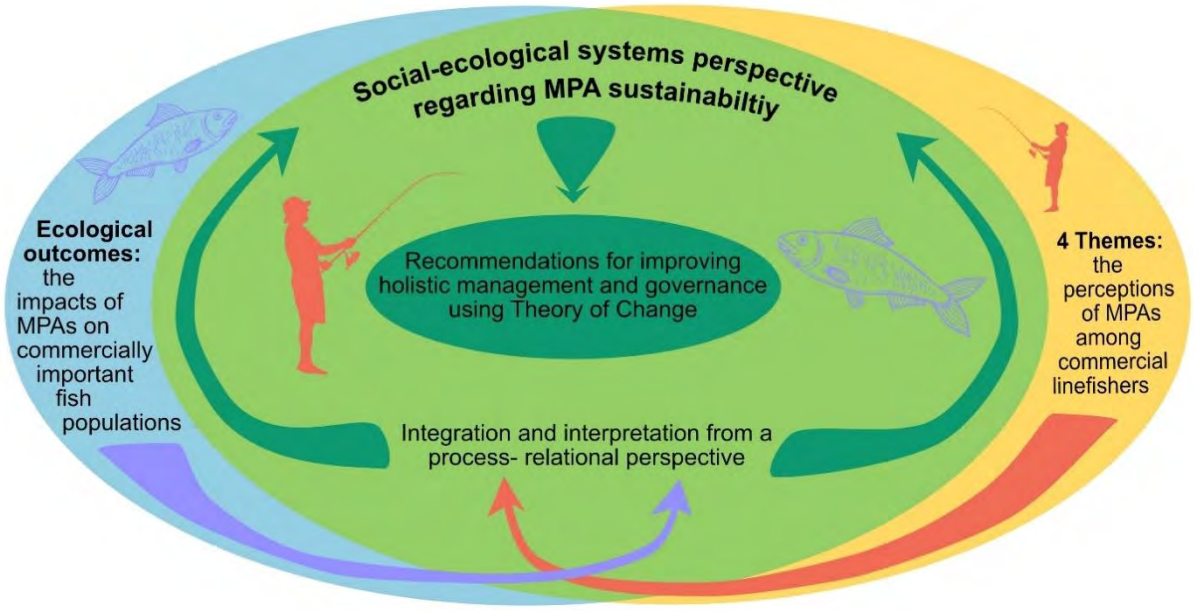

Figure 5.1: A graphical overview of this chapter´s contents in the context of the whole research project. The blue oval indicates ecological research conducted for Chapter 2, while the yellow oval indicates social research conducted for Chapter 3. The green overlapping area indicates the integrated social-ecological perspective which will be explored in this chapter.

5.3 Overview of the problem space

The MPAs in and next to KZN were declared with a list of objectives indicating their intended purpose (RSA (Republic of South Africa), 2004, 2019b). As indicated in the first chapter, a shared purpose among them is "*to facilitate species management and sustainable use of linefish by supporting fisheries recovery and enhanced species abundance in fished areas*" (RSA (Republic of South Africa), 2019b). Although the Pondoland MPA declaration does not share this exact statement of purpose, its purpose aligns (RSA (Republic of South Africa), 2004), and the above purpose statement will be used for all the MPAs relevant to the linefishing sector in KZN from here on out. The primary focus of this thesis is to enable this shared purpose by building knowledge of the SES of MPAs and the commercial linefishing sector in KZN, which can be used to inform a *SES management baseline for MPAs*, with commercial linefishing rights holders as key experts. This chapter focuses on how this knowledge can be used to improve the holistic management and governance of these MPAs from a strategic perspective.

The above purpose statement can be picked apart to minutiae, especially if one considers the debate around the term "sustainable use" and what it means. This research accepts the definition by Wilkinson et al., (2001), which indicates that sustainable use ensures that the trade-off between current economic pressures and the future (and present) needs of the environment is fairly maintained. In the context of fisheries and the purpose of MPAs, this would mean that the balance between fishing for economic purposes and the protection of fish stocks to ensure the commercial viability of future populations of Commercially Important Fish (CIF) must be maintained. This project has laid a SES management baseline for the CLS in KZN by seeking to understand the impacts of MPAs and their governance on CIF populations and on the commercial linefishing sector. To briefly revisit the findings of the disciplinary components of this thesis, the below statements summarise:

1. MPAs, especially No-Take Areas (NTAs), effectively protect populations of CIF, and they do this most effectively when they remain in place for a long time. (Chapter 3, section 3.7.4, Discussion)
2. Because they protect the most important spawning fish in No-Take Areas, MPAs can enhance the viability and sustainability of fisheries in the long term and are a powerful tool to ensure the sustainable use of commercially important fish (Chapter 3, section 3.7.1, Discussion)
3. It becomes necessary to monitor areas outside MPAs more intensively if stereo-BRUVs are intended to continue providing an accurate understanding of the effectiveness of MPAs for protecting and supporting the recovery of CIF populations. (Chapter 3, section 3.7.7, Discussion)
4. Commercial linefishers believe that well-managed MPAs are effective and necessary for fisheries sustainability. (Chapter 4, section 4.5.3, Theme 1)
5. Monitoring and enforcement of fisheries and MPA regulations are poor and must be improved. This relates particularly to the regulation of the recreational boat-based linefishery, which is currently not well controlled and in direct competition with commercial linefishers. (Chapter 4, section 4.5.3, Theme 2)
6. A poor relationship between MPA management, fisheries management, and commercial linefishers, hinders the effectiveness of MPAs. (Chapter 4, section 4.5.3, Theme 3)
7. A lack of diverse sources of information leads to misguided decision-making and long-term unsustainability of MPAs and fishery management. (Chapter 4, section 4.5.3, Theme 4)
8. In a complex environment, and especially where enforcement capacity is low, it becomes critical to build a system that encourages commitment to shared values as a form of behavioural control, and co-management with commercial linefishers can contribute to this goal. (Chapter 4, section 4.6.3, Discussion)

The fact that MPAs are already working to protect CIF populations, despite poor enforcement and monitoring around their enforcement, is impressive, especially considering that poor enforcement is globally recognised as one of the biggest factors hindering MPA effectiveness (Himes, 2003; Gill et al., 2017). However, institutional issues around governance and management impede them from attaining their potential value for fisheries, as the relationship between governance, managing bodies and user groups is poor, leading to a situation where the legitimacy and acceptability of decision-making are questioned. This, alongside a lack of adequate enforcement, means that poaching and related illegal activities are out of control and severely impacting fish stocks. From a process-relational perspective (Mancilla García et al., 2020), two statements can then broadly describe the problems faced by MPAs in KZN:

1. Institutional processes that are currently in place do not adequately support MPAs in ensuring the sustainable use of commercially important linefish in KZN, and
2. The relationships within this SES are not healthy and must be improved if MPAs are to reach their stated goal of ensuring the recovery and sustainable use of CIF stocks.

This means that in order to manage the MPA SES for its intended purpose, the key focus should be on improving the governance and management of the system as a mechanism for improving the relationships that exist there. Improved relationships between system components are seen here as a key leverage point for improving the sustainability of our human interactions with the rest of nature (West et al., 2020; Foggin, Brombal & Razmkhah, 2021).

5.3.1 The linefishery as a complex multi-stakeholder context and social justice considerations

It is important to acknowledge that the commercial linefishing sector is only one of numerous overlapping sectors in the South African linefishery, which is made up of a diversity of stakeholders with different identities and socio-economic, historical and political contexts (see Figure 1.1). In South Africa, the history of Apartheid has impacted the socio-economic situation severely, and its legacy lives on in the linefishing sector, specifically regarding the allocation of fishing rights and the division of resources among constituents (Sunde & Erwin, 2020). Understanding and dealing with the social justice issues in this sector is an important component of ensuring the sustainable management of the linefishery SES as a whole but is not the focus of this work. This thesis focuses only on the sub-system of the SES involving MPAs and the *commercial linefishing sector*, and explores how the management of MPAs and the fishery can become more sustainable from an ecological perspective and from the perspective of the commercial linefishery.

As a researcher, I am not sufficiently versed in the complex political multi-stakeholder and social justice issues at play in the entire linefishing sector to comment on anything other than the specific focus of this work. I agree that the work being done to pursue social justice for the whole linefishery is important and necessary for the sustainability of the entire linefishing SES (Sunde & Erwin, 2020). The ToC that is explored later in this chapter, therefore, does not seek to comment on how the pursuit of social justice should be done, nor how to manage these complex socio-political issues.

5.4 A SHARED VISION FOR AN IDEAL FUTURE FOR MARINE PROTECTED AREAS IN KWAZULU-NATAL

Findings from previous chapters indicate that from the perspective of the fish (Chapter 3) and the commercial line fishers (Chapter 4), there are three issues of concern in the management of MPAs, which can severely impact their effectiveness. These priorities are also widely discussed in the literature on MPAs and protected areas more generally. These are (in no particular order):

1. Commitment to shared values among stakeholders (Malhotra, 2002; Nkhata & McCool, 2012; Bennett & Dearden, 2014b,a; Weigel et al., 2014; Bennett, 2016; Bennett et al., 2019)
2. Monitoring of ecological effectiveness (Fox et al., 2014; Foster, Hosack, et al., 2020; Foster et al., 2021)
3. Sufficient compliance and enforcement on regulations, both inside and outside MPAs (Arias et al., 2015; Gill et al., 2017; Mann-Lang et al., 2021)

Therefore, an ideal future for MPAs in KZN would be one where enforcement and compliance both inside and outside MPAs are effective, monitoring of ecological effectiveness is sufficient for robust analysis comparing areas inside MPAs to those outside, and stakeholders agree with the values according to which governance and management decision-making occurs. Improvements in each of these areas could shift MPA governance and management toward a more holistically sustainable future and help to ensure that they reach their goals.

Before writing this chapter, in the spirit of doing research that aligns with the ethics of transdisciplinarity, I presented my findings to the commercial linefishers in KZN in two workshops, to ensure that research outcomes were accurate to their perceptions and understanding of the situation. Although this was not used as an opportunity for data collection, the discussions in these workshops supported the findings from the previous chapters and verified that the above-mentioned points were of primary concern to the

fishers, thereby confirming that the decision to focus on these aspects of MPA governance and management is correct. Section 4.4.2.2.4 in Chapter 4 describes these workshops in more detail.

5.5 Imagining a better future: a Theory of Change

Theory of Change is widely used in development planning (Taplin et al., 2013), making it suitable for the practical context related to this research. ToC results in a set of guidelines which can be built upon and revised so that further contextual knowledge and specificities are included in future iterations that could be developed, in this case, by MPA managers and decision-makers. Another key benefit of ToC is that it can help to ensure transparency in governance and management and highlight underlying assumptions about how the system of interest works. Finally, it helps with the prioritisation of management activities and clarifies where progress is dependent on certain objectives being completed. This is an important consideration, as capacity issues are ubiquitous in South Africa, and planning for progress may sometimes need a long time horizon. Being aware of possible difficulties long in advance can help to ensure that they can be overcome timeously by starting to create enabling conditions early. Note that in order to maintain adaptability, this project has not identified indicators, as these will depend on what can realistically be measured by the governing and managing bodies. The identification and description of relevant indicators is critical to building a working ToC and should be prioritised if this ToC will be adapted.

The outcome pathway focuses on improving relationships among actors in the SES due to the process-relational worldview that underpins this research (Chapter 2; Mancilla García et al. (2020), with the understanding that institutional processes can result in changing relationships. Relationships become stronger when more trust is present between constituents (de Vos & van Tatenhove, 2011), and although improved trust is an outcome of its own in this pathway, it is also a sign of strengthening relationships, such that the strongest relationships will be those where trust is maximised, exemplified here by a working co-management relationship, and, eventually, a situation where all stakeholders align their actions with MPA values. It makes sense that new or changed institutional processes can encourage changes in the relationships present in a system (de Vos & van Tatenhove, 2011). The ToC below (Figure 5.2) therefore focuses on strengthening the relationship between the Department of Forestry, Fisheries and Environment (DFFE), Ezemvelo KwaZulu-Natal Wildlife (EKZNW), and the commercial linefishing sector (CLS) as one way to ensure that MPAs achieve their common purpose. The outcome pathway illustrates three intermediate outcomes which build a positive working relationship between DFFE, EKZNW, and the CLS, culminating in co-management, which is supported both in South African policy (RSA, 2000) and in

research indicating that, under the right conditions, it can be a powerful tool to manage complex SES such as MPAs (Armitage et al., 2009; Weigel et al., 2014). The fourth intermediate outcome, "commitment to shared values among stakeholders", is much broader and includes *all stakeholders, particularly those involved in the broader linefishing sector, including small-scale and recreational fishers*. It is at the top level because it is the most effective way to ensure that MPA rules are followed (Malhotra, 2002), but, in order to be properly realised, other priorities must also have been realised: managers and the government are also stakeholders in MPAs and unless they commit fully to fulfilling their roles, it cannot be said that all stakeholders have committed themselves to the values according to which MPAs are delineated.

Interventions that can facilitate the achievement of these outcomes are categorised as either improving compliance and enforcement (Red), improving commitment to shared values among stakeholders (Yellow), or improving the monitoring of MPA effectiveness inside and outside MPAs (Blue). Only once these issues have all been sufficiently addressed, can MPAs be considered effective for their intended purpose. This ToC can be considered broad and shallow (Taplin et al., 2013), as it identifies all preconditions to the achievement of the long-term goal that I could identify in the scope of this research, but it leaves out specific information about how each intervention should be achieved. In reality, many of these interventions will require a lot of planning and some, such as setting up co-management agreements, may require years of preparation and research before they can be successfully implemented. This ToC advances the outcomes of this research project by illustrating, broadly, what would be necessary for MPAs in KZN to achieve their stated goal and can act as a framework that EKZNW and DFFE can use to develop their own respective ToCs that are better suited to their individual mandates. Only the two biggest assumptions have been made explicit in this ToC, although it is possible that more exist, and these should be explored in depth if the ToC will be used. Note that this ToC only explores one component of the SES and seeks to inform the sustainable management and governance of this component while recognising that a solution for the entire system requires expertise and an understanding of how to address social justice issues as well as broader ecological justice issues which have not been considered. Regardless, one of the recommendations in the yellow intervention pathway in this ToC create spaces for these conversations around justice to occur and where this is applicable, it is indicated by the inclusion of "*other actors*", which would include actors in both the recreational and subsistence linefishing sectors, as well as the commercial linefishing sector. Other recommendations in this pathway can also facilitate better inclusion of other groups in the decision-making process. Below the key elements of the ToC are discussed in further detail.

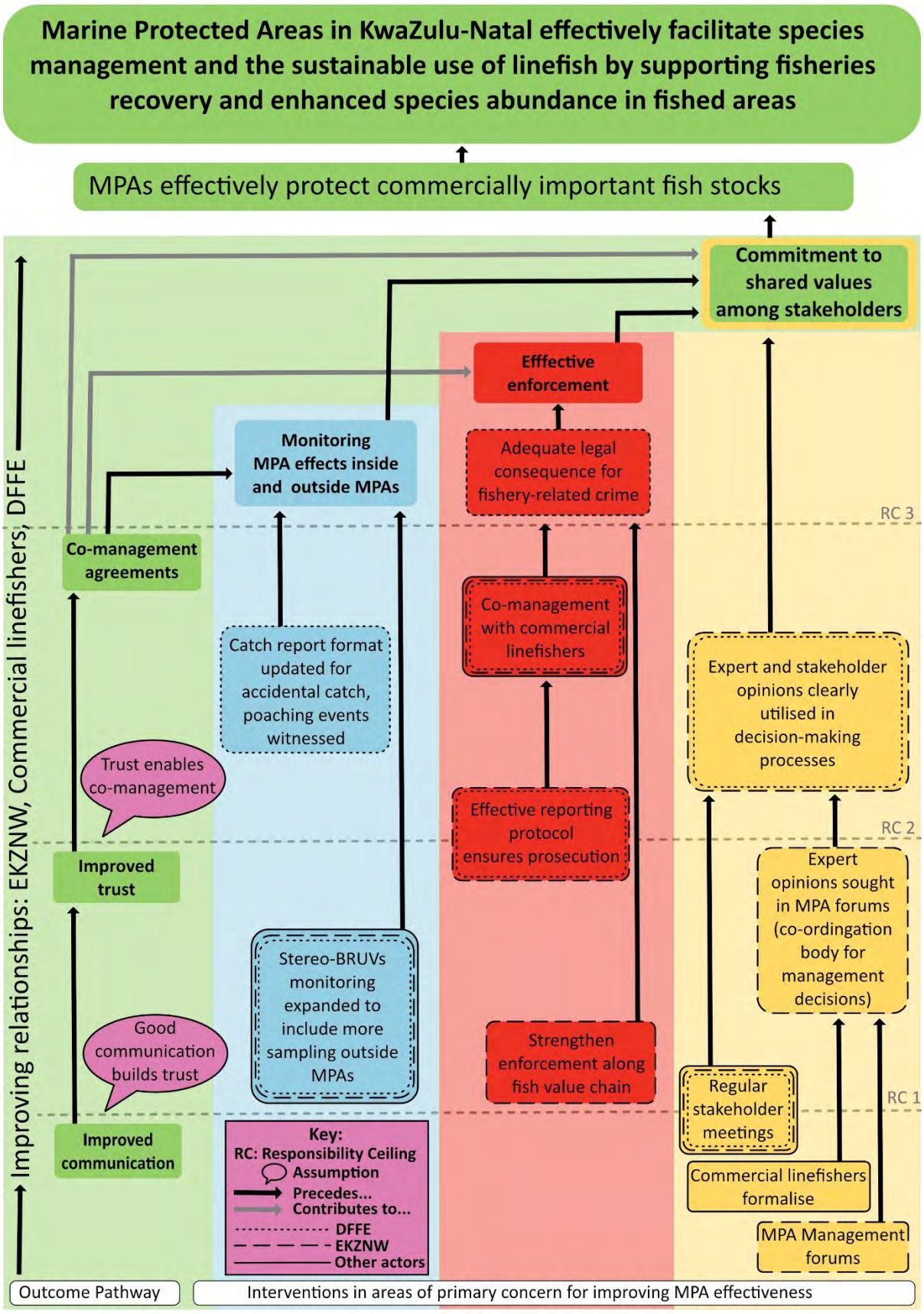
Marine Protected Areas in KwaZulu-Natal effectively facilitate species management and the sustainable use of linefish by supporting fisheries recovery and enhanced species abundance in fished areas
MPAs effectively protect commercially important fish stocks
Improving relationships: EKZNW, Commercial linefishers, DFFE
Commitment to shared values among stakeholders
Efffective enforcement
Monitoring MPA effects inside and outside MPAs
Adequate legal consequence for fishery-related crime
RC 3
Co-management agreements
Co-management with commercial linefishers
Catch report format updated for accidental catch, poaching events witnessed
Expert and stakeholder opinions clearly utilised in decision-making processes
Trust enables co-management
Effective reporting protocol ensures prosecution
RC 2
Improved trust
Expert opinions sought in MPA forums (co-ordingation body for management decisions)
Stereo-BRUVs monitoring expanded to include more sampling outside MPAs
Good communication builds trust
Strengthen enforcement along fish value chain
Regular stakeholder meetings
RC 1
Improved communication
Key:
RC: Responsibility Ceiling
Assumption
Precedes...
Contributes to...
DFFE
EKZNW
Other actors
Commercial linefishers formalise
MPA Management forums
Outcome Pathway
Interventions in areas of primary concern for improving MPA effectiveness

Figure 5.2: Theory of Change diagram for improving the relationships between the Department of Forestry, Fisheries, and Environment, the commercial linefishers, and Ezemvelo KwaZulu-Natal Wildlife. Responsibility ceilings, indicated by grey dotted lines, indicate when an outcome is achieved, and interventions which cross a responsibility ceiling enable the achievement of outcomes above and below the responsibility ceiling. The outcome pathway is within the green coloured band. Interventions are either intended to improve compliance and enforcement (red band), commitment to shared values among stakeholders (yellow band), or the monitoring of MPA effectiveness inside and outside MPAs (blue band). Note that only 2 assumptions are made explicit here, although it is possible that more exist.

5.5.1 Improving communication

The first and most fundamental outcome is improved communication between DFFE, EKZNW, and commercial linefishers (as well as other stakeholders, particularly including recreational ski-boat fishers and subsistence fishers). Good communication builds trust (Q 4:15, Chapter 4; Zeffane et al., 2011). This has been included as an assumption for the outcome pathway (Figure 5.2). The need to create spaces where fishers can engage with and affect the management decisions being made in MPAs, is well recognised (Armitage et al., 2009; de Vos & van Tatenhove, 2011). South African MPAs are intended to have MPA Management Forums set up for each MPA as part of their respective Management Plans (Bruce Mann, ORI, pers. comm.), but these Management Plans have not yet been implemented for most KZN MPAs, as they are still in the process of being developed and ratified. In the case of the Pondoland MPA, the current Management Plan (Mann & Venter 2012) is outdated and in need of revision. Given that these planning spaces are so important for building a shared understanding and commitment to the values of MPAs, attention should be paid to ensuring that this happens as soon as possible (Nkhata & McCool, 2012; Kirkman et al., 2023). These forums should be a place where representatives from all fishing sectors have an opportunity to contribute to MPA management decisions and have an opportunity to discuss their differences and needs in a constructive environment. Once MPA management forums are set up, given that commercial linefishers are eager to engage with issues around management (Theme 3, Q 4:14,Q 4:15), it could be expected that their sector will be encouraged to formalise and participate. Another important intervention which could improve communication and build trust is regular meetings with stakeholders. The MPA management forums are certainly one type of stakeholder meeting, but these are specific in their aim and are focused on discussing management and getting input from specific stakeholders. Additional meetings between stakeholders should also be implemented. These could be dedicated “Task Teams” to resolve pressing issues (such as issues with social justice for example), or they could also be a more informal space for any interested parties to learn more about MPAs, their rules, and how they are supposed to work, as well as share research (e.g. catch returns data, Theme 3) or experiences

related to MPAs. Creating such spaces for dialogue can create cohesion and a mutual understanding of the values and priorities associated with MPAs and can enable governance processes to effectively capture expectations and problems related to MPAs, early on (Weigel et al., 2014). With spaces like these available, fishers and other stakeholders can see that there is a level of commitment on behalf of managers to understand and empathise with their perspectives, which could further build trust among stakeholders (Head, 2012).

Furthermore, improving communication is not only about ensuring that there are spaces available in which different parties can share their perspectives, but includes the need for leadership that is capable of holding space for complicated conversations and ensuring that the outcomes of stakeholder meetings and MPA forums are constructive and make sense to everyone who was involved in the discussion. Black et al. (2011) identified ten key traits and expectations associated with effective leadership in species conservation programmes, which are relevant here. Among these traits is the ability to use and manage creative friction between partners in conservation programmes and government departments. Improving communication (and the achievement of the following outcome, improving trust), would therefore require skilful facilitation of dialogue among stakeholders and those in charge of the governance and management of the system, as well as leadership that is committed to ensuring that the outcomes of these dialogues are adequately incorporated in decision-making processes (Weigel et al., 2014).

5.5.2 IMPROVING TRUST

Communication on its own is not sufficient to build trust, and in addition to improved communication, trust requires an authentic commitment to shared goals (Zeffane, A Tipu & Ryan, 2011). Given that managing bodies (DFFE, EKZNW) are expected to carry out certain duties to ensure that MPAs are effective, and fishers are only expected to want to catch fish, it makes sense that management should be the first group to prove their commitment to these goals, if they want fishers to do the same (Q 4:5-Q 4:10, Theme 2). Management takes various forms and includes spheres such as spatial decision-making, enforcement, compliance, and ecological monitoring. Managing these aspects effectively requires specialists to cooperate and ensure that the decisions being made in each management sphere make sense both to other managers and to those who use MPAs. If managing bodies prove sufficient commitment to fulfilling their roles in MPAs and in the management of the fishery as a whole, this could help to build trust with commercial linefishers, who currently do not believe that the management of MPAs is being conducted fairly or correctly, in accordance with their purpose (Figure 4.3: Pie charts indicating commercial linefishers´ responses to questions which were answered either according to

predefined answers or on a Likert rating scale, with 1 generally being the most negative answer and 5 the most positive answer. ; Q 4:3; Theme 2; de Vos & van Tatenhove, 2011). Even with good communication, trust will not automatically reach a level where it would make sense to engage in a co-management relationship (Pomeroy & Williams, 1994). The second outcome of improved trust, therefore, refers not to reaching a state of absolute trust but rather to a situation where the DFFE, EKZNW, and commercial linefishers feel that they trust one another *enough* to be able to engage and commit properly to a co-management arrangement with the fishers included. This is included as an assumption along the outcome pathway, and realistically, reaching this point would require leadership, particularly from the government authorities mandated to do this work, that is committed to ensuring that these relationships of trust are built and maintained, as well as skilful facilitation of dialogue aimed at building this relationship between various MPA stakeholders and managing bodies (Weigel et al., 2014).

The interventions associated with the objective of improving trust are things that could be done for more effective management of the system as it currently stands, without relying on additional co-management agreements. Expanding the Stereo-BRUVs monitoring programme to monitor areas outside MPAs while maintaining the current sampling effort within MPAs could build confidence in communicating about the impacts of MPAs on fish populations outside the protected areas. This is important, because one of the purposes of MPAs is to increase fished populations *outside* MPAs. The commercial linefishers often spoke about catch returns not being a reliable dataset (Q 4:19; Theme 4), and even if they were reliable, it would not be possible to confidently attribute an increase in catch directly to MPAs, using a sampling method that cannot also be used inside MPAs (Hayes et al., 2019; Foster, Monk, et al., 2020). Proof of the ecological effectiveness of MPAs tends to lead to better support from stakeholders, which is correlated with better rule-abiding behaviour (Mann-Lang et al., 2021).

Another way that MPA management could improve trust is through the improvement of monitoring and enforcement around MPA and fishery regulations. This could include a legal intervention, such as mandating Vessel Monitoring Systems (VMS) for all boats on the water (including recreational fishing vessels), and management interventions such as improving enforcement on fish shops and other retailers, who currently buy fish from illegal sellers (Q 4:24, Theme 4; Theme 2). In line with increasing stakeholder commitment to MPA values, recognising the legitimacy of expert knowledge (from various sectors in the linefishery) in MPA forums and actively seeking out this type of knowledge will further build trust by starting to move the dynamic from one which relies on passive trust (which is habitual and embedded in the social environment), to active trust (which involves actively placing trust in others, and relying on them

to maintain their integrity) (de Vos & van Tatenhove, 2011; Pedersen, 2012). It will also benefit the management of MPAs by increasing the amount of system knowledge that is available to decision-makers (Fazey et al., 2006), and increasing social monitoring among fishers (Alexander et al., 2018). Finally, an intervention that could move the relationship to a place where co-management starts becoming possible would be to improve reporting protocols so that they ensure effective and adequate prosecution in the court for fishery-related crimes. Current reporting protocols are ineffective and this disincentivises fishers who witness illegal behaviour from reporting what they see (Q 4:16, Q 4:14, Theme 3). Even just having effective reporting protocols could be seen as a basic form of co-management and would be a practical way to start sharing enforcement power, which is important where local enforcement capacity is low (Pomeroy & Williams, 1994; Pomeroy & Berkes, 1997; Armitage et al., 2009).

5.5.3 Co-management agreements

Co-management arrangements are any type of arrangement where the management duties are shared with local communities or resource users, and in fact some of the suggestions at the lower levels of this outcome pathway (e.g.: stakeholder engagement and effective reporting protocols) already count as a form of co-management (Pomeroy & Berkes, 1997). However, these are at the lower levels of co-management, where the government (and, in this case, the managing body, EKZNW) still maintains most of the power, responsibility, and authority over management. This third outcome in the outcome pathway aims to shift power more meaningfully to the commercial linefishing community, so that their inputs into management actions bear more weight. Therefore, this outcome refers to an intentional shift toward more powerful active trust relationships, which build upon a base of the easier and more ubiquitous passive trust that is cultivated at lower levels in the ToC outcome pathway (Pedersen, 2012). As already discussed, this shift of power and responsibility toward the local community can be a powerful tool to help MPAs achieve their stated goals (Hutton et al., 2001). Increasing the community´s power to engage in management not only increases enforcement and monitoring capacity in a complex system but could also help to increase the community´s positive perceptions of governance and management processes as they become more involved with them (Armitage et al., 2009; Bennett & Dearden, 2014a; Alexander et al., 2018).

Commercial fishers have clearly articulated a desire to work more closely with MPA management (Q 4:13, Q 4:14, Q 4:16, Q 4:18, Theme 2). The reality is that formal co-management agreements need a lot of planning and groundwork to be done before they can be effectively implemented (Pomeroy & Williams, 1994; Pomeroy & Berkes, 1997; Armitage et al., 2009), and even after institutional arrangements have been set up, they require work to maintain them and ensure their effectiveness in implementation (de Vos & van Tatenhove, 2011). Shifting to co-management agreements where more power is granted to the community, (e.g. through joint action, partnership, community control or inter-area co-ordination) may be desirable or not, depending on the needs of the community, the DFFE, and EKZNW. Planning for this requires careful thought on behalf of all parties, to ensure that expectations are realistic to what is achievable. This research has identified two elements of MPA management in which fishers would like to participate more:

1. They would like their catch returns to be updated so that accidentally caught fish are also reported (in response to the seventy-four situation described in Theme 4 (e.g. Q 4:22, Q 4:23)), which will allow fisheries researchers to monitor the recovery of banned fish populations using catch returns.
2. They would like their contributions to stakeholder meetings (and, in future, MPA forums), to be clearly and demonstrably utilised in decision-making processes (Section 4.5.3, Theme 3, Theme 4).

These are co-management arrangements that are not too complicated to set up and which would make a big difference with regard to fishers´ perceptions of the legitimacy and acceptability of management and governance, as well as strengthening MPAs and fisheries significantly. Depending on whether it is desirable to fishers and managers, further arrangements such as this could potentially be discussed in future, once a solid foundation of trust and good, bi-directional communication has been established. Co-management in the marine environment is supported in South African policy (RSA, 2000), but its effective implementation on the ground will rely on building good leadership and ensuring that adequate governance and management capacity are built to enable these processes. Cundill & Fabricius (2010) found that in South Africa, a major challenge in this regard is creating conditions that facilitate self-organisation and cross-scale linkages. This is also an outcome of this research and one which the outcome pathway attempts to address. Other challenges identified by Cundill & Fabricius (2020) include access to long-term funding for enabling adaptive decision-making processes, community access to reliable

information regarding natural resources (also addressed in this outcome pathway), support for communities from outside agencies, and access to information regarding how decision-making bodies can be legally recognised. These are major issues and an intention to commit to co-management will require commitment to breaking down these barriers to its effective implementation.

5.5.4 COMMITMENT TO SHARED VALUES AMONG STAKEHOLDERS

This outcome relates to ensuring that the context within which MPAs operate (both social and ecological) allows them to be as effective as they have the potential to be. As described earlier, commitment to shared values among stakeholders is regarded as the most powerful outcome for ensuring that MPAs are effective. This is supported by much of the research cited throughout this thesis (Bennett et al., 2019; Bennett & Dearden, 2014a; Malhotra, 2002; Weigel et al., 2014, etc). In theory, it seems like an easy goal to achieve through increasing stakeholder engagement and ensuring that civil society has some understanding, and some say in MPAs and how they work and are managed. However, it is not only civil society that must commit to these values. Commitment must come from all parties involved (Zeffane, A Tipu & Ryan, 2011), including other actors with an impact on the whole linefishery, such as subsistence and recreational fishers, the South African Government, and the legal and institutional environment within which MPAs operate (Kirkman et al., 2023). There is only so much that can be done by civil society and subcontracted managing bodies such as EKZNW to support MPAs. Fisheries-related crime, including poaching, corruption, and the illegal sale of fish, must be adequately punished to deter criminals (Theme 2), and realistically, much work is still required to clarify and delineate what constitutes fishery-related crime and what constitutes subsistence or recreational fishing (Sunde & Erwin, 2020). Until these definitions are agreed upon and all parties are fully committed to ensuring that MPAs work to fulfil their intended purpose, they will not be completely effective.

Kirkman et al. (2023) published a detailed review of the governance and management context within which South African MPAs are currently operating and made eight key recommendations which will allow MPAs to reach their potential. These recommendations are:

1. Specify detailed objectives for each MPA
2. Fast-track management plans for new MPAs
3. Improve law enforcement and compliance* (see section 4.5.3, Theme 2, pg 123 -- 127)
4. Enhance participation of adjacent communities and other stakeholders* (see section 4.5.3, Theme 3, pg 127-129)

5. Address MPA-related injustices and improve benefit-sharing* (see section 4.5.3, Themes 2 & 3, pg 123 - 129)
6. Ensure financial sustainability
7. Strengthen evaluations of management effectiveness* (see section 4.5.3, Themes 3 & 4, pg 127 -132, and section 4.6.2, pg 134 - 135)
8. Improve cooperation between government authorities responsible for MPAs and fisheries.

Four of these recommendations (indicated by stars above) were outcomes that were also supported by the findings from this research project. That is not to say that the other outcomes from the Kirkman et al. (2023) review are less important. This research project has a clearly defined scope, focusing specifically on the relationship of the commercial linefishing sector with MPAs in KZN, while the Kirkman et al. (2023) publication had a broader scope (the whole of South Africa) and also focussed much more specifically on the management and governance of all the MPAs in this country. This research has made it clear that issues related to the management and governance of the entire linefishery are causing MPAs to be less effective than they have the potential to be. Therefore, this research supports all of the recommendations made by Kirkman et al. (2023) and would like to emphasise that these issues must all be addressed if MPAs are to reach their potential and properly support the sustainable use of linefish, as per their intended purpose.

5.6 Conclusion

This chapter has explored a broad and shallow, outcome-based pathway that can facilitate co-management and how this may work towards more effective governance of MPAs in South Africa. Many of the suggestions in this chapter echo and build upon recommendations made by Kirkman et al. (2023). These authors explore some further institutional arrangements which will assist with ensuring MPA effectiveness and should be considered alongside this thesis chapter for deeper insight into national priorities regarding MPA governance. Research by Weigel et al. (2014) also provides a good background on the necessary conditions for the effective management and governance of MPAs that are intended to support the sustainable use of marine resources. It would make sense to consider their research alongside that of Kirkman et al (2023) in forming a ToC for the governance and management of the linefishing SES, if this work is to be built upon and used in a practical setting.

By exploring a pathway toward co-management of the commercial linefishing sector and making explicit which groups are responsible for different activities (Figure 5.2), I hope that this chapter has contributed

to a better understanding of the SES surrounding MPAs in KZN and how its governance may improve to ensure that they attain their stated goal of ensuring the sustainable use of commercially important linefish species in the long term.

The ToC built in this chapter relied equally on findings from ecological and social science research methods (Chapter 2, section 2.3; Figure 2.1). From the ecological component, indicators related to mature fish abundance, mature fish biomass, and the proportion of immature fish made explicit the contribution of MPAs to the sustainable use of commercial linefish species through protecting breeding stocks. From a social perspective, the interviews clarified expert linefishers´ perceptions regarding the effectiveness of MPAs, the legitimacy of their knowledge, governance and management, and their social impacts. Through the integration of findings from two knowledge systems in the pursuit of solutions for difficult problems, the outcome pathway can address problems that influence both the ecological and social components of the system, thereby working toward meaningful and feasible solutions for the sustainability of the social-ecological system as a whole. The MOSE framework developed by Picone et al. (2020) is valuable for the assessment of management performance and the social-ecological benefits of MPAs, but does rely heavily on indicators related to the social sphere, with only two indicators related to the ecological performance of MPAs. I could only find one other study which had independently and separately assessed both ecological and social metrics and then integrated these findings to understand a MPA SES as a whole (López-Angarita et al., 2014). Interestingly, this study came to a similar conclusion regarding the urgent need for co-management approaches to strengthen the adaptive capacity of the system.

The contribution to research made by this project therefore includes a methodical and methodological approach that uses ecological monitoring (stereo-BRUVs) data that is widely used and results in metrics that allow deep insight into the effects of MPAs on fish populations, as well as a simple interview set that explores some of the most salient issues affecting the human dimension of MPAs, to understand more about the SES. In South Africa and other countries where stereo-BRUVs are already being used to monitor MPAs from an ecological perspective (Bernard, 2012; De Vos et al., 2014; Heyns-Veale et al., 2019), these methods could be employed for various sectors to understand more about the strengths and weaknesses of our MPAs both from an ecological standpoint and in the perceptions of those who rely on MPAs and an effective fishery management system for their livelihoods. Replicating these methods country-wide and for all MPAs would provide valuable information on the differences in the perceptions of different user groups and in different parts of the country regarding MPAs. This research has shown how the integration of such perceptions research with findings from available ecological data can inform a more

complete understanding of the system and help to identify the most salient issues for improving the management and governance of MPAs, to build a SES that is both ecologically and socially sustainable in the long term.

CHAPTER 6

6 CONCLUSION AND RECOMMENDATIONS FOR FURTHER RESEARCH, POLICY AND PRACTICE

6.1 CONCLUSION

This thesis has used interdisciplinary methods, combining ecological research (Chapter 3) with social research (Chapter 4) to enable an understanding of important dynamics between the Commercial Linefishing Sector (CLS) and Marine Protected Areas (MPAs) in KwaZulu-Natal (KZN), South Africa. The knowledge gained can be useful in building a whole SES baseline, including both ecological and social metrics for MPA monitoring, which is needed in South African MPAs (Mann-Lang et al., 2021). The final empirical chapter (Chapter 5) demonstrated how this knowledge could be used in practice by exploring a potential pathway toward more sustainable governance and management of the system. Theory of Change was used to describe this pathway, focussing on establishing conditions conducive to co-management, in alignment with recommendations in the White Paper for Sustainable Coastal Development in South Africa (RSA, 2000). This research shows that co-management could enable MPAs to reach one of their stated goals: To effectively facilitate species management and sustainable use of linefish by supporting fisheries recovery and enhanced species abundance in fished areas. However, co-management will only work in a broader fisheries context that effectively manages the human dimension through effective communication, fair enforcement, and a governance and management context that enables effective collaboration between constituents in the linefishing sector (including linefishers in all sectors, managers, decision-makers, government departments, and the legal environment). Given that the results of this thesis were discussed in detail in the previous chapter, the below table (Table 6.1) briefly describes findings related to each of the objectives and research questions for this project.

This research constitutes a first attempt to describe, from a social-ecological systems (SES) perspective, the dynamics between the Commercial Linefishing Sector and MPAs in KZN. In alignment with national imperatives (RSA, 2016), this project encourages MPA scientists to move towards more transdisciplinary,

collaborative, and solution-oriented research by enabling transdisciplinary engagement with the SES surrounding MPAs in KZN.

Table 6.1: An overview of findings in this thesis, showing how each component addressed an objective of this thesis and its related research questions.

	Objective	Research Questions	Findings
Component 1: Ecological research	Determine how MPAs affect the populations of Commercially Important Fish (CIF) in KZN, in terms of biomass, abundance, and proportion of immature fish.	Are the populations of mature CIF different within MPAs, compared to fished areas outside?	MPAs contain more and bigger CIF than fished areas outside, and No-Take Areas are the most effective for protecting important breeding stocks. No-Take Areas in MPAs have a higher proportion of mature fish than Controlled Areas and Fished Areas outside, indicating that they effectively protect fish from fishing pressure, thereby allowing big fish to breed and replenish fished stocks outside.
		Are the populations of mature CIF different in different MPA management zones?	
		How do MPAs affect the population structure of CIF?	
Component 2: Social research	Understand perceptions of Commercial Linefishing rights holders in KZN regarding the MPA network and its current governance, as well as how this may be improved in future.	How do commercial linefishing rights holders perceive MPAs?	Four themes from this research indicate that commercial linefishers value and support MPAs for their potential, but issues related to their governance and management, especially related to enforcement and communication, decrease their legitimacy and acceptability for the commercial linefishing community. Improvements in these areas will render MPAs more effective.
		How do commercial linefishing rights holders believe MPAs could be improved?	
Component 3: Integration of ecological and social results, recommendations for improved governance and management of MPAs	Integrate results from the previous components to investigate options for improving the sustainability of the MPA network in KZN from a social-ecological perspective	What key insights from this work can inform a SES mananagement approach aiming to ensure that MPAs reach their potential for enabling the sustainable use of linefish?	MPAs are a powerful tool for ensuring the sustainable use of CIF, but they are not as effective as they could be due to issues with the governance and management of MPAs and the wider fisheries context within which they operate. Changes in fisheries and MPA enforcement, ecological monitoring, and stakeholders´ commitment to the values according to which MPAs are declared, can help to improve their effectiveness. MPA governance and management could be improved by moving toward co-management with commercial linefishers as an ultimate goal.
		How can the knowledge gained from these chapters be used to improve governance and management processes in MPAs?	

6.2 RECOMMENDATIONS FOR FURTHER RESEARCH

During the workshops with commercial linefishers and my engagement with this research, I realised that there are some gaps in the research which should be filled as soon as possible. I would like to describe these from personal experience, with the hope that in future, those committed to MPAs and the sustainability of our fisheries may take them on and consider using transdisciplinary-aligned approaches to do so.

1. Effective science communication
    - Fishers in the workshops shared that they would appreciate more opportunities to interact with scientists who are doing the research in MPAs. These areas are critical to their livelihoods, and they would appreciate direct engagement regarding the research being done. Research on what constitutes effective scientific engagement would be useful for this, but more importantly, I believe that a commitment from fisheries scientists to share their work with non-scientists and encourage critical engagement with their work would strengthen research immensely. I learned so much about this system just from being in conversation with people on the ground. Research on the value of transdisciplinary research has confirmed this, time and again (Breckwoldt, Lopes & Selim, 2021; Syddall, Thrush & Fisher, 2021)
2. Values related to MPAs and fish
    - When I was in workshops with fishers, they shared a perspective with me that we need to understand more about how people relate to fish. Society´s relationship with fish, according to them, has shifted. People now generally see fish as a source of food and a way to make money. They don´t necessarily consider the sustainability of their actions, and we need to understand more about why this is happening and how we can change that relationship so that people once again respect and value the lives of the fish they eat and sell.
    - The recreational boat-based linefishing sector, in particular, needs more research about the values of participants in the sector, including why they choose to fish offshore and their values around fishing as an activity. This research has made it clear that the sector needs to be more controlled and it would be easier to do this in

a fair way if we understand their reasons for fishing and how they make decisions around compliance with laws both inside and outside MPAs.

- It would also help to understand more about how people perceive MPAs more generally. Commercial linefishers are only one small group who have an important impact on fish stocks, but they are hugely outnumbered by recreational and small-scale fishers (Potts et al., 2020). If we really want MPAs to work, we have to understand how all of these people think about MPAs, and, if their perceptions are negative, we need to understand how we can work toward solving this. Commercial linefishers support MPAs, but what about all the others?

3. Context-specific institutional research
    - Research by Kirkman et al. (2023) and Potts et al. (2020) lay a strong base for further research into how we can create an institutional environment that supports a sustainable linefishery in South Africa. I believe that more in-depth research looking at the exact barriers to implementing some of these recommendations would help to ensure that governance decision-making and strategy can effectively address these challenges.
4. Social research related to MPAs and fisheries more generally
    - This thesis is one of few projects in South Africa that have attempted to understand the social side of our conservation decisions. Literature (e.g.: Bennett & Dearden, 2014; Charles & Wilson, 2009; Weigel et al., 2014) indicates that this is something we desperately need to understand if we want to build systems that work to support our fisheries. We have to understand the whole system and the dynamics at play in it. I do not believe that we will ever fully understand ecology, and research within this discipline should continue. But we must also understand and start describing how the social component of the system impacts the rest of it. Just understanding the non-human component is not going to give us enough knowledge to build a sustainable future.
5. Social-Ecological research on the impacts of different types of Controlled Areas within MPAs.
    - It would help MPA decision-making if there was a better understanding of the actual value of Controlled Areas for fish populations.

- Focussed social research to understand whether these areas have value for fishing groups might also be valuable for MPA decision-makers.

6.3 Recommendations for policy and policy implementation

Although the policy environment is favourable to co-management and transdisciplinary research, these policies are not being implemented broadly yet. This research has shown that it would benefit MPAs and fisheries more generally if South African policy on co-management and transdisciplinary research was implemented more effectively.

6. Raise awareness about policy regarding co-management and transdisciplinary research
    - Those in charge of managing protected areas and conducting research on their effectiveness should be aware of the policy environment in which they operate so that they can align their decisions with the long-term attainment of these goals.
7. Mandate Vessel Monitoring Systems (VMS) for all boat-based fishers
    - This will create a fair enforcement environment and will make it easier to manage a recreational boat-based linefishing sector that is currently not effectively managed and has a strong negative impact on fish populations because of it.
8. Ensure that fishery-related crime is effectively punished in the courts
    - This will require a better understanding and delineation of the different sectors in the linefishery and a clear definition of what type of activity is a crime and what activities are acceptable.

6.4 Recommendations for practice

The previous chapter (Chapter 5) has explored, in-depth, a set of practical recommendations which could help to ensure that MPAs become more effective. This list briefly summarises.

9. Ensure that the fisheries environment is managed fairly and that enforcement on fisheries law is effective throughout the fish value chain.
    - Attention must be paid particularly to managing the boat-based recreational sector better, as it is not currently managed well, and therefore potentially poses a threat to the sustainability of commercial (and subsistence) fisheries.
10. Improve communication among all linefishing sector stakeholders, including fishers of all sectors, managing bodies, and the relevant government departments.

11. Create an environment where trust among constituents in the linefishing sector is adequate, by ensuring that managers and the legal environment are conducting their expected duties to an acceptable standard for resource users who rely on these signals to perceive the governance and management of the fishery as legitimate.
    - This requires expertise in leadership and collaboration, with stakeholder engagement that effectively takes the needs of resource users into account and visibly utilises their contributions in the decision-making process. Reporting back to stakeholders on how their knowledge was used will help with this.
    - Ensure that ecological monitoring programmes are robust and provide the correct data for conclusive evidence to be drawn from research on the effectiveness of MPAs.
    - Build active trust by creating effective reporting protocols for linefishers to report poaching and engage with management in a way that is meaningful to them.
12. Move toward co-management with commercial linefishers in MPAs and fisheries
    - Building an environment that allows for effective co-management requires an intentional shift in the management strategy for MPAs. Including experts such as commercial linefishers can be a powerful way to ensure the effective management of the fishery, given the severe constraints on resources in South Africa.
13. Address weak points in MPA and fisheries governance as per recommendations by Kirkman et al. (2023), keeping in mind the findings of Weigel et al. (2014) regarding the governance of MPAs that are intended to support the sustainable use of fish as a resource.

CHAPTER 7

7 ABOUT THE RESEARCHER: PERSONAL REFLECTION

I´m a Master´s student at the moment, more than anything. But beyond that, the person who started this project was different to the one who´s finishing it. Not because someone else picked up the work halfway through and finished it for me nicely, but because I´ve grown and changed a lot. One of my best friends told me the other day that it´s weird for me to be so organised, for example. Well, it´s not weird anymore. I´ve settled into it, he just wasn´t around to see me grow. But I´m getting ahead of myself.

I´m a Namibian at heart, but South African by birth. My family moved to Namibia when I was seven and it changed my life, of course. It was my first time experiencing different cultures. Suddenly, I couldn´t understand a word of the language that Hilde, our domestic worker / nanny / second mom, spoke to her children. All the things I thought I knew were suddenly different. And it took me ages to understand what happened. It was pretty unsettling. But that move made sure that I got to experience the childhood my parents wanted for me. A childhood with loads of time in *really* wild places. A childhood where I could go to school barefoot and experience the warm summer rains (much better than the cold winter here). A childhood that had me so privileged that I spent one notable family holiday with my nose in a Harry Potter book because I was actually *bored* of seeing these incredibly raw, beautiful, wild places, full of elephants, giraffes, sometimes lions and even one leopard… When I think back on it now, I almost wish books hadn´t been invented, and I´m incredibly grateful not to have had a phone! Although it probably wouldn´t have made a difference: there´s no signal there anyway. So, I got to experience wilderness as a child, from an incredibly privileged perspective. A safe perspective. A perspective that didn´t need me to walk through lions´ homelands to fetch water. And that particular combination of safety and wildness eventually became something I crave. My privilege allowed me to experience Europe as well. A place that I always thought must be perfect, with its social support system and all the wealth doing the rounds there (Thanks, Africa!). But every time I´ve been there, I´ve come back home so grateful for the life I was given. That place is nice, but it´s missing something so central to the human experience. People there don´t know wildness the way I do. They haven´t looked into a wild elephant´s eye or seen what it´s like for people and animals who are truly hungry because of a drought. And I think these things give us a depth of appreciation; an unshakeable knowledge of how connected and intertwined we all are. How much our own fate is the fate of the elephant, the African penguin, or the red steenbras. Maybe not individually,

but certainly as a collective. If I´m being honest, all I really want is for all the Earth´s people to understand this and feel this as deeply as I do. I think if we all did, we would live differently. We would also love differently. More widely, and less sparingly. Between species and cultures.

This is the thing that made me first study journalism at UCT, which I dropped out of because I realised I wasn´t going to understand the stories I wanted to tell from there. My BSc in Conservation Ecology at Stellenbosch University remedied that by teaching me what we know about how nature works, and how people traditionally manage places we want to keep wild. It was fulfilling, and I still believe it´s the only thing that could have kept me in university for all these years (our institutions are rotting slowly, but that reflection is for another day). At Stellies, I realised that there´s a new wave of conservation coming. One that includes people as a part of nature in its worldview. It felt right to become part of that change because I have always felt that I belong in nature, and nature belongs in me. I´ve also always loved the sea, and never had a chance to learn deeply about it. So, this Masters´ opportunity that dropped into my lap was great, because it allowed me to explore the sea. And on top of that, my supervisor was kind enough to allow me to expand and stretch the thing to include humans in the ecology I studied. Ant introduced me to Jess and Bruce, and with a team of people who really believe in building a better future for all of nature (humans included), I suddenly had within my grasp the potential to learn so much, about so many things I had never experienced. I learned about marine science and social science with this thesis. I learned about how fisheries science works, which always seemed like some kind of voodoo.

I also learned how our institutions maintain the status quo, which really shouldn´t be maintained. For example, there´s not really space in academia for engaged research that includes practitioners and local experts from beginning to end, according to the ethics of Transdisciplinarity. There isn´t space, really, to go back after your interviews and host workshops just to give feedback on what you found, to the people who helped you find it. If you want to do this stuff, you do it on your own time, and you have to find funding for that, from someone who believes in it and has access to spendable money. Also, making research useful is not the point of academia. It´s just there. For some lucky people to learn about stuff they find interesting. But there´s no imperative to make sure it gets used. Publications are certainly not useful for most of humanity, with their paywalls and jargon. And I´m not alone in saying this. So I was lucky to be connected with people who cared about this stuff. Without funding allocated to me from Mandy Lombard´s SARCHI grant, a social-ecological systems perspective on what´s happening with MPAs in KZN would have been impossible to build in my mind, and this project would have looked very different.

I wanted this work to result in something that was useful in a broader way than research normally is, and that definitely affected what I did and how I approached it. It´s the main reason why I chose Theory of Change as my integration method. It´s something that could actually be useful to managers and decision-makers. More useful than a publication in a journal they don´t know about, especially if I email my ToC to them (which I just might do). I´m also firmly convinced that this is part of the reason why I had such wonderful engagements with the fishers. On one hand, I´m a smallish girl with a big smile, who didn´t really know much about fishing and fisheries, and being upfront about that gave fishers an opportunity to educate me on the subject and have their perspectives heard without pushback. I wanted to hear everything they had to say about it, to create space for all their thoughts to be expressed and considered in earnest, and to learn from the experts. On the other hand, I am also someone who doesn´t shy away from criticism of my work or my field and the institutions I participate in. I often criticise them myself: I believe that we can only improve things if we understand the problems we´re dealing with, and I know that it´s not just those of us who are educated in academia who can spot those problems. In fact, it is often an outsider who will see what´s wrong with something, more than the one who has gotten used to the way it works and accepted the dogma it requires to participate... All cults seem great to those involved in them. So, when fishers said they don´t trust fisheries science, I could understand. After all, I also thought it seemed like voodoo, not too long ago. And the truth is, they have valid reasons for their mistrust. We can´t sample every location at the same hour, or even in the same season or the same year. So, no matter who you ask, what we have available is not the best data. It´s the best we can get right now, but it´s not objectively the best. I can trust it more than fishers can, because I know a bit more about how statistics and modelling take these things into account. But fishers know the sea better than I do. They always will. I might understand something of the science of it, but they understand the life of it. They have a personal relationship with it. I´m not scared to admit that I also have my doubts about science. This meant, quite simply, that I was open to engaging in a conversation that possibly many scientists would shy away from. We generally don´t want the legitimacy of our work questioned, which is, I think, one of the reasons we struggle so much to engage with those who want to question it. It´s kind of funny, actually, because science is supposed to be all about questions and finding those truths that can withstand any amount of questioning. And if we can´t explain something in a satisfactory way to someone who doesn´t understand it, can we really say that *we* understand it?

All these things I´ve mentioned affect my research and the questions I choose to ask, deeply. Who I am makes my research look the way that it does. I have a natural suspicion for hierarchies and dogma, and this means that I try to question them and tend to side with those who question things before I shift to a

defensive position. I wasn´t even sure that MPAs work before this project, and I wasn´t committed to proving that they do. And maybe that´s why, upon bringing all my new knowledge together, I feel comfortable saying that yes, it seems like they can work. But no, they aren´t working. Not as well as we need them to. I now feel comfortable saying that I don´t think it´s the idea that´s flawed. It´s the institutions that are supposed to be supporting that idea and upholding its values, that are deeply flawed and need to be fixed. And fixing them doesn´t need to be incredibly difficult. It can start small and grow.

Learning about this story and writing it down has been exactly the type of work I dreamed of doing when I went to UCT. This story won´t end here. This thesis is not a sign that this work is done. It´s only starting. I hope that this project has built a foundation that will empower the fishers to demand what they are owed, when it comes to justice in MPAs. For the price of 50% of their profits, they are owed MPAs that are effectively enforced and managed. They are owed MPAs that will ensure that their grandchildren can make a living with *their* generational knowledge, *their* boats, *their* fishing marks, and *their* community, intact. An investment into the future has been forced upon them. The least that can be done, is to ensure that it delivers on its promise. That´s really all they´re asking for.

In closing, I´m not sure if this reflection is properly reflexive or ticks all the boxes, but I think it gives you an idea of the person who wrote this thesis. Of course, I´m more than all that I´ve written, and, in some ways, I´m sure I´m less than what I´ve written. The ego is a funny thing, and I´m not sure that my perception of self is accurate yet. I´m still young. I hope I´ll always be young. Youngsters learn quickly and see the world with fresh eyes, and contrary to popular belief, I think that makes them wise somehow. I recently learned about a project called “The Seeds of a Good Anthropocene”. Going forward, all I can say for sure is that I want my life to be a seed of the good Anthropocene. Eventually, when this seed grows up, maybe it will be a tree wise enough to plant many more seeds and change everything. Or maybe it will just stay a seed, and all I´ll do is fertilise the soil for others to grow. The direction this life takes is very undecided, and there´s always a lingering possibility that I go off to become a potter in some small town. It seems fun, after all, and it adds to the beauty in this world. Possibly in a more nihilistic way, but still... At the moment, though, I´m planning and working hard at finding the path that lets me become a huge, seedy tree. With branches in every direction. Transdisciplinary practice, here I come!

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9 APPENDIX

A.1: APPENDIX 1

Table A 1.1: Parametric coefficients for management analyses, which compared the impact of spatial management regulations on a variable, with three categories describing the spatial management, namely: No-Take MPA, Controlled MPA, and Fished Area. For these analyses, all data were grouped according to the spatial management strategy and there was no segregation of data coming from different locations. Significant p values are made bold.

Parametric terms for management analyses	**P values**		
	m1	**m2**	**m3**
Intercept	**< 0.001**	**< 0.001**	**0.008**
Management – Controlled Area	**0.002**	0.082	**< 0.001**
Management – Fished Area	**0.006**	**< 0.001**	**< 0.001**
Habitat – Reef low	0.598	0.972	0.180
Habitat - Sand	**< 0.001**	**< 0.001**	0.133
Habitat – Sand Inundated reef	**< 0.001**	**0.004**	0.329

Table A 1.2: Parametric coefficients for MPA analyses, for which sampling sites were grouped by MPA such that all samples from an MPA (including NTA and CA) were included, and the zonation within each MPA was therefore not considered. Significant p values are made bold.

Parametric terms for MPA analyses	**P values**		
	m4	**m5**	**m6**
Intercept	**< 0.001**	**< 0.001**	**0.024**
MPA – Pondoland	0.244	0.173	**<0.001**
MPA – uThukela	**0.015**	0.393	0.249
MPA – Fished Area	0.203	0.159	0.095
Habitat – Reef low	0.735	0.972	0.051
Habitat - Sand	**< 0.001**	**< 0.001**	**0.035**
Habitat – Sand Inundated reef	**< 0.001**	**0.007**	0.251

Table A 1.3: Parametric coefficients for Zone analyses, which compare each type of zonation within each MPA and the adjacent fished areas. This led to seven categories, namely: Pondoland No-Take Area, Fished Area (South), Fished Area (Central), uThukela MPA No-Take Area, uThukela MPA Controlled Area, iSimangaliso MPA No-Take Area, and iSimangaliso Controlled Area. These analyses combine the two previous groups of categories for a detailed overview of the mature CIF population at each sampling location, considering the effects of zonation within MPAs and adjacent areas outside MPAs. Significant p values are made bold.

Parametric terms for MPA analyses	**P values**		
	m7	**m8**	**m9**
Intercept	**< 0.001**	**< 0.001**	**< 0.001**
Zone – Exploited South	**< 0.001**	**0.001**	**< 0.001**
Zone – Exploited Central	**0.041**	**0.032**	**< 0.001**
Zone – uThukela No-Take Area	0.098	0.493	**0.010**
Zone – uThukela Controlled Area	**0.002**	0.284	**< 0.001**
Zone – iSimangaliso No-Take Area	0.332	0.230	0.492
Zone – iSimangaliso Controlled Area	**0.013**	0.315	**< 0.001**
Habitat – Reef low	0.475	0.715	**0.045**
Habitat – Sand	**< 0.001**	**< 0.001**	0.065
Habitat – Sand Inundated Reef	**< 0.001**	**0.004**	0.312

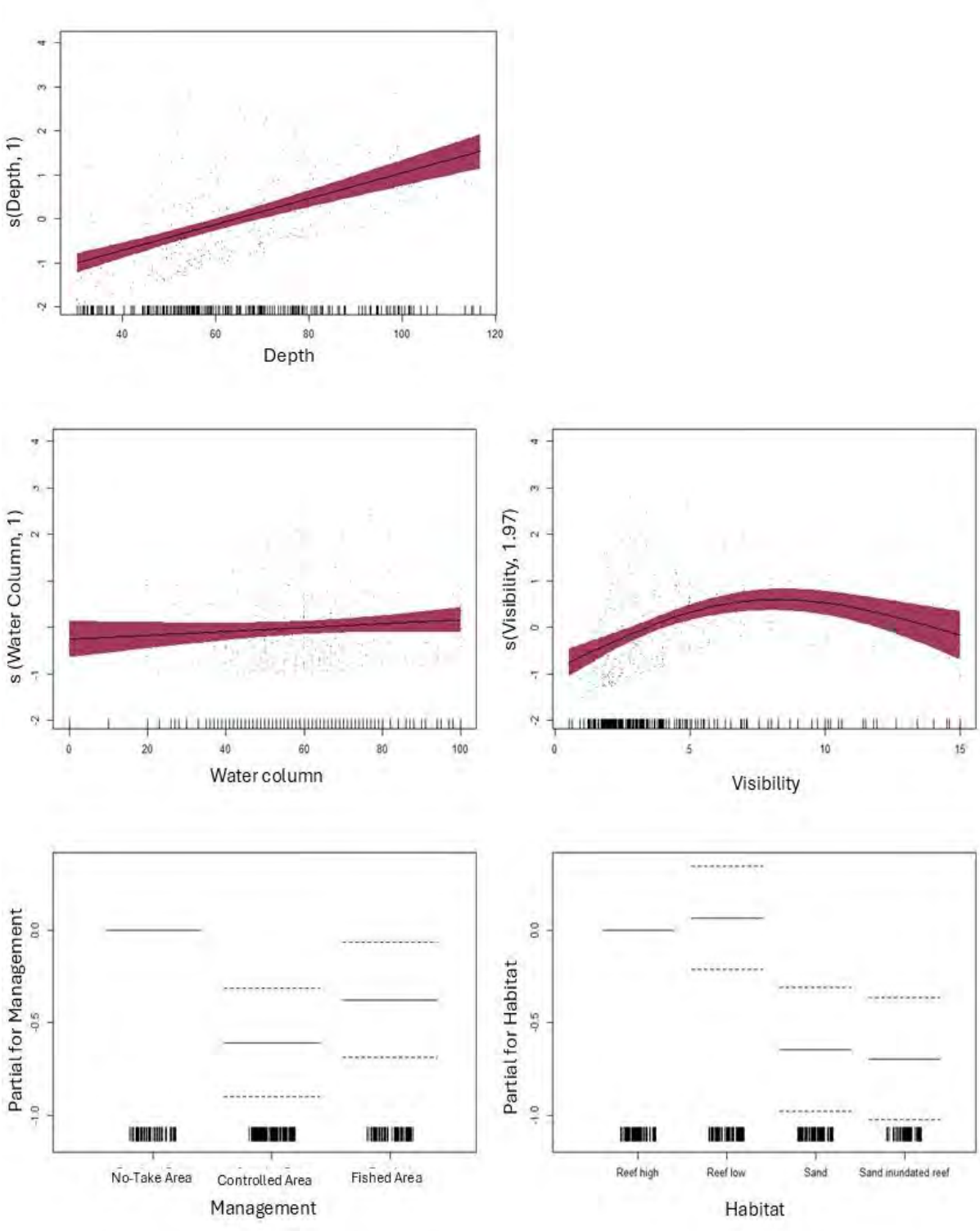


Figure A 1. 1: Term plots for parametric and smooth terms for m1, which looked at the effect of spatial management on the mature biomass of commercially important fish.

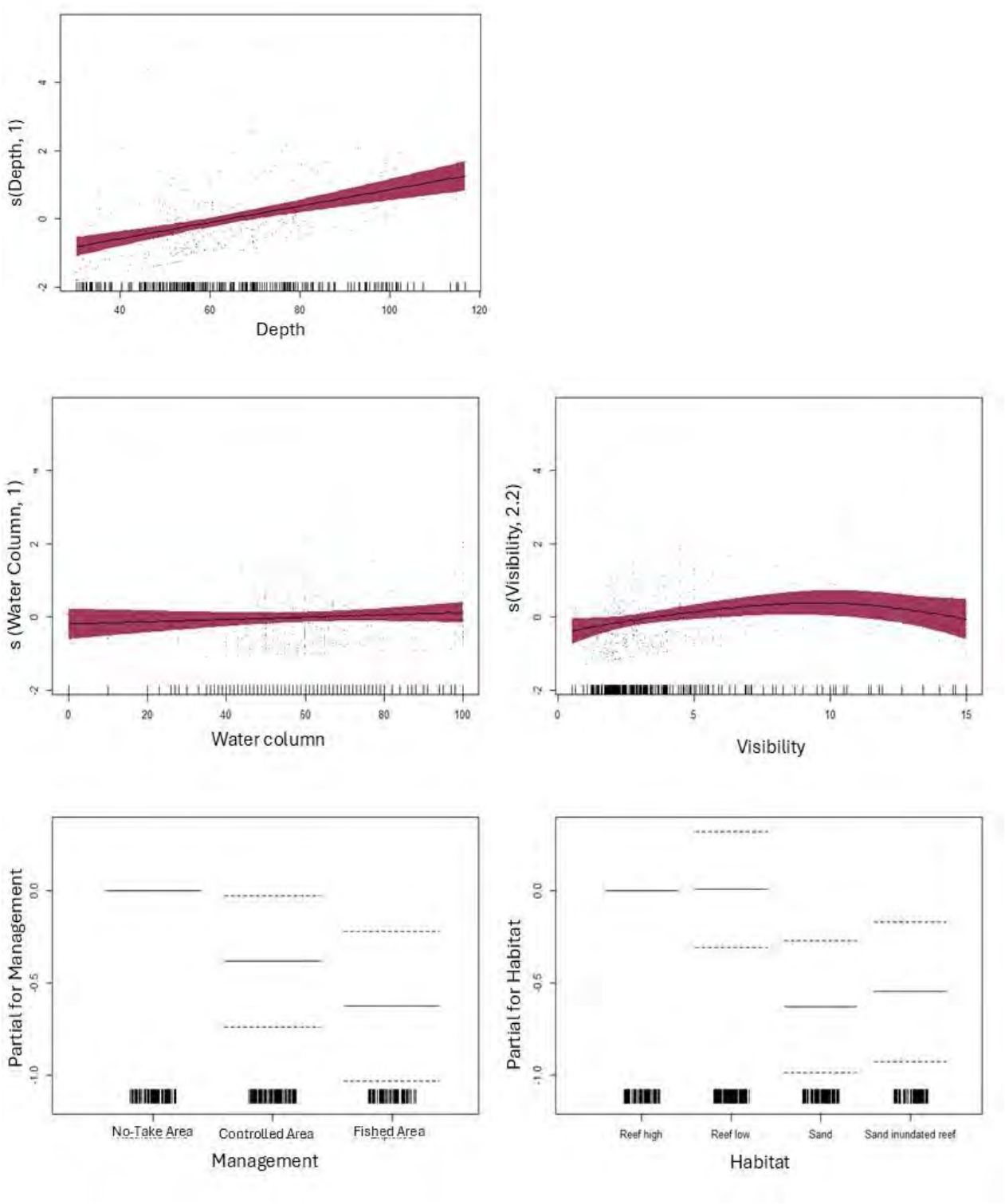


Figure A 1.2: Term plots for parametric and smooth terms for m2, which looked at the effect of spatial management on the mature abundance of commercially important fish.

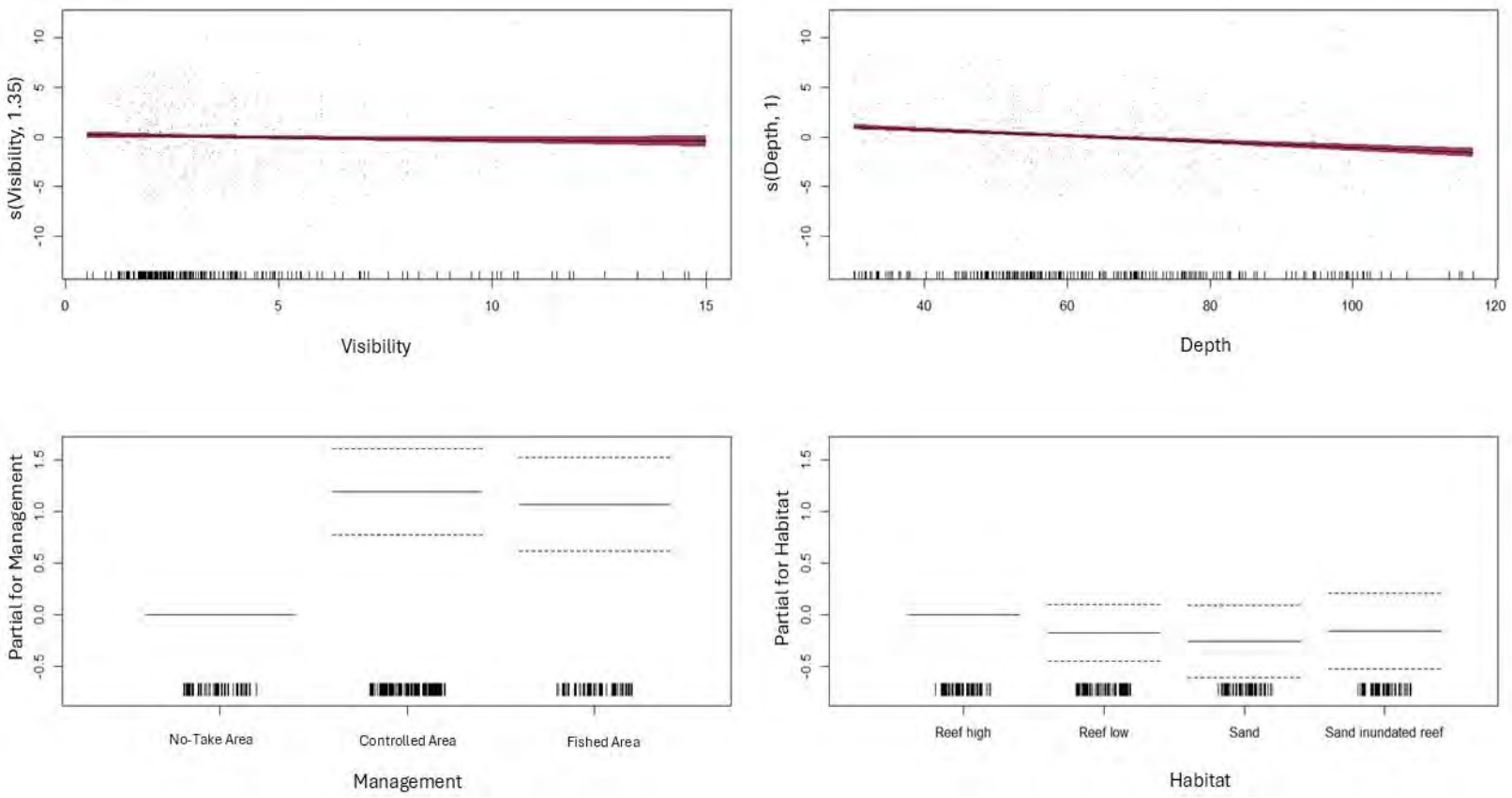


Figure A 1. 3: Term plots for parametric and smooth terms for m3, which looked at the effect of spatial management on the proportion of immature commercially important fish.

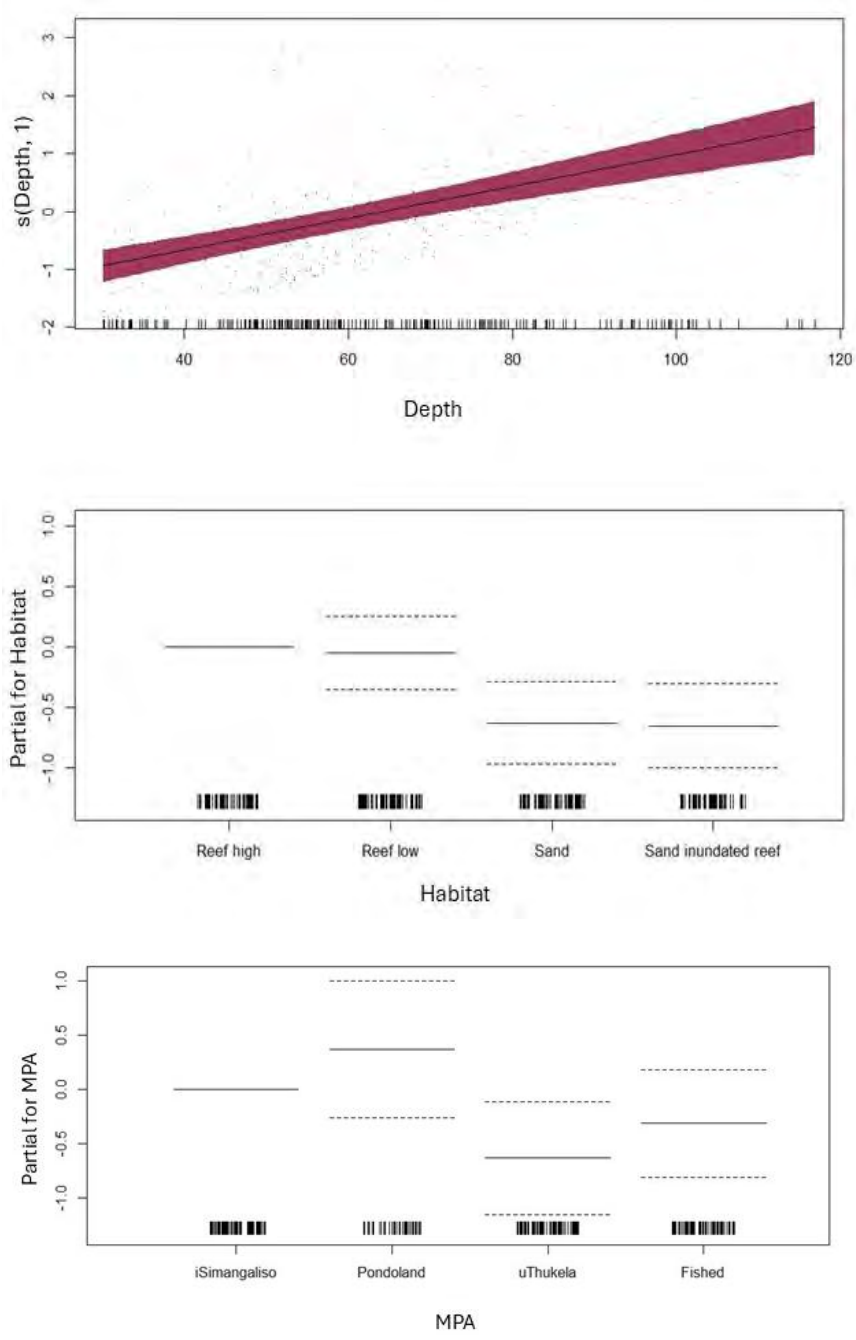


Figure A 1. 4: Term plots for parametric and smooth terms for m4, which looked at the effect of individual MPAs on the mature biomass of commercially important fish.

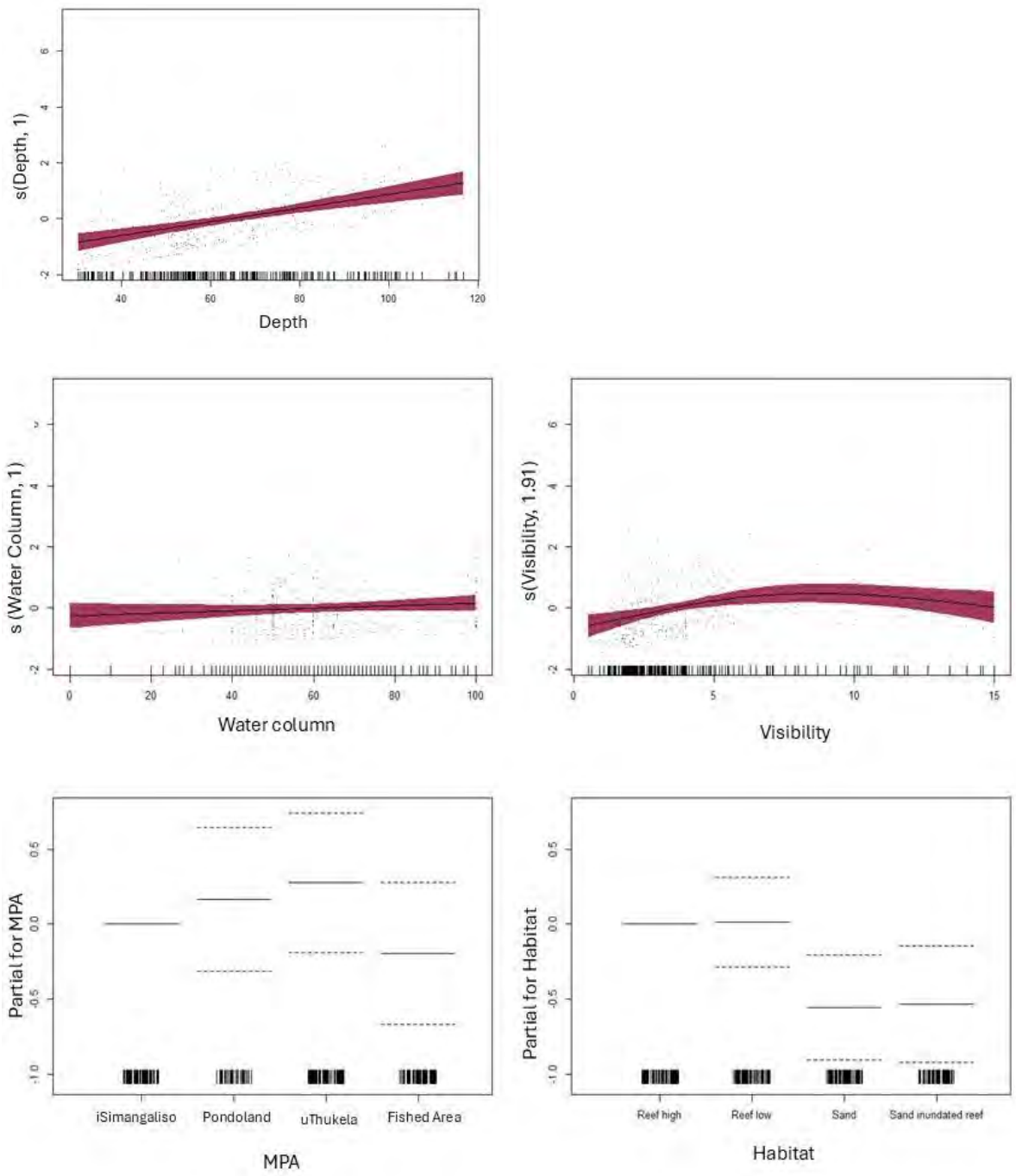


Figure A 1. 5: Term plots for parametric and smooth terms for m5, which looked at the effect of individual MPAs on the mature abundance of commercially important fish.

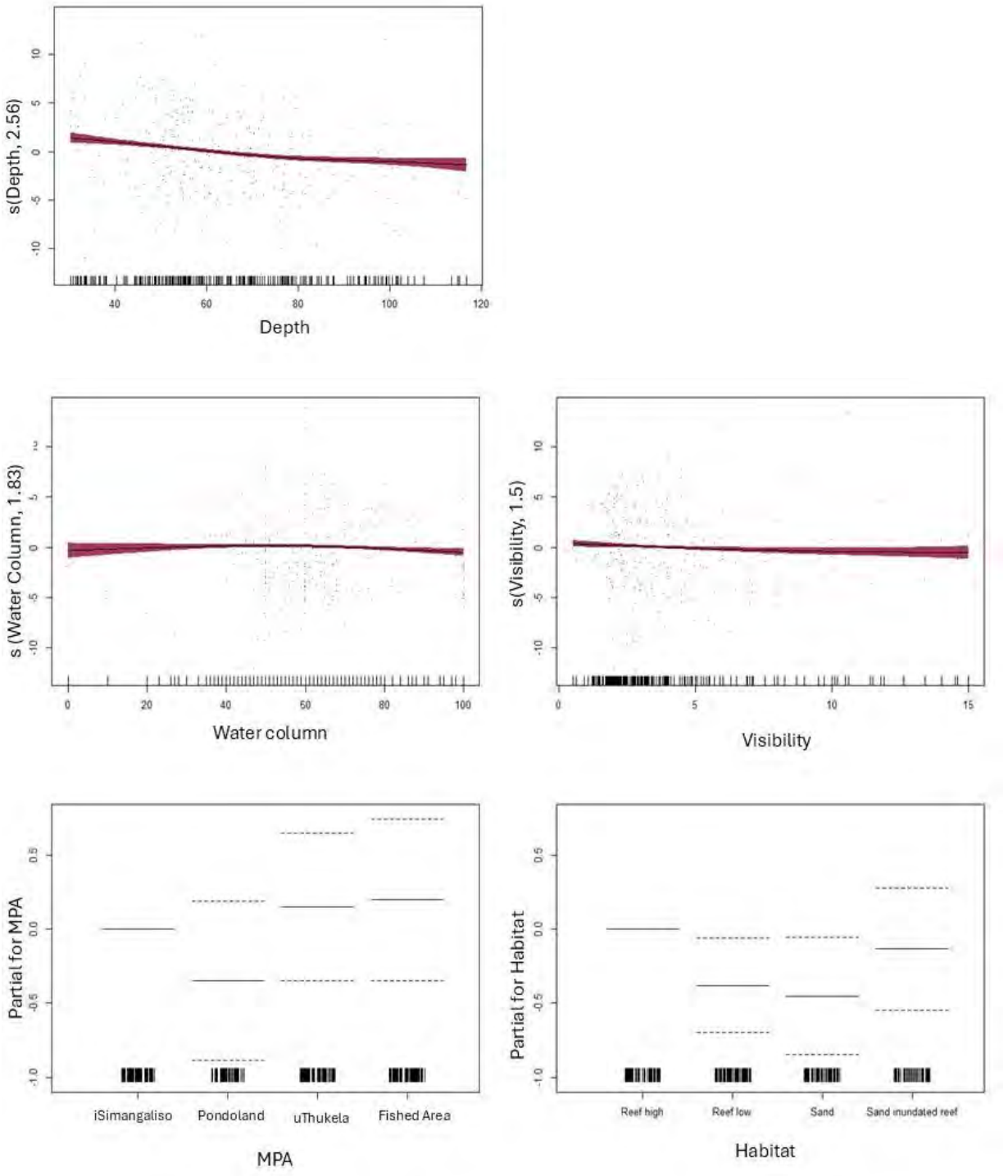


Figure A 1. 6: Term plots for parametric and smooth terms for m6, which looked at the effect of individual MPAs on the proportion of immature commercially important fish

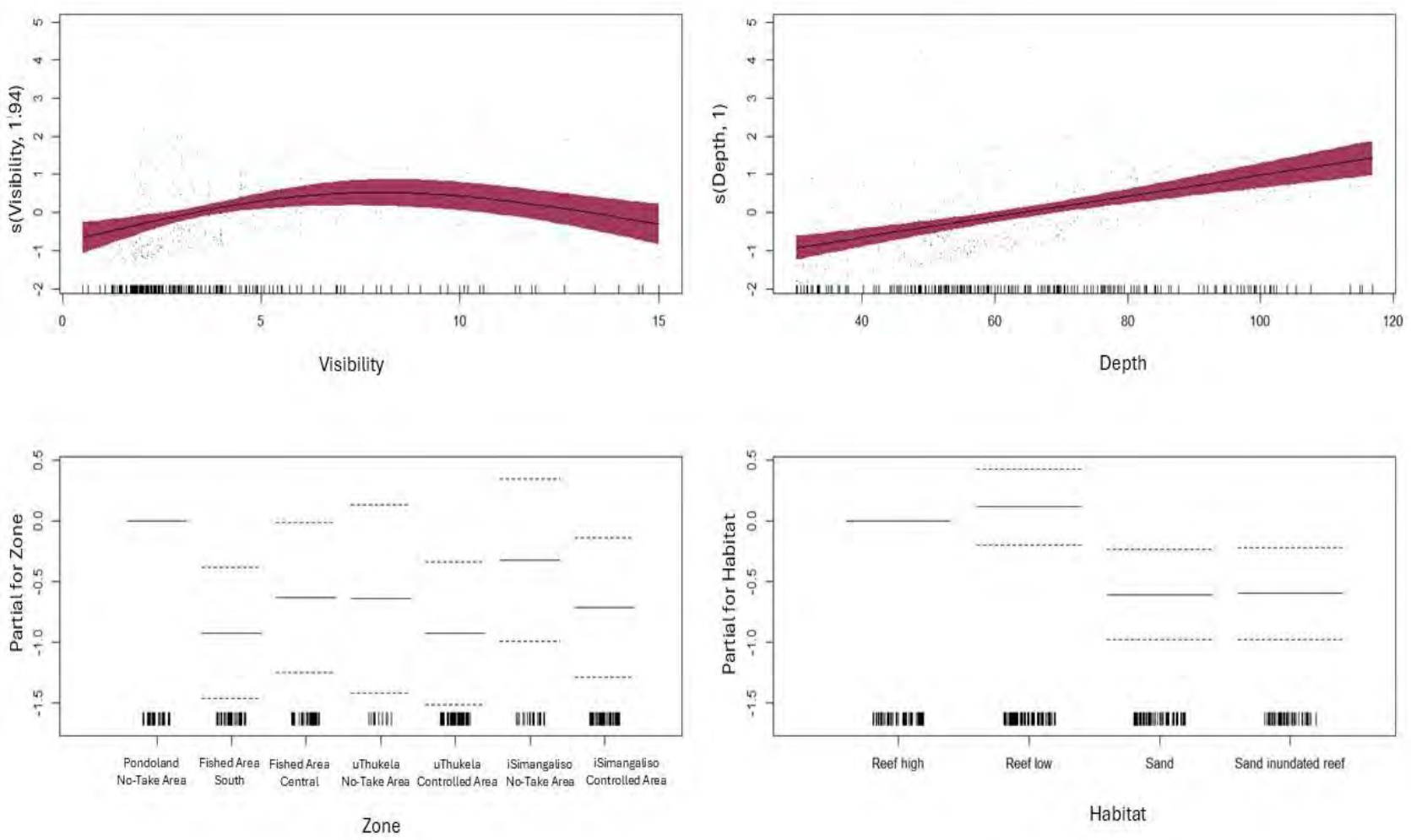


Figure A 1. 7: Term plots for parametric and smooth terms for m7, which looked at the effect of MPA Zonation on the mature biomass of commercially important fish.

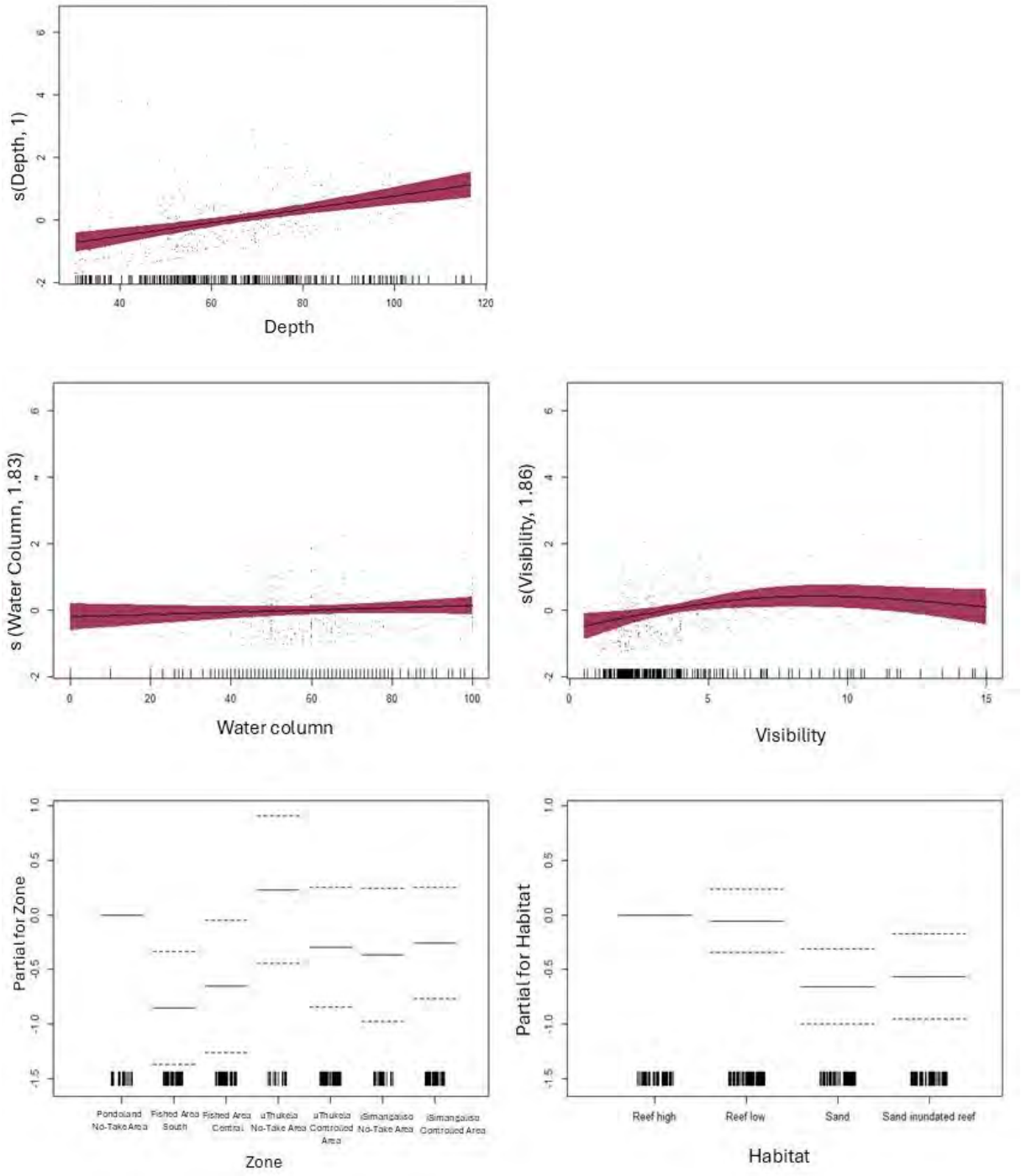


Figure A 1.8: Term plots for parametric and smooth terms for m8, which looked at the effect of MPA Zonation on the mature abundance of commercially important fish.

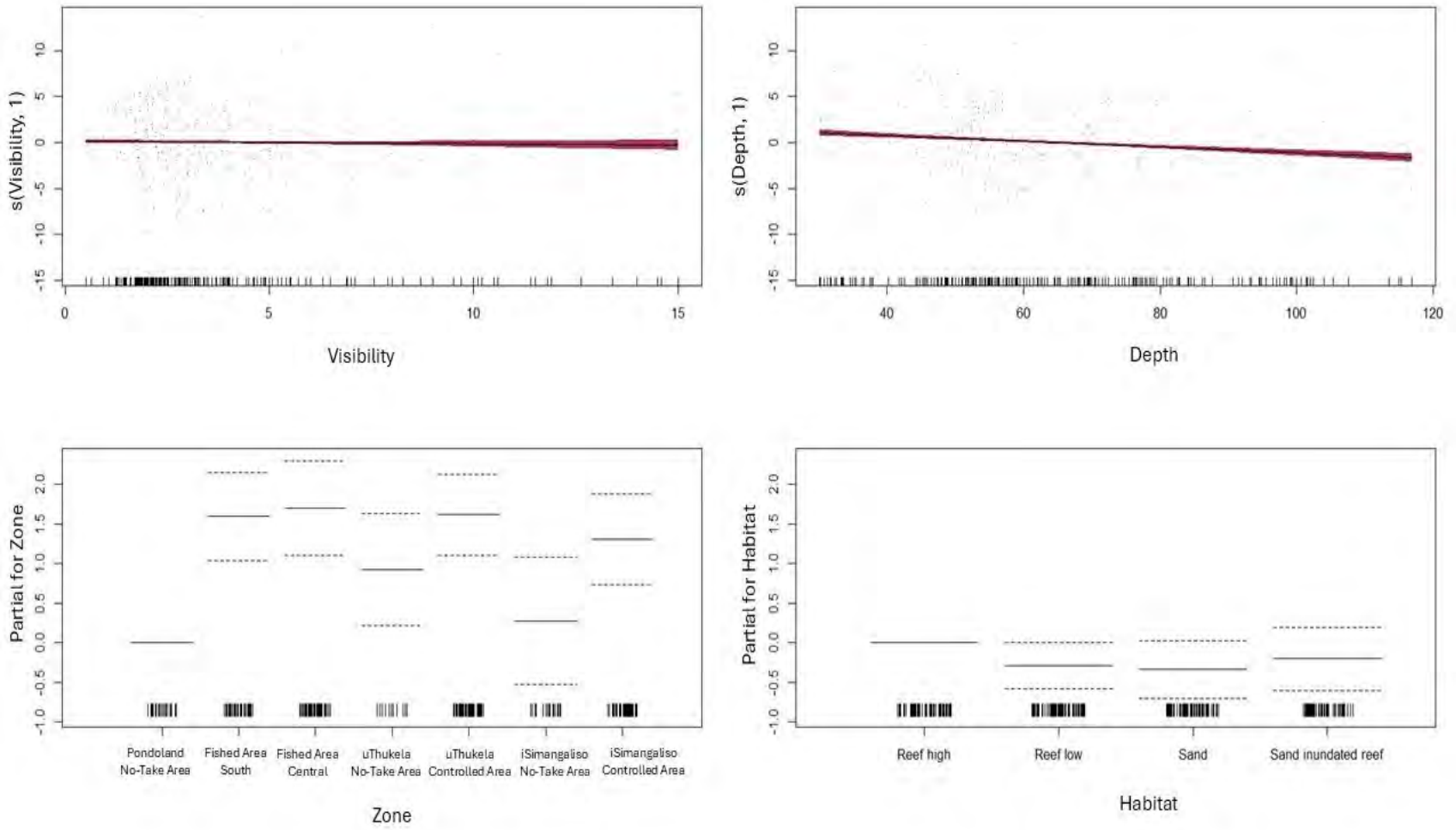


Figure A 1. 9: Term plots for parametric and smooth terms for m9, which looked at the effect of MPA Zonation on the proportion of immature commercially important fish.

A.2: APPENDIX 2

A2.1: INTERVIEW QUESTIONNAIRE

Adapted from the interview developed by Bennett et al (2019)

Date:

Nearest MPAs:

Respondent´s name:

INTRODUCTIONS AND WARM-UP

I introduce myself and the project, consent forms are worked through and the co-researcher (person being interviewed) signs consent before continuing.

Ease into the conversation with the following prompt:

1. Could you tell me about the role that fishing plays in your life?

DEMOGRAPHICS

2. How many crew do you employ?
    - Are they permanently employed?
3. Where do you launch most often?
4. Where do you fish most often?
5. What is your maximum travelling distance to get to a fishing spot?
6. Do you do work other than fishing?
    - What other types of work do you do?
7. Do you believe that the number of fish in the sea are:
    a. Increasing
    b. Decreasing
    c. Staying the same
    d. Varies
8. Can you explain to me what a Marine Protected Area is?

PERCEPTIONS OF MARINE PROTECTION IN GENERAL

9. Do you think that it is necessary to protect and manage fish stocks for long-term sustainability?
10. Do you think that Marine Protected Areas are a good tool for managing fish stocks for long-term sustainability?
    - Why / why not?

PERCEPTIONS OF ECOLOGICAL EFFECTIVENESS OF MPAS

11. How do you think the MPAs affect the marine habitats (environments) inside the MPAs? - This question was removed in the field because it did not elicit the desired response.
12. How do you think the MPAs affect the number of fish in the sea?

PERCEPTIONS OF SOCIAL IMPACTS OF MPAS

13. In what ways do you think that the MPAs near your fishing grounds have affected your livelihood / the ways that you get income?
14. How do you think that the MPAs have affected the commercial linefishing sector / commercial linefishing community as a whole?
15. Have MPAs affected your relationship to the sea in any way?
16. Do you believe that the impacts of the MPAs are fairly and correctly distributed along the KZN coastline? Please elaborate on your answer.
17. Do you believe that the impacts of MPAs are fairly distributed among different user / fishing groups? Please elaborate. – Change for clarity.

PERCEPTIONS OF GOVERNANCE

For the following two questions, answer using the following scale:

Fully disagree	Somewhat disagree	Neutral	Somewhat agree	Agree
1	2	3	4	5

18. The rights of commercial linefishers are taken into account in MPA planning and management

19. MPA management aligns with the livelihood needs of commercial linefishers
20. Where can you access research and scientific information about:
    - the marine environment and the status of fisheries and fish stocks?
    - MPAs and MPA rules?
    - Fishing regulations?
21. Which of the following statements best describes the way that MPA management decisions are made?

MPA decisions are made without any consultation of the commercial linefishers	I don´t know if commercial linefishers are being consulted in the decision-making process	Commercial linefishers have the opportunity to comment on decisions that are being made	Commercial linefishers are part of the decision-making process and our opinions are valued

22. Is there a process that can be followed when issues arise for commercial linefishers in relation to the management of the MPAs? Please elaborate. simplify
23. How would you classify the level of trust between commercial linefishers and MPA management?
    e. Are there any reasons for this that come to mind?
24. Are MPA rules enforced?
    - What does enforcement look like?
    - How often does enforcement occur?
25. How fair do you think the enforcement of the MPA rules is?
26. How would you classify the level of support of the commercial linefishing community (as a whole) for Marine Protected Areas?

Strong opposition	Some opposition	Neutral	Some support	Strong support
1	2	3	4	5

Can you elaborate on why you say this?

DESIRED CHANGE IN MPAS

---

27. Imagine a future where marine protected areas are effective for rebuilding fish stocks and at the same time allow people to use the ocean in a sustainable way. In your opinion, what needs to change to allow such a future to become reality?

A2.2: CONSENT FORM

Participant Informed Consent declaration

(To be signed by research participants)

Research Project Title: Marine Protected Areas for Fish and Fishers: Investigating the multidimensional effects of KwaZulu-Natal's Marine Protected Area Network on the commercial linefishing sector

Enya Melissa Munting, an MSc student at the department of Environmental Science at Rhodes University, has requested my permission to participate in the above-mentioned research project.

The nature and purpose of both the research project and this form have been explained to me in a way that I understand.

I am aware that:

1. The purpose of this research is to collaboratively build and contribute knowledge on the efficacy of Marine Protected Areas (MPAs) in KwaZulu-Natal (KZN) for the commercial offshore linefishery by using a multi-methods approach to determine how well the MPAs protect and replenish commercially important fish stocks and how the MPA network and its current governance affects commercial linefishers.
    - o
2. The project is funded by the National Research Foundation and the Blue Action Fund, and is part of the larger African Coelacanth Environmental Protection (ACEP) SMART Zone Project, which will run for three years, and feeds into the larger uThukela Marine Protected Area (MPA) Ecosystem Based Adaptation (EbA) Project. Both of these overarching projects have been described to me. The information that I share through my participation in this project may be used and referred to during the course of any of these larger projects.
    - o
3. Rhodes University has given ethical clearance to this research project (NHREC Registration number: RC-241114-045) and I have seen / may request to see the clearance certificate by contacting the Ethics Coordinator (ethics-committee@ru.ac.za)
    - o
4. By participating in this research project, I will be contributing towards the ACEP SMART Zone Project, which will feed into the uThukela MPA Ecosystem Based Adaptation Project that is run by WILD oceans. My contribution will help to build an understanding of the perceptions of commercial linefishers regarding the Marine Protected Area network in KwaZulu-Natal. I acknowledge that the results of this research may be published and that I will receive credit for my contribution to the work.
    - o
5. I will participate in this project by sharing my perceptions of Marine Protected Areas and their ecological and socio-economic effects and my perceptions around their governance, in an interview. I may also attend a workshop where the results of other components of the research and the results of the social research will be discussed, after which a future visioning exercise, using the three horizons framework, will be completed collectively. During this exercise, we will discuss and imagine an ideal future for marine protection in KwaZulu-Natal that is both socially and ecologically sustainable from the collective perspective of the commercial linefishers attending the workshop.

o

6. My participation will require me to avail myself for one interview of approximately one hour and possibly one workshop of approximately four hours, with suitable notice given beforehand.

o

7. A recording device will be used by the researcher to supplement field notes. Recording may be done by using a voice recorder or a video recording device or both of these, and I will indicate my consent for these at the bottom of this page.

o

8. My participation is entirely voluntary and should I at any stage wish to withdraw from participating further, I may do so without any negative consequences.

o

9. I will not be compensated for participating in the research.

o

10. The following risks are associated with my participation: potential for conflict in the workshops due to sensitive discussions about the future of the commercial linefishing sector. This will be mitigated as well as possible through sensitive facilitation. The risks of participation in this research are not greater than what I would be exposed to in my day-to-day life.

o

11. The researcher intends to publish the results of this research in the form of a thesis and two manuscripts in peer-reviewed journals. However, confidentiality and anonymity of records will be maintained, and my name and identity will not be revealed to anyone who is not involved in conducting the research, unless I indicate to the contrary or recognise that as a public figure, my identity will inevitably be/become known, in which case I agree to accept the loss of confidentiality.

o

12. I recognise and accept that the researcher intends to make a video to communicate the results of this research to the general public, and acknowledge that my opinions and views will be represented within this video in a nonspecific way, unless I agree to footage of me being used in the video, in which case I acknowledge and accept the loss of confidentiality. I will indicate my preferences regarding appearance in the video at the bottom of the page.

o

13. In terms of the Protection of Personal Information Act (no 4 of 2013) it remains my right to request the researcher to provide me with a detailed explanation of exactly how confidentiality and anonymity will be achieved for the data I provide. I may also request to know exactly how my personal information will be stored securely and for how long it will be stored.
    - o
14. I possess the right to receive feedback about this research. This will take the forms of verbal feedback which I will receive during the workshop that I attend and a video that the researcher will produce to share the findings of the work with the general public. I will expect to receive these forms of feedback unless I do not to attend any of the workshops, or I have elected not to receive feedback. If I want feedback but cannot attend a workshop, feedback will be provided by email.
    - o
15. Any further questions that I have regarding the research or my participation will be answered by Enya Munting (e.munting@saiab.nrf.ac.za) (cell number: 0737366910). In case she cannot answer my questions, I can contact her main supervisor, Dr Anthony Bernard (ATF.bernard@saiab.nrf.ac.za, or 0833839228) or her co-supervisors, Dr Jessica Cockburn (j.cockburn@ru.ac.za or 0721022875) and Dr Bruce Mann (bruce@ori.org.za or 0723566629)
    - o
16. By signing this informed consent declaration, I am not waiving any legal claims, rights, or remedies.
    - o
17. A copy of this informed consent declaration will be given to me, and the original will be kept on record.

I, …….. , have read the above information / confirm that the above information has been explained to me in a language that I understand and I am aware of this document´s contents. I Have asked all the questions that I wished to ask and these have been answered to my satisfaction. I fully understand what is expected of me during the research.

I have not been pressurised in any way and I voluntarily agree to participate in the above-mentioned project.

I **AGREE / DISAGREE** (Select applicable) to the researcher´s request to take **video footage** of me as part of the research project, recognising that agreement here is likely to raise the risk of compromising my anonymity.

I **AGREE / DISAGREE** to the researcher´s request to **voice record** my comments and opinions during interviews , the purpose of which is to ensure the accurate recording of my views. Furthermore, I have the right to request a copy of interview transcriptions to confirm that my opinions are accurately recorded.

…… ……..

Participant´s signature Date

A2.3: CODE BOOK

Table A2.4: The attribute codes used for this thesis. Attribute codes are for coding out demographic and attribute information. Each code category is related to an introductory question which was asked of each fisher before perceptions were explored, and the subcodes group the possible short answers.

Code category	Code	Code description
Closest MPA		The first question of the interview was always: "Which MPA impacts you the most?" This category contains a code for each MPA
	Tugela	
	iSimangaliso	
	Protea Banks	
	Aliwal Shoal	
	Pondoland	
Launch site		Question 3: "Where do you launch most often?" Inductive. A category code containing a code for each launch site.
	Blythedale	
	Durban Harbour	
	St Lucia	
	Glenmore	
	Meerensee Skiboat club	
	Mtunzini	
	Mapelane	
	Munster	
	Ramsgate	
	Rocky Bay	
	Varies	
	Zinkwazi	
	Shelly Beach	
	Richards bay	
	Valencia boat club	
	Port Edward	
	Tinley manor	
	Umhlali Skiboat club	
Need for management		Question 9: "Do you think that it is necessary to protect and manage fish stocks for long-term sustainability?" Deductive.
	Yes	
	No	
Number of crew		Question 2: "How many crew do you have and are they permanently employed?" Deductive.
	9	
	5	
	4	
	8	

	6	
	3	
	7	
	Additional land crew (3)	Inductively added to incorporate one fisher´s employment of a 3-man land crew for cleaning and sorting of fish.
	Permanent	
	Impermanent	
Other work		Question 6: "Do you do work other thank fishing? What other types of work?" Deductive for Yes / No + Inductive for type of other work if yes.
	Yes	
	No	
	Macadamia agriculture	
	Charters	Fishing charters
	Selling chemicals	
	Maintenance	Plumbing, welding, and maintenance work
Perception of fish populations		Question 7: " Do you believe the number of fish in the sea are increasing, decreasing, staying the same, or that it varies?" Deductive.
	Decreasing	
	Increasing	
	Staying the same	
	Varies	
	Decreasing size	This code was added inductively, as one fisher mentioned this and it seemed relevant
Relationship to fishing		Question 1:" Could you tell me about the role that fishing plays in your life?" Inductive.
	Love	Where fishers mention a relationship of enjoyment, love, or connection to fishing other than the fact that it is their main income.
	Main income	Where fishers mention fishing as their main livelihood
Travelling distance		Question 5: "What is your maximum travelling distance to get to a fishing spot?" Inductive, in 5km distance categories for the first 20 km, and then in 20 km categories.
	10-15km	
	15-20 km	
	20-30km	
	30-40km	
	40-50km	
	50-60km	
	70-80km	
	140-150km	

Table A 2.5: Codes in the "Observations" category. Observations have been separated from perceptions in this study, such that observations refer to concrete occurrences which have been experienced by fishers or someone they know. These occurrences could be related to and feed into their perceptions, but are not themselves considered as perceptions.

Code category	Code	Code description
Fishery management		Observations related to the management of the fishery as a whole.
	False catch returns	Comments related to false catch returns being used
	Naïve	Comments related to naïve management of the fishery as a whole
	Catch returns inadequate	Applied when a fisher mentions that catch returns are an inadequate data source for understanding fisheries properly. These comments are often made in association with fish species which are illegal for commercial fishers to catch and therefore should not be entered into the catch return book, even if fishers are accidentally catching them and then releasing them again.
	Apathetic	Applied when there is any indication that the management of the fishery does not care about the problems faced by the fishers due to MPAs and their management
	Unfair	Applied when fishers speak on how unfair the management of the fishery is as a whole, not specific to MPAs
	Total lack of enforcement	Applied when fishers indicate a lack of enforcement not only of MPA rules, but all fishery regulations
	In another country	Applied when fishers speak about how fisheries are managed in another country
General		General observations related neither to the management of the fishery nor MPA management go here.
	Unsustainable small-scale fishing	Applied whan fishers indicate that small-scale fishing is unsustainable
	Commercials not abiding by law	Evidence of commercials poaching or otherwise not abiding by the law
	Commercial care for fish stocks	Evidence of commercials caring about fish stocks
	Commercial care for marine ecology	Evidence that commercials care for the marine ecology as well as the fish stocks
	Local care for fish stocks	Evidence of the general populace caring for fish stocks
	DAFF less effective	Observations related to DAFF / DFFE being less effective at MPA management than EKZN wildlife / Ezemvelo /
	Decreasing fish populations	Observations pointing to decreasing fish stocks over time.
	Fish behaviour	Observations of fish behaviour
	Fish population increase	Observations pointing to increasing fish stocks over time.
	Fishers not abiding by law	Observations of unspecified fishers disobeying the law in any way.

	Fishing trends	Trends in general fishing behaviour
	Pollution	Observations related to pollution
	Dusky kob / snotties / kabeljou	Observations about dusky kob / snotties / kabeljou
	Weather	Observations related to weather patterns
	Seventyfours	Applied when fishers speak about the Seventyfour population
	Tension between user groups	Applied when there is any indication of tension between different user groups for the ocean, often in relation to commercial vs recreational linefishermen.
	Geelbek	Any talk about geelbek
	Steenbras	Applied when a fisher speaks about steenbras
	Sharks	Applied when fishers speak about the impact of sharks on their fishing
	Overfishing	Applied when fishers mention overfishing
	Decreasing fish size	Applied when fishers discuss a decrease in the size of fish that they are catching
	Parasites	Applied when fishers discuss the impact of parasites on fish populations
	Corrupt	Any indication that there is corruption in the way that permitting is done or management decisions are made in fisheries. Indications of corrupt dealings
	Learning through experience	Observations related to fishers feeling that experience has taught them anything that they would not have learned otherwise
	S / N divide	Applied when fishers mention the differences between the fishing communities in the South and North, or that the two groups / communities / areas are not comparable.
Recreational fishers		Still as a group of general observations, this code category is related particularly to observations related to recreational fishing, as these were common.
	Recreationals selling fish	Observations of recreational fishermen selling fish
	Recreationals not abiding by law	Observations of recreational fishers not abiding by the law
	Poaching because of economy	Observations that poachers poach due to lack of options
	Too many recreationals	Observations of high recreational pressure on the system or where fishers indicate that the recreational impact is higher than the commercial impact
	Recreational fishing trends	Observations of recreational fishing trends
MPA management		Any observations relevant to the way that MPAs are managed.
	Evidence based	Observations of evidence-based decisionmaking
	Geelbek exemption	Conversations around the exemption for commercial fishers to fish for geelbek inside Marine Protected Areas during the spawning season. This was a court case which was won in 2022.
	Need compliance	Observations around a need for more compliance of MPA rules

	Recreational poaching	Observations of frecreational fishers fishing inside MPAs.
	Unclear communication	Observations of unclear communication of MPA managing bodies with fishers, or of unclear avenues for communication between fishers and management.
	Commercial poaching	Applied when there is evidence of commercial poaching behaviour

Table A 2.6: Codes in the "Negative perceptions" category. Negative perceptions of MPAs were added into a folder, with categories created where specific impacts or types of impacts are regularly discussed, with more detail in the codes. A category also exists for uncategorised negative perceptions, which are not specific to a commonly mentioned issue but are still relevant

Code Category	**Code**	**Code description**
Communication		Negative perceptions of the ways that communication is carried out by MPA management
	Unclear communication	When communication from DFFE is vague and hard to understand.
	Engagement not possible	Issues related to a lack of meaningful 2-way engagement
	Engagement - not meaningful	Applied when the fisher does not believe that engagement with the managing body of the MPA has been meaningful thus far. Answers question X (CHECK).
	Lack of	Any indication that there is a lack of communication between DFFE and the commercial fishers
	Decreased	Indication that better communication channels existed in the past
	Consultation - Not meaningful	Perceptions of the consultation process not being meaningful / constituting a tick-box exercise / fishers opinions not being adequately valued. These perceptions are related specifically to consultation and stakeholder engagement processes around the management and design of MPAs and not other forms of engagement, which are covered by a different code.
	Consultation - not occurring	Applied when the fisher does not believe that any consultation occurs between the commercial linefishers sector and the manáging bodies Answers question x (CHECK). These perceptions are related specifically to consultation and stakeholder engagement processes around the management and design of MPAs and not other forms of engagement, which are covered by a different code.
	Indirect	Applied when fishers indicate a lack of direct communication from the managing bodies
Decisionmaking		
	Illogical	When fishers think that MPA decisionmaking does not make sense to them
	Insufficient data	When fishers think that MPA decisions are made without enough prior research
	Misguided	When fishers think that MPA decisions are made with good intentions but do more harm than good.

	Unfair	Applied when fishers think that decisions have been made unfairly
	Corrupt	Applied when fishers indicate that decisionmaking around MPAs was self-motivated or corrupt, not with honest intentions
Enforcement		
	Apathetic officers	Officers not caring about their work or not taking initiative to do what is necessary to protect MPAs when it is not exactly part of their job description
	Difficult	Comments related to the difficulty of enforcing MPAs
	Inconsistent	Comments around inconsistent enforcement / blitz´s / enforcement coming and going, not maintaining a presence, etc
	Irrational	Comments around enforcement being conducted in an irrational way, officers enforcing rules too strictly in some places, not enforcing other rules, etc
	Lack of	Comments claiming that there is no enforcement
	Naïve officers	Comments around enforcing officers not knowing the fishery in KZN well enough to enforce effectively
	Unfair	Comments around enforcement being conducted more strictly on certain groups than others, feelings of being targeted, feelings of unfairness.
	(Management) decreased effectiveness (DAFF vs EKZN)	Comments about the shift from EKZNW to DFFE causing management to become less effective in any way.
	Mistrust	Applied when a fisher indicates a bad relationship or bad trust with the enforcing body
	Paper parks	Applied when fishers talk about the MPAs in any way that applies to the description of paper parks: "Many marine protected areas exist on maps and in legislation but offer little real protection in the water. Often referred to as “paper parks”, these sites represent a failure of efforts to protect resources and ecosystems."
	Recreational poaching in MPA	Applied when fishers specifically mention that recreational fishers are fishing *inside* MPAs. This is different to "Pirate commercials" or other terms for recreationals catching over quota and selling their fish, which may be occurring either inside or outside the MPAs.
	Lack of resources	Applied when fishers mention a lack of resources for effective monitoring and control / enforcement
Financial impact		
	Alternative income needed	Comments about needing different income streams more after the MPAs came into force
	Cost increase	Anything related to the cost of fishing increasing with the declaration of new MPAs
	Loss of profit	Anything related to the loss of profit as a result of MPAs or the ways that MPAs are managed.
	Decreased fishing	Applied when MPAs are said to have decreased the amount of fishing being done or the number of fish being caught by a fisher
Uncategorised.n		This code category is for the negative perceptions which have been identified but which do not belong in a higher category.

	Consultation - Not meaningful	Perceptions of the consultation process not being meaningful / constituting a tick-box exercise / fishers opinions not being adequately valued.
	Criminalisation of fishers	Perceptions of MPAs criminalising normal fishing behaviour, making criminals out of fishers, creating feelings of guilt or making fishers run out of options other than poaching.
	No spillover	Applied when fishers do not believe that fish are moving out of MPAs to replenish stocks
	Displacement	References to feelings of displacement
	Safety impacts	References to MPAs affecting the safety of fishing
	Effects take too long	References to the long timeframes needed for MPAs to work
	Frustration	This code is applied when it is clear from the language or directly from what is said, that the fisher is feeling frustrated about the ways that MPAs impact them.
	Impacts - unfairly distributed	This code is applied when fishers speak about unfair enforcement of rules on various user groups or when fishers mention how others are benefitting from MPAs when they are losing out.
	Inconvenience	Applied when the inconvenience of dealing with new MPAs is discussed.
	Ineffectiveness	Applied when fishers perceive MPAs not to be working or to be ineffectively enforced or otherwise suffering from a lack of evidence for their effectivveness
	Loss of fishing grounds	Applied when fishers speak about the fishing grounds that they have lost due to the declaration of MPAs
	Mistrust of research	Applied when fishers indicate in any way that they do not trust the research or that the research is incapable of completely and accurately understanding the reality.
	Only commercials abide by rules	Applied when fishers speak about commercial fishers being the only ones abiding by rules, or being the only ones receiving enforcement or anything similar
	Overfishing non-MPA grounds	Applied when fishers discuss the higher fishing pressure that is felt in non-MPA spaces and how it impacts them
	Opposition to MPAs	Applied when fishers indicate that they or the community oppose MPAs
	Too big	Applied when the size of an MPA is mentioned as a problem to the fishers, in any way.
	Travel distance increase	Applied when fishers mention an increase in their daily travelling distance to reach suitable fishing grounds .
	Zonation - complex	Applied when the complexity of MPA zonation is called into question or in any way criticised, or when this is mentioned as being confusing to navigate
	Rights not considered	Applied when fishers believe that their rights were not taken into account in MPA planning and management. Answers question x (CHECK)
	Livelihood needs not considered	Applied when fishers believe that their livelihood needs were not taken into account in MPA planning and management. Answers question x (CHECK)

	Consultation - not occurring	Applied when the fisher does not believe that any consultation occurs between the commercial linefishers sector and the manáging bodies Answers question x (CHECK)
	Encroachment	Applied when fishers indicate that MPAs have been designated specifically in the areas where they like to fish
	Commercials do not support MPAs	Applied when a fisher indicates that they do not believe that the commercial linefishers support MPAs.

Table A 2.7: Codes related to positive perceptions.

Category	**Code**	**Code description**
Enforcement		
	Renewed effort	Applied when fishers mention a renewed effort in the enforcement of fishing regulations through any means
	Occurs	Applied when fishers mention that MPA regulations are enforced, with any optimistic tone or in a more optimistic context. Not to be applied when the context is in agreement with the statement "Enforcement occurs but it is not enough"
	Occurs often	Applied when fishers indicate that enforcement is regularly occurring
	Is fair	Applied when a fisher indicates that they believe that enformcement of MPA rules is fair
Uncategorised.p		
	Breeding	Applied when fishers mention that fish are breeding in MPAs
	Zonation good	Applied when fishers mention the zonation in a positive light
	Consultation occurred	Applied when fishers mention any consultation processes in MPA decisionmaking that have occurred
	Desire for well-managed MPAs	Applied when fishers indicate that they desire well-managed MPAs, or that they are generally in support of MPAs, provided that the management is in alignment with the purpose
	Effectiveness	Applied when fishers indicate that they have experienced an MPA as being effective for any reason, including but not limited to seeing an increase in fish stocks near the MPA
	Evidence based	Applied when fishers indicate that they believe that the MPAs have been declared and managed in an evidence-based way
	Fishing behaviour - no effect	Applied when fishers indicate that MPAs have not changed or impacted their fishing in any way.
	Future stock stability	Applied when fishers mention MPAs as protecting fish, fish stocks, or breeding grounds for future sustainability
	Good location	Applied when fishers indicate that they believe an MPA is well-placed
	iSimangaliso is working	Applied when fishers mention the success of iSimangaliso MPA
	Livelihood needs taken into account	Applied when fishers indicate that MPA management takes their livelihood needs into account

	Necessity of MPAs as a management tool	Applied when fishers indicate in any way that the MPAs are important or needed or that they are a good tool for managing fish stocks
	Pondoland is working	Applied when fishers talk about the success of Pondoland MPA
	Protecting fish stocks	Applied when fishers speak about MPAs protecting fish stocks
	Rights taken into account	Applied when fishers indicate that their rights are taken into account in MPA mplanning and management
	Rules are known	Applied when fishers indicate that the rules are well known / well communicated / not vague or confusing in any way
	Spillover	Applied when fishers speak about spillover in any way. Spillover is defined as the movement of fish from inside the MPA to the area outside, where fishers may catch them.
	Trust management	Applied when fishers indicate that they trust the enforcing or managing bodies of MPAs
	Neutrality	Applied when fishers indicate neutrality or non-negative emotions related to MPAs. Considered a positive perception as it is not negative
	Commercial support for MPAs	Applied when a fisher believes that those in the commercial linefishing sector generally support MPAs
	Communication exists	Any indication that there is a possibility to communicate with DFFE about fishing regulations or poaching which is occurring
	Impacts fairly ditributed	Applied when fishers indicate that they believe that the impacts of MPAs are faily distributed along the coastline
	Communication - direct	Applied when there is evidence of direct communication between fishers and DFFE
	Commercial compliance	Applied when fishers speak about commercial compliance
	Protecting habitats	Applied when fishers mention MPAs protecting habitats
	Commercial support for research	Any indications that commercials work to collaborate with MPA researchers

Table A 2.8: Codes related to fishers´ suggestions for improvements to make MPAs more sustainable.

Code	**Code description**
Change fishery feedback format	Applied when fishers suggest that feedback from fishers about the fish stocks should be done in a different way (not only the blue book / catch returns that are currently in place)
Moving MPAs	Applied when fishers suggest that MPAs should move and not constantly remain in one place, thereby allowing the recovering/ recovered stocks to be fished
Need buy-in from fishers	Applied when fishers indicate that there needs to be more support garnered for MPAs among the fishing community so that they will willingly follow the rules

Share evidence freely	Applied when fishers indicate that information regarding MPAs and fish stocks needs to be distributed more readily, be more easily accessible or more easily understandable
Stricter enforcement	Applied when fishers indicate that there is a need for stricter enforcement of MPA rules
Stronger repercussions for rule-breaking	Applied when fishers indicate a need for stronger repercussions for breaking MPA rules. Also when fishers make an example of another place where rule-breaking is punished more strictly during a conversation about MPAs and how they can improve
VMS/AIS for recreationals	Applied when fishers indicate that recreational fishers should also have Vessel Monitoring Systems (VMS) or Automatic Identification Systems (AIS) on their boats, so that all boats in the marine space can be tracked with equal effectiveness
Different types of evidence needed	Applied when a fisher refers to a need for various sources of data on which to base fishing regulations and law, over and above the catch returns
Commercial fishing inside MPAs	Applied when a fisher indicates that they believe that the commercial linefishing sector should be allowed to fish inside MPAs
Restrict recreational fishing	Applied when fishers belive that recreational fishers should be further restricted and managed more intensively
Proper monitoring	Applied when a fisher speaks about a need for monitoring in MPAs
Communication improvement	Applied when fishers indicate that better communication would improve trust /
Consultation improvement	Applied when fishers indicate a need for more consultation in MPA processes
Involve skiboat clubs	Applied when fishers suggest that involving skiboat clubs in communication about MPAs and / or enforcement of MPA rules will help.
Collaboration with commercials for research	Applied when fishers indicate that they would like to be more involved in research activities
Longer fishing rights	Applied when fishers suggest that longer fishing rights would be beneficial
Compensate fishers for financial impact	Applied when fishers believe that compensation would improve MPA management
Divide Zone C S & N	Any speak about dividing the management zone for the KZN commercial Linefishing into two zones, S and N.
Give each fisher a portion of sea	Suggestions of giving exclusive fishing rights per section of ocean to fishers
Simple zonation	Applied when a fisher mentions that simple zonation is helpful to improving enforceability of MPA rules
Open seasons	Suggestions related to opening MPAs to fishing seasonally
Improve relationship with fishers	Applied when a desire for a better relationship between fishers and management is implied

A2.4 METHODICAL REFLECTIONS

Orientation to Data

A critical orientation to data means that the focus is on finding the mechanisms that construct systems of meaning, and requires a lot more interpretation and assessment of how meaning is built, as opposed to an experiential orientation, which considers the speaker´s words as a reflection of their personal, internal state, arising from their own experiences. My orientation to this data was strongly experiential.

Approach to analysis

For the approach to analysis, deductive coding refers to coding done prior to analysis, in accordance with the objectives of the research. Inductive coding is coding that is done while reading / analysing the data, and codes are developed directly from the content of the transcript, so that they convey a meaning that is found directly in the text. I chose to combine inductive and deductive coding, as described below.

Approach to coding

Finally, one´s approach to coding can vary from semantic, which is only concerned with the words that were spoken, to latent, which is concerned with both that which is explicitly conveyed and that which is not made explicit but can be implied through the way a sentence is constructed or through body language. I chose to lean more towards a semantic approach, although I also coded with consideration to latent meaning when I felt strongly that the way that I had been made to understand a certain sentiment during the interview process was not directly in alignment with the words that were transcribed from that conversation. For example, I met one fisher who spoke very positively about MPAs, but had many complaints. He often complimented them directly before sharing a problem with me. I did not take this to mean that he is entirely against MPAs, but I did not code it as a positive perception each time he said "MPAs are a good thing", before continuing to discuss a problem that he had with them. Positive perceptions were only coded for when he continued to speak positively about the MPA in that portion of the conversation. Another important thing to note about the way that I approached coding is the fact that I did not limit each code to being applied once per fisher. If a fisher brought up a topic multiple times in the conversation, it would be coded for multiple times. Code density is therefore a result of how often something is discussed, and not how many fishers discussed a topic.

A2.5 SANKEY DIAGRAMS

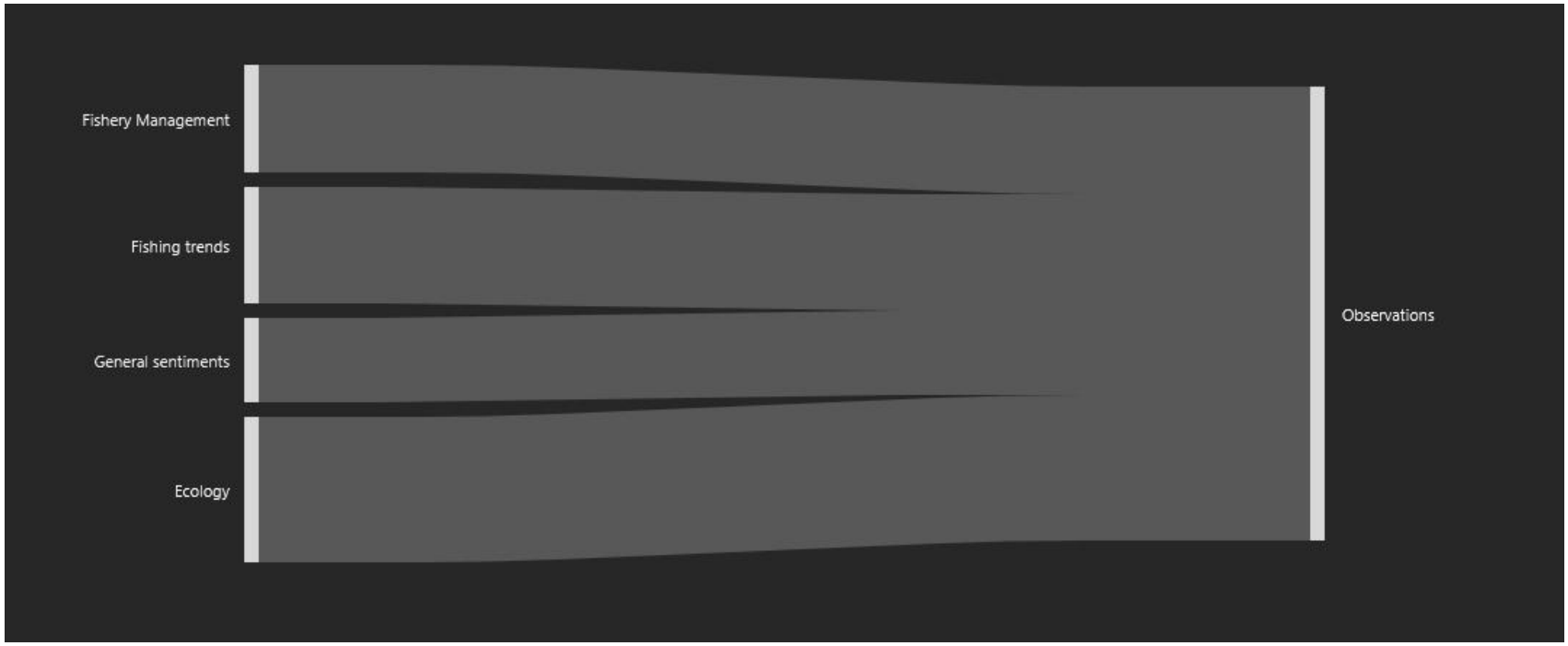


Figure A 2.5.10: Sankey diagram showing the relative code density of sub-categories within the “Observations” category.

Figure A 2.5.11: Sankey diagram showing the relative code density of sub-categories within the “Positive Perceptions” category

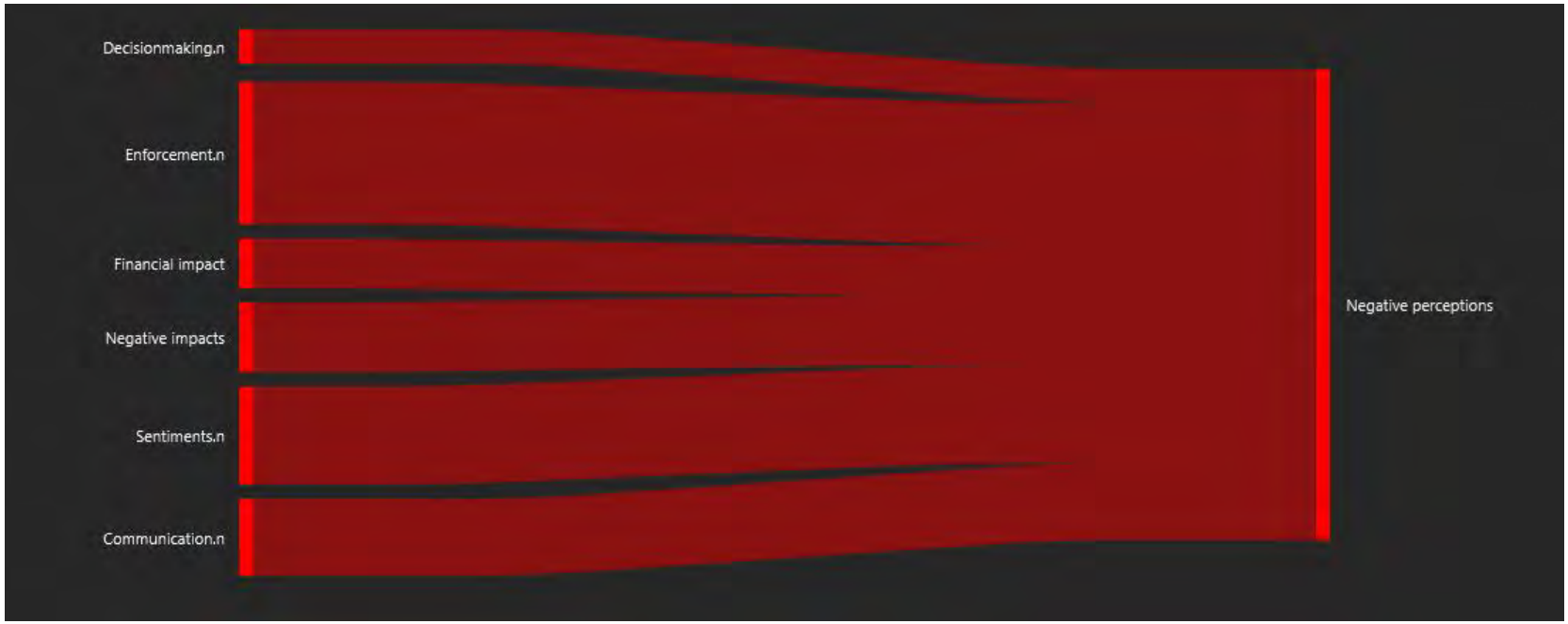


Figure A 2.5.12: Sankey Diagram showing the relative code density of sub-categories within the “Negative Perceptions” category

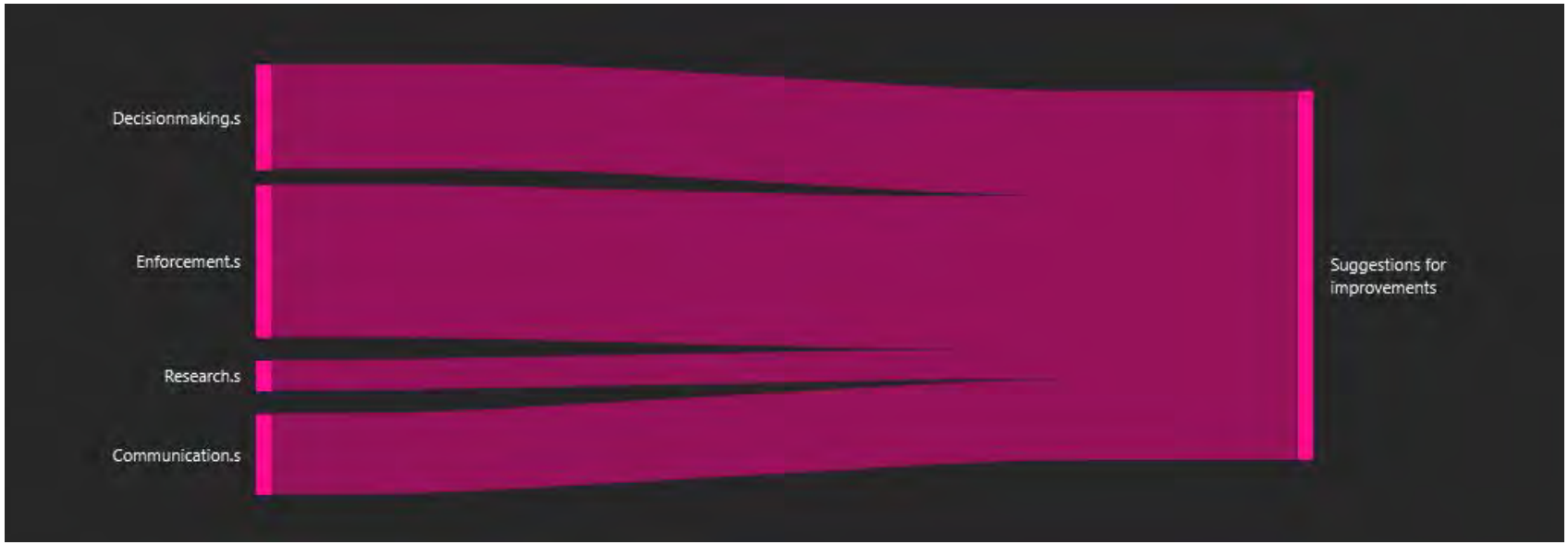
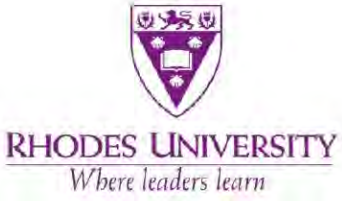


Figure A 2.5.13: Sankey diagram showing the relative code density of sub-categories within the “Suggestions for improvements” category

A2.6 ETHICAL APPROVAL LETTERS

A2.6.1 ETHICAL APPROVAL FOR HUMAN RESEARCH



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https://www.ru.ac.za/researchgateway/ethics/

31 October 2022

enya munting

Email: g22m6910@campus.ru.ac.za e.munting@saiab.nrf.ac.za

Review Reference: 2022-5931-7221

Dear enya munting

Title: Marine Protected Areas for Fish and Fishers: Investigating the multidimensional effects of KwaZulu-Natal's Marine Protected Area Network on the commercial linefishing sector

Researcher: Enya Munting

Supervisor: Dr Anthony Bernard

This letter confirms that the above research proposal has been reviewed and **APPROVED** by the Rhodes University Human Research Ethics Committee (RU-HREC). Your Approval number is: 2022-5931-7221

Approval has been granted for 1 year. An annual progress report will be required in order to renew approval for an additional period. You will receive an email notifying you when the annual report is due.

Please ensure that the ethical standards committee is notified should any substantive change(s) be made, for whatever reason, during the research process. This includes changes in investigators. Please also ensure that a brief report is submitted to the ethics committee on the completion of the research. The purpose of this report is to indicate whether the research was conducted successfully, if any aspects could not be completed, or if any problems arose that the ethical standards committee should be aware of. If a thesis or dissertation arising from this research is submitted to the library's electronic theses and dissertations (ETD) repository, please notify the committee of the date of submission and/or any reference or cataloguing number allocated.

Sincerely,

Dr Janet Hayward

Chair: Rhodes University Human Research Ethics Committee, RU-HREC

cc: Ethics Coordinator

A 2.6.2 ETHICAL CLEARANCE EXTENSION LETTER FOR HUMAN RESEARCH

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16 October 2023

Miss Enya Munting

Email: g22m6910@campus.ru.ac.za

Review Reference: 2023-5931-8133

Dear Miss Enya Munting

Re: Human ethics renewal application: Marine Protected Areas for Fish and Fishers: Investigating the multidimensional effects of KwaZulu-Natal's Marine Protected Area Network on the commercial linefishing sector

Researcher: Miss Enya Munting

Supervisors: Dr Jessica Cockburn ,

This letter confirms that the above Annual Report has been reviewed and **APPROVED** by the Rhodes University Human Research Ethics Committee (RU-HREC). Your Approval number is: 2023-5931-8133

Approval has been granted for 1 year. An annual progress report will be required in order to renew approval for an additional period.

Please ensure that the Human Research Ethics Committee is notified should any substantive change(s) be made, for whatever reason, during the research process. This includes changes in investigators. Please also ensure that a brief report is submitted to the ethics committee on the completion of the research. The purpose of this report is to indicate whether the research was conducted successfully, if any aspects could not be completed, or if any problems arose that the Human Research Ethics Committee should be aware of. If a thesis or dissertation arising from this research is submitted to the library's electronic theses and dissertations (ETD) repository, please notify the committee of the date of submission and/or any reference or cataloguing number allocated.

Sincerely,

Dr Janet Hayward

Chair: Rhodes University Human Research Ethics Committee, RU-HREC

cc: Ethics Coordinator

A 2.6.3 ETHICAL APPROVAL FOR ANIMAL RESEARCH

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https://www.ru.ac.za/researchgateway/ethics/

7 March 2022

Anthony Bernard

Email: A.Bernard@ru.ac.za

Review Reference: 2022-5444-6596

Dear Anthony Bernard

Re: Animal ethics application: Conservation value of the uThukela MPA

Principal Investigator: Dr Anthony Bernard

Collaborators: ,Miss Thembelihle Dube, Miss Jade Vermeulen, Miss Enya Munting

This letter confirms that the above research proposal has been reviewed and **APPROVED** by the Rhodes University Animal Research Ethics Committee (RU-AREC). Your Approval number is **2022-5444-6596.**

Approval has been granted for one year from the date of this letter. **An annual progress report** will be required in order to renew approval for an additional period of one year.

Please ensure that the RU-AREC committee is notified should any substantive change(s) be made, for whatever reason, during the research process. This includes changes in investigators. Please also ensure that a brief report is submitted to the ethics committee on the completion of the research. The purpose of this report is to indicate whether the research was conducted successfully, if any aspects could not be completed, or if any problems arose that the RU-AREC should be aware of. If a thesis or dissertation arising from this research is submitted to the library's electronic theses and dissertations (ETD) repository, please notify the committee of the date of submission and/or any reference or cataloging number allocated.

Sincerely

Dr. Shelley Edwards

Chair: Rhodes University Animal Research Ethics Committee, RU-AREC

cc: Ms Danielle de Vos - Ethics Coordinator