SPATIAL ANALYSIS OF THE IMPACT OF HUMAN ACTIVITIES ON THE MARINE ENVIRONMENT IN ALGOA BAY, SOUTH AFRICA

A THESIS

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by

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DECLARATION

I, **TIDIMALO MAPHOTO**, hereby declare that I have read and understood the University's plagiarism policy. The thesis titled "**Spatial analysis of the impact of human activities on the Marine environment in Algoa Bay, South Africa**" is my original work and has never been previously submitted for assessment at any institution. All secondary sources used in writing this thesis have been acknowledged and referenced following the rules and regulations of Rhodes University.

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I praise the Lord God Almighty for granting me strength through my studies.

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DEDICATION

This thesis is dedicated to my parents.

Ke rata go leboga BaTau boMmalegola Mashego, BaKwena bo Madigage'a chimu le Bakone ba Nchi dikgolo.

May the good Lord richly reward you.

ABSTRACT

Background:
Humans have a long history of using the marine environment in multiple ways and continued use has led to a decline in the ecosystem services provided by marine systems in many places. In addition, human activities have steadily increased with time and advances in technology, further increasing impacts on marine systems. To understand and manage these impacts, we need to assess the spatial distribution and intensity of human activities in the marine environment, and quantify, where possible, their cumulative impacts on marine ecosystems. The spatial consideration of human activities and their associated impacts is important for conservation planning, Integrated Ocean Management and Marine Spatial Planning (MSP) initiatives. The main deliverable of this research study was to develop a cumulative impacts layer of human activities in Algoa Bay, South Africa, to support the Algoa Bay Marine Spatial Planning Project.

Objective and Relevance: This research analyses the spatial impacts of human activities on the Algoa Bay marine environment (excluding the seashore). Algoa Bay is located on the south coast of South Africa in the Eastern Cape. The research explores stakeholders' perceptions of their knowledge of the human activities that take place in the bay. This research is informed by an expert-based geographical information systems (GIS) approach and cumulative impact assessment in order to map the spatial impacts of the activities as part of marine spatial planning. "Experts" were defined as stakeholders that contributed valuable knowledge of the human activities and their impacts; this definition of expert included "professional" and "non-professional" contributors to knowledge. The spatial aspect of the research is a significant contribution to the field as it will help inform decision-making in the Algoa Bay Marine Spatial Planning Project.

Design and Methods: A mixed-method approach was used to generate data. A snowball sampling approach was used to identify research participants from key informants. Primary data were collected through questionnaire surveys, interviews and a focus group. Secondary data sources consisted of GIS data and reports from scientific organizations.

Findings and Conclusion: The research findings indicate that the top three pressures that cause the greatest impact on the Algoa Bay marine environment are fishing, pollution and shipping. The cumulative impact of these activities was highest near harbours in Algoa Bay. The marine ecosystems that were most impacted by pressures were the Agulhas Island and the Agulhas Mixed Shore. The Warm Temperate marine ecosystems had fairly low cumulative impacts. The research findings indicate that there is a complex mix of human activities that impact the marine environment. This research supports the findings of other researchers that reveal that the highest cumulative impact is in areas closer to the coast and harbours owing to high population densities.

Value of Study: This study builds onto the existing data by expanding the knowledge base and including more stakeholders to integrate as many human activities as possible and bring a holistic picture of the ocean's uses to inform MSP in Algoa Bay.

KEYWORDS: Spatial analysis, cumulative impacts, human activities, marine environment, Algoa Bay

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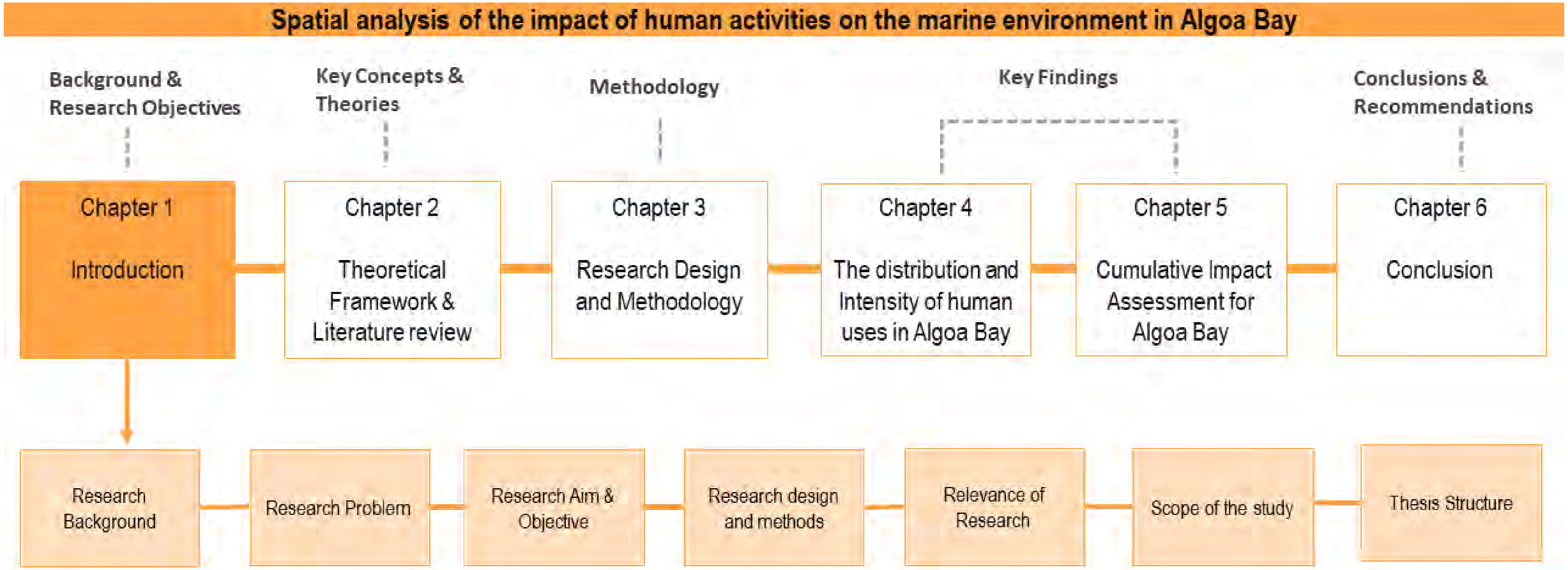
ACRONYMS AND ABBREVIATIONS

AENP	Addo Elephant National Park
AMA	Aquaculture Management Area
CBD	Central Business District
CIA	Cumulative Impact Assessment
CoP	Community of Practice
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphorus
EBM	Ecosystem-Based Management
ECSECC	Eastern Cape Socio-Economic Consultative Council
GIS	Geographic Information Systems
HAB	Harmful Algal bloom
HELCOM	Helsinki Commission (Baltic marine protection)
IDZ	Industrial Development Zone
MPA	Marine Protected Area
MSP	Marine Spatial Planning
NBA	National Biodiversity Assessment
NMBM IWMP	Nelson Mandela Bay Municipality Integrated Waste Management Plan
NMBM	Nelson Mandela Bay Municipality
PE	Port Elizabeth
PU	Planning Unit
SAEON	South African Environmental Observation Network
SCP	Systematic Conservation Planning


Introduction
1



Chapter One Overview

1. INTRODUCTION

1.1 Research Background

The ocean, which provides valuable services to humans, has been treated as an inexhaustible resource through recreation, mining, overfishing, pollution and construction (Ansong et al., 2017). The human uses of the ocean (which are often conflicting) create pressures that occur concurrently, resulting in unexpected ecosystem responses (Parravicini et al., 2012) and threatening the ability of the environment to support marine life (Pınarbaşı et al., 2017).

Ehler & Douvere (2009:18) define Marine Spatial Planning (MSP) as “a public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic and social objectives that are usually specified through a political process”. MSP is considered to be a “suitable” management option as it uses an Ecosystem-Based Management (EBM) approach, which is a “spatially explicit” plan that accounts for the management of multiple pressures (Parravicini et al., 2012). The purpose of EBM is to increase the benefits of the use of the ocean while minimizing the degradation of ecosystems (Crain et al., 2009) and transforming conflicts into solutions (Pınarbaşı et al., 2017).

Since human pressures on the marine environment have a spatial component (Parravicini et al., 2012), mapping and quantifying the spatial distribution of human pressures will help improve our understanding and the management of the impacts of the activities on the marine ecosystem (Halpern et al., 2008; HELCOM, 2010).

This study uses participatory Geographic Information Systems (GIS) to map the social perceptions of human activities within the study area. Participatory GIS integrates local and indigenous knowledge and stakeholders’ perspectives into the GIS tool (Quan et al., 2001). A global assessment of cumulative impacts on the ocean (Halpern et al. 2008), followed by several other regionally focused studies (HELCOM, 2010; Korpinen et al., 2012; Andersen & Stock, 2013; Micheli et al. 2013; Menegon et al., 2018) developed a methodology for filling these knowledge and data gaps. The cumulative impacts method consists of producing maps of the intensity of individual stressors and combining them into maps of cumulative impacts by accounting for differences in ecological vulnerability across marine ecosystems. This cumulative impact approach is valuable to management because it can be used to identify areas that are the most heavily impacted as well as the least impacted areas. It can inform managers which pressures should be of greatest concern in different areas, and it can help planning efforts by providing information about which pressures are the most harmful to different marine ecosystems, as well as which marine ecosystems are the most impacted across a given study area. In this study, the products and findings from this approach will be used to build onto the existing data by expanding the knowledge base, including more stakeholders (Curtin & Prellezo, 2010), integrating as many uses as possible (Olsen et al., 2014), and bringing a holistic picture of the uses of the ocean.

1.2 Problem Statement

The global oceans are heavily impacted by the increasing pressures caused by human activities. The decline in marine services and resources has led to an interest in MSP to manage and achieve sustainability of the marine environment (; Foley et al., 2010; Ban et al., 2013a). Halpern et al. (2015) found that within the two-thirds of the ocean experiencing an increase in stress, five per cent of the world's oceans are heavily impacted by human activity and require immediate attention.

Algoa Bay has recently had a new Marine Protected Area declared (the Addo Elephant National Park Marine Protected Area), but there is little understanding of the impacts of human activities in the bay and thus in the MPA. This study will help with management planning for the new MPA. Secondly, the Algoa Bay Project (2019) is developing a Marine Spatial Plan for the bay. More fine-scale information on human uses, the intensity of these uses and their impact on biodiversity in the bay are needed to inform this MSP**.** The National Biodiversity Assessment (NBA) has conducted studies in 2011 and 2018 (Sink et al., 2012; 2019)**,** but the scale of the work is broad. As a result, finer-scale (higher resolution) data are needed. The Algoa Bay Systematic Conservation Planning (SCP) report (Algoa Bay Project, 2019) collected all available data on human uses in Algoa Bay. Some of the data layers included expert data, which provided a base for this research. This study will build onto the existing data by expanding the knowledge base, including more stakeholders, integrating as many uses as possible and building a holistic picture of the uses of the ocean.

1.3 Research Aim and Objectives

The research aims to investigate the spatial distribution of human activities and their impacts on the Algoa Bay marine environment.

1.3.1 <u>Research Questions</u>

a) What are the human activities and their spatial distribution in Algoa Bay?
b) What is the impact of human activities on the marine ecosystems in Algoa Bay?

1.3.2 Objectives

To assist with the development of a MSP for Algoa Bay outlined by Dorrington et al. (2018), the research objectives for this study are as follows:

a) To identify and map the spatial extents and intensities of human pressures in Algoa Bay.
b) To adapt a pressure-ecosystem matrix that reflects the relative, assumed impact of each pressure on the marine ecosystems.
c) To create a spatially explicit Cumulative Impact layer for Algoa Bay.

1.4 Research Methodology

The overall design of this study was based on a mixed-methods design. A mixed-methods design is a research design where the investigator collects, analyses and presents data using both quantitative and qualitative approaches in a single study (Tashakkori & Creswell, 2007). This mixed-methods approach was used as a means to understand the impacts of human activities on the Algoa Bay marine system.

The rationale behind adopting a mixed-methods approach in this study is the recognition that marine issues resulting from human activities can be understood through a combination of both quantitative and qualitative data. Combining the methods and data will bring about a more comprehensive understanding of the research questions and provide a more nuanced and detailed understanding of the particular space of Algoa Bay's global marine ecosystem. Browne-Nuñez & Jonker (2008) state that an approach that uses mixed methods will strengthen and improve the results of the study. This research emphasises the generation of data, specifically GIS data, that can be used in other stages of the Algoa Bay MSP Project.

Primary data were obtained from questionnaire surveys, interviews, focus groups and expert mapping. Secondary data were obtained from the 2018 NBA (Sink et al., 2019) and SCP (Algoa Bay Project, 2019) reports and through GIS datasets from scientific organizations. Qualitative and quantitative data analyses were performed on the data, followed by data integration and comparison. Figure 1.1 illustrates the research design flow used in this study. A detailed explanation of these methods used in this research is described in Chapter Three.

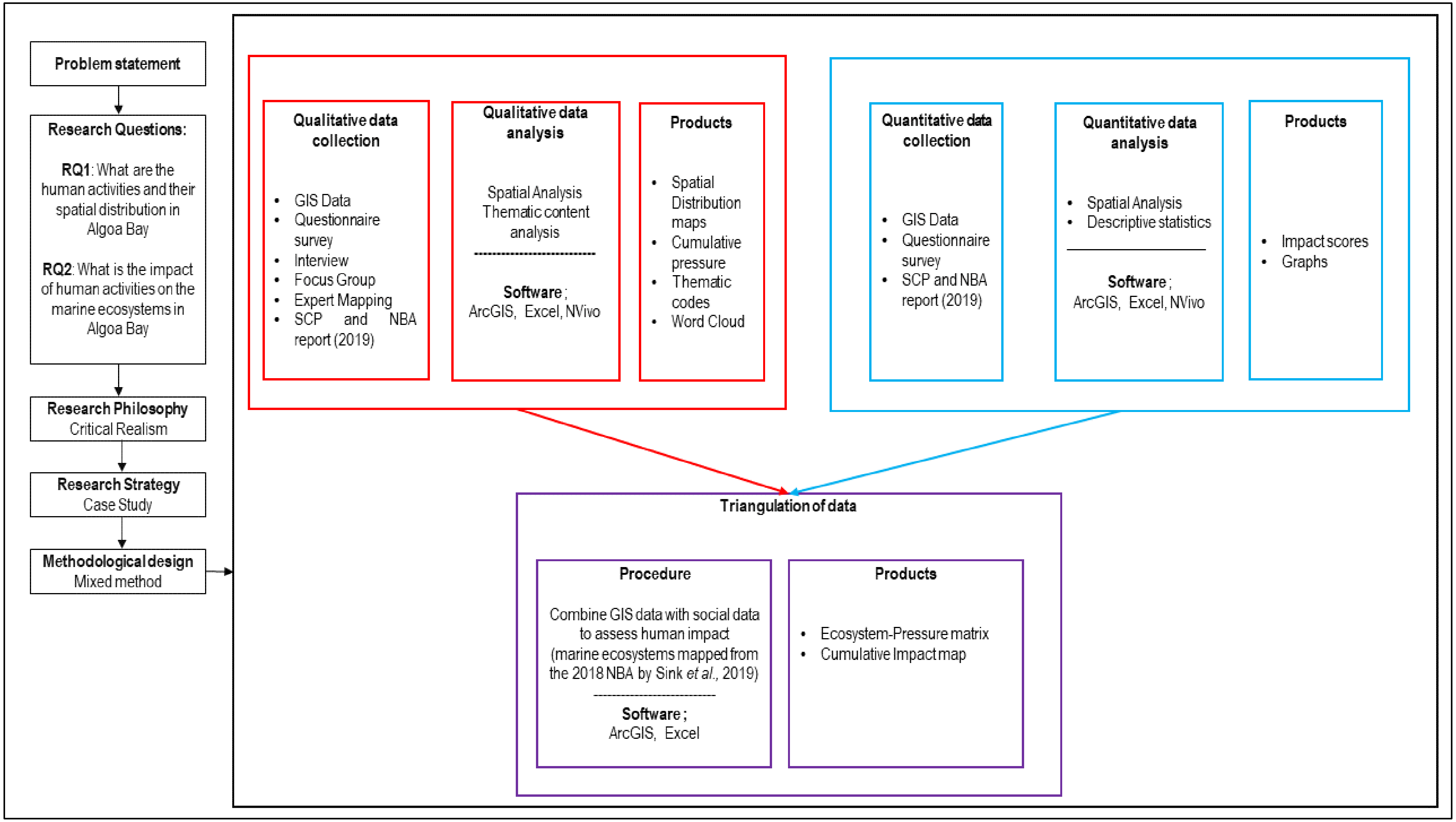


Figure 1. 1: Research Design flow for this study.

1.5 Relevance of Research

The decline in marine services and resources has led to an interest in MSP to manage and achieve sustainable use of the marine environment (Ban et al., 2013a; Foley et al., 2010).
This study will contribute to a better understanding of the impact of human activities on marine systems in Algoa Bay. Additionally, the study will build on the knowledge gained from the 2018 National Biodiversity Assessment (NBA) by Sink et al. (2019) – the NBA is part of South Africa's first MSP project – by assessing and investigating the impact of human activities as pressures on the marine environment in Algoa Bay. The findings of this project will contribute new knowledge on the socio-ecological systems of Algoa Bay, which is a need identified by Dorrington et al. (2018).

1.6 Scope of the Study

1.6.1 Study Area

Algoa Bay situated between the Cape Padrone (33°46′ S, 26°28′E) and Cape Recife(34°02′ S, 25°42′E) ,is a multi-use coastal zone with various recreational and commercial interests (Algoa Bay Project, 2019). It is a marine biodiversity hotspot that is situated on the south-east coast of South Africa in the Eastern Cape Province. The Bay is located between the Agulhas and Benguela currents - which are the major oceanic systems of the southern ocean (Goschen & Schumann, 2011). Socio-economic activities in the coastal zone, such as fisheries, shipping and coastal tourism, have been identified as major threats to biodiversity objectives in the southern Benguela and Agulhas Bank ecosystems along the coast of South Africa (Grantham et al., 2011). Figure 1.2 shows the location of the study area.

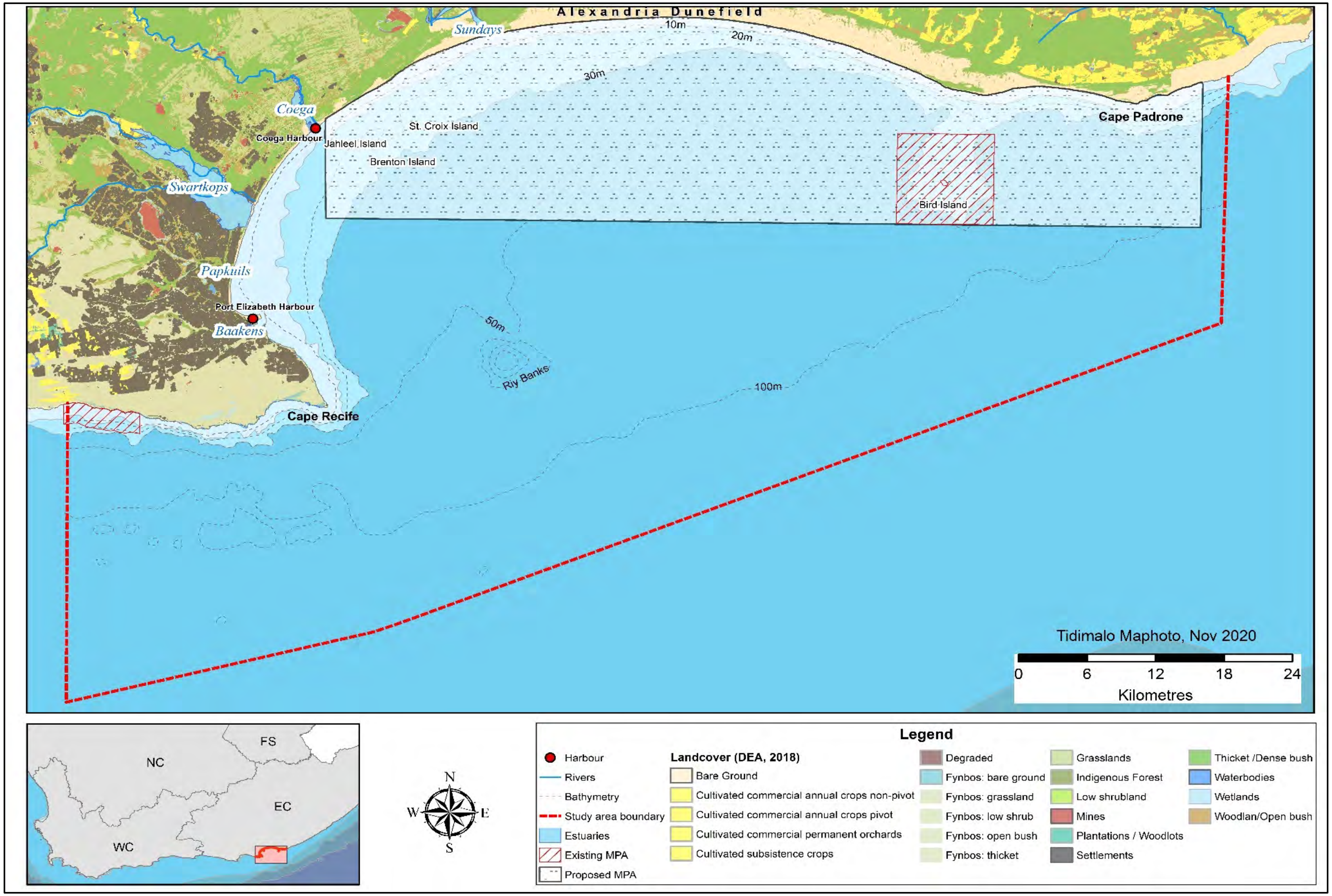


Figure 1. 2: The features and location of the study area in Algoa Bay, South Africa.

1.6.2 Definitions of Terms

This study contains specific key terms defined in this section to ensure that the reader makes sense of what is presented in the following chapters.

Human uses: Human uses are defined as human actions and activities that have the potential to create pressure on the marine ecosystems (Dailianis et al., 2018). Human uses and human activities are used interchangeably in this study.

Human pressures: Human pressures refer to the mechanism by which human uses have an impact on the marine environment (Dailianis et al., 2018). Human pressure and pressure are used interchangeably in this study.

Experts: Experts refer to all the participants that took part in this study. This includes stakeholders, scientists, and practitioners as defined by Perera et al. (2012).

1.7 Structure of the Thesis

This thesis consists of six chapters. Chapters 4 and 5 are written in a format that lends itself to the preparation for publication. Therefore, they are written in a way that may seem repetitive in order to give a coherent representation of the full thesis content. Figure 1.3 presents the overall structure of the thesis.

1.7.1 Chapter One: Introduction

This chapter provides an introduction to the study by outlining the background, the rationale, problem statement, aims and objectives, the methodology followed and the significance and contributions of the study.

1.7.2 Chapter Two: Theoretical Framework and Literature Review

This chapter provides the theoretical underpinnings of the research as well as a review of the literature. The review includes an examination of work that has contributed to the methodological approach used in the study.

1.7.3 Chapter Three: Research Design and Methodology

This chapter presents an in-depth elaboration of the methods and strategies used in conducting this research and fulfilling the objectives.

1.7.4 Chapter Four: The Distribution and Intensity of Human Uses in Algoa Bay

This chapter examines the use of the ocean by humans. It addresses objective 1 by presenting the methods for collecting data and analysing the spatial distributions of the activities in Algoa Bay. This chapter also presents some of the spatial distributions of these activities and a discussion thereof.

1.7.5 Chapter Five: Cumulative Human Impact Assessment for Algoa Bay

This chapter addresses objectives 2 and 3 of the research by providing the method of assessment of the impacts of the human activities as pressures on Algoa Bay's marine environment. This chapter also presents the results of this assessment and a discussion thereof.

1.7.6 Chapter Six: Conclusion

This chapter concludes by providing the framework derived from this research and a conclusion to the research findings. This chapter also highlights the limitations of this study and provides recommendations for future research.

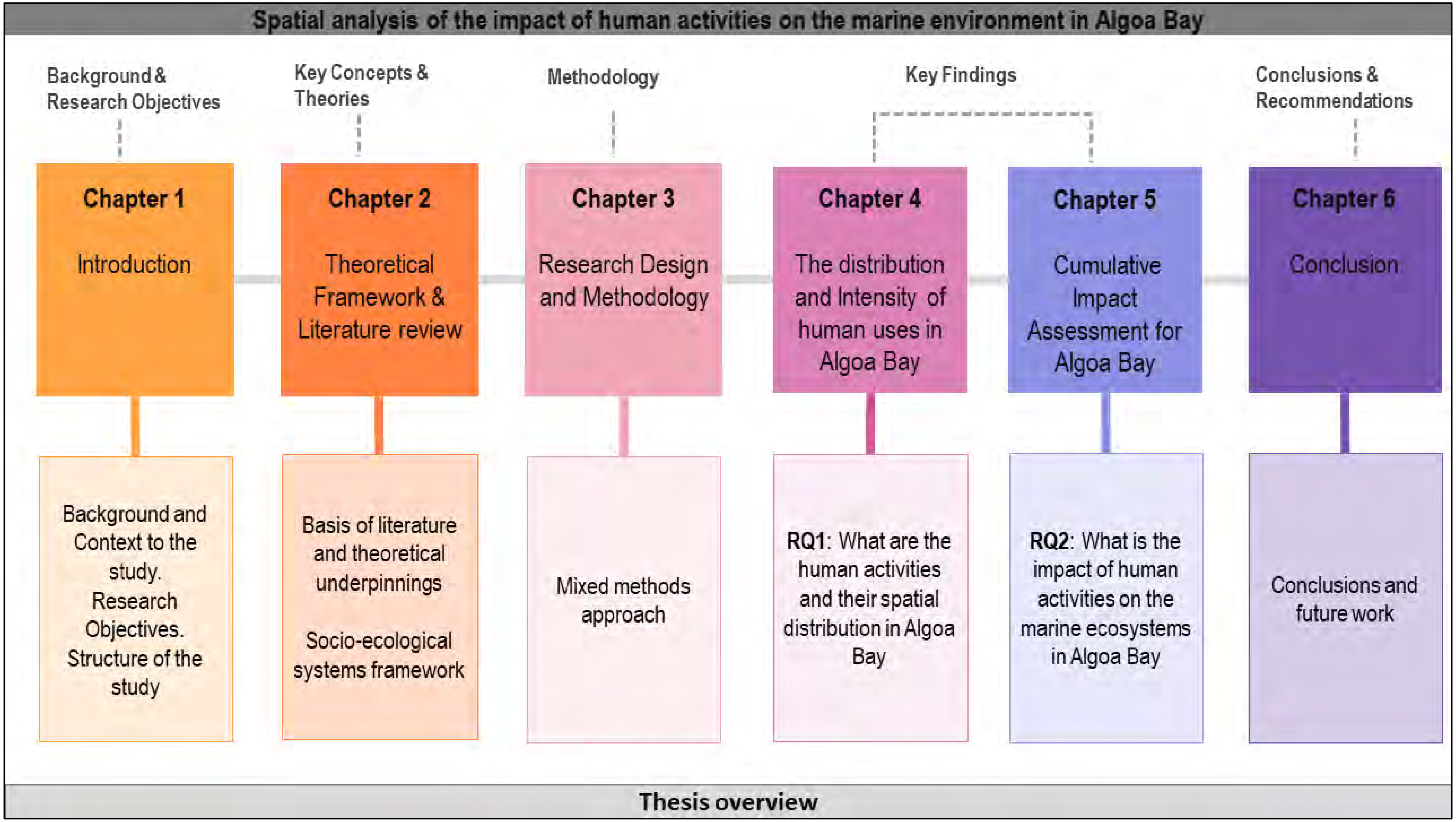
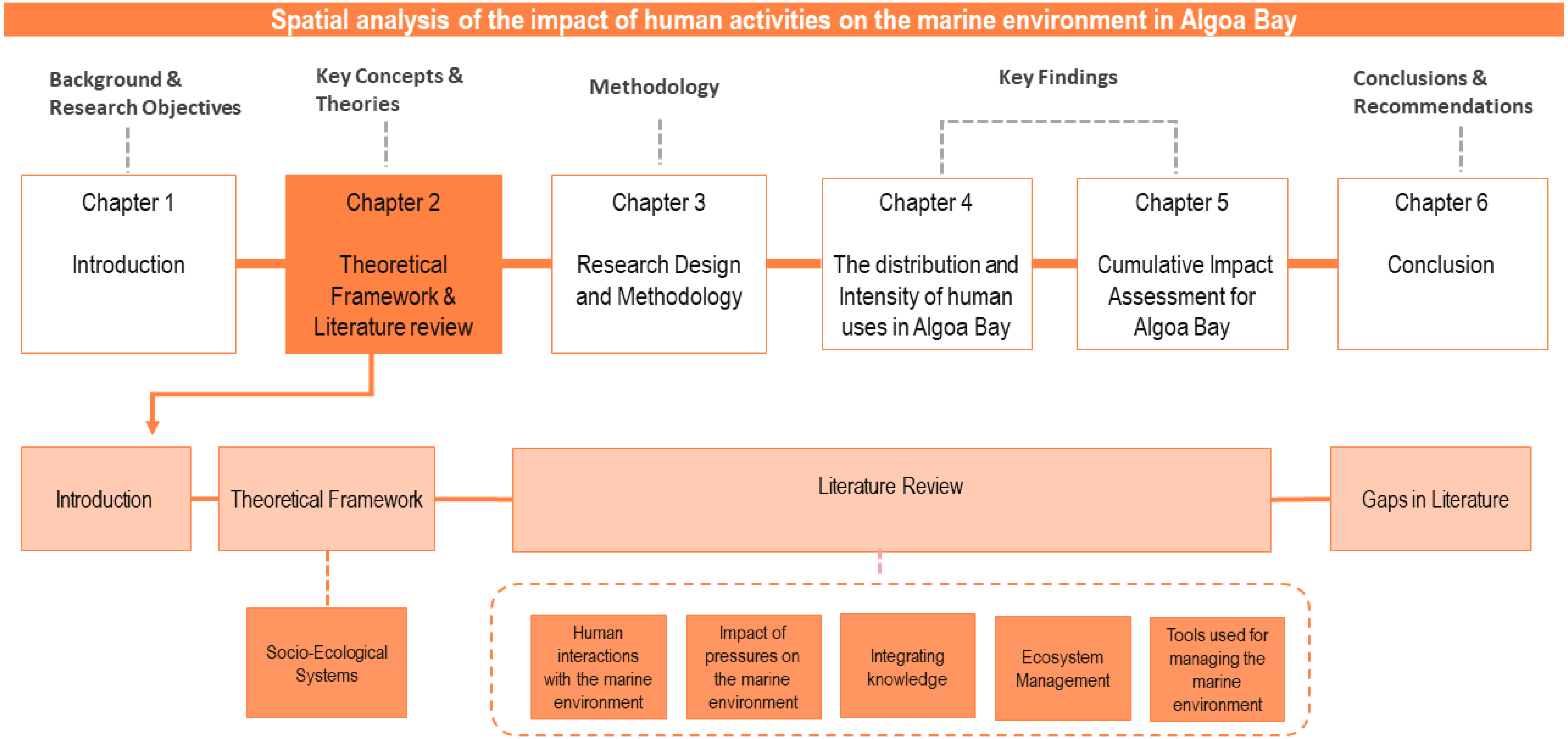


Figure 1. 3: Outline of Chapters.


Theoretical Framework &
Literature Review
2



Chapter Two Overview

2. THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1 Introduction

The chapter presents studies that used socio-ecological systems theory and further clarifies why this theory was selected for the study. The reviewed literature is on the important themes and concepts arising from the theoretical framework.

2.2 Theoretical Framework

Researchers have used various theories as the theoretical and conceptual basis in marine research. This chapter presents the relevant theories and the related literature upon which the study is built. In understanding the impacts of human uses on the marine environment, the socio-ecological systems theory, as shown in Figure 2.1, is proposed by looking at the DPSIR (Driver-Pressure-State-Impact-Response) framework as the conceptual framework for analysis. The chapter presents studies that used socio-ecological systems theory and further clarifies why this theory was selected for the study. The reviewed literature is based on the important themes and concepts arising from the theoretical framework.

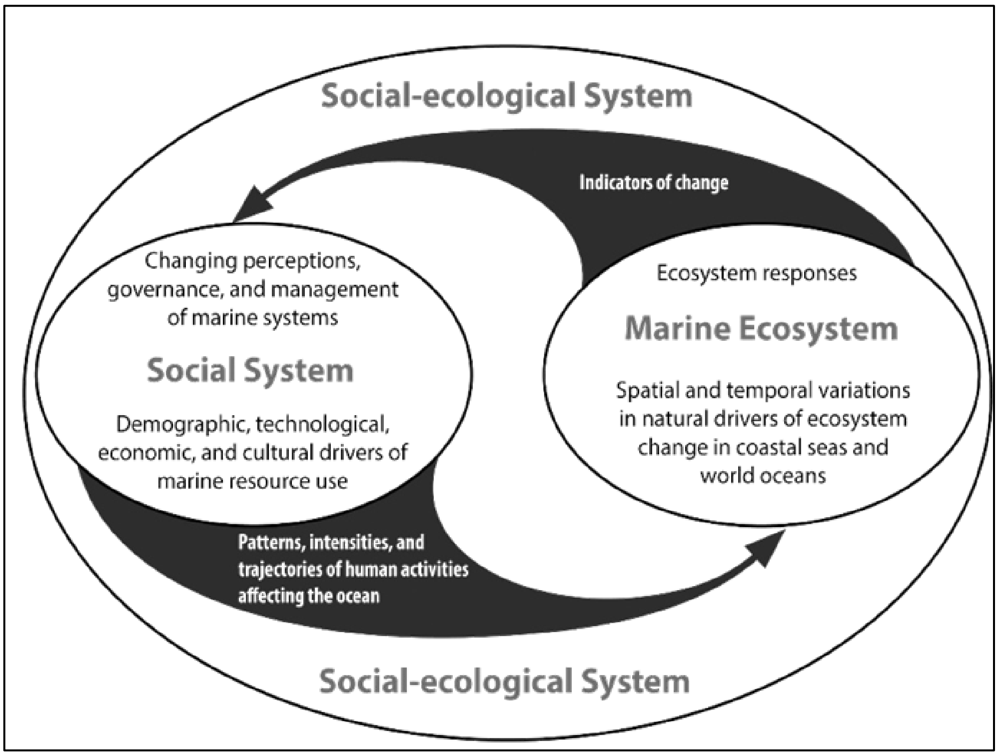


Figure 2. 1: Socio-Ecological Systems (Schwerdtner Máñez et al., 2014).

2.2.1 Socio-Ecological Systems

The growing human influences on biophysical processes have led to many perceived environmental problems (Anderies et al., 2004). According to Bousquet et al. (2005), different scholars have been conducting research on socio-ecological systems (SES) to understand various types of relationships between the environment, management and society. SES are multilevel, nested systems that provide essential services to society (Berkes & Folke, 1998). Other terms used to denote such systems are "socio-ecological system" (Anderies et al., 2004) or "human-environment system" (Scholz & Brand, 2011).

Scholz & Brand (2011) identified the following three forms of interaction between the ecological (E) and the social (S) systems:
E $\rightarrow$ S: the ecological system influences the social system. A vulnerability framework is proposed in this interaction, where the ecological system affects the social system (Binder et al., 2013). The ecological system is viewed from an anthropocentric perspective (Binder et al., 2013)

S $\rightarrow$ E: human activities affect the ecological system or ecosystem services. In this interaction, a policy and ecocentric framework are proposed. In the policy framework, human activities affect the ecological system, and changes to the ecological system affect the social system; an example of this is the DPSIR framework. DPSIR measures the state of the environment over time (Binder et al., 2013). The ecological system is viewed from an anthropocentric perspective (Binder et al., 2013). Human activities affect the ecological system in the ecocentric framework, and direct feedbacks from the ecological to the social system are not considered (Binder et al., 2013). The ecological system is viewed from an ecocentic perspective (Binder et al., 2013).

S $\leftrightarrow$ E: the reciprocity between the social system and the ecological system is considered, including feedback loops and learning processes in the social system in response to changes in the ecological system. In this interaction, an integrative framework is prosed, this includes different feedbacks within the social system and between the social and ecological system in different time and scale (Binder et al., 2013). The ecological system is viewed from an anthropocentric perspective. An example of this is the Human-Ecological systems (HES) framework (Binder et al., 2013). The HES framework has been developed as a "heuristic" tool for structuring the study of human-environment interactions (Scholz & Brand, 2011).

The HES framework can be applied to studies where human-environment interactions are important and are applicable at any scale (Binder et al., 2013).

Cumming (2014) asserts that any theoretical framework to describe issues in real-world SESs must cover observed patterns and processes of interest and a self-conscious analysis of the research process because in a social system, the process of research influences the results. Most theoretical frameworks for SESs are generally hierarchical, with different degrees of the same theory explaining different aspects of the research study in different levels of generality (Cumming, 2014). Binder et al. (2013) emphasize that it should be clear to what extent frameworks treat the human and the ecological dimension in equal depth and include their co-development. The overall lack of theoretical connection in SESs research makes it challenging, amongst additional points, to identify communication within the research of SESs makes it generalisations between case studies to choose the conceptual importance of separated scientific findings (Cumming, 2014). Binder et al. (2013) established frameworks for analysing socio-ecological systems based on the following criteria;

i. whether a framework conceptualizes the relationship between the social and ecological systems as being uni- or bidirectional
ii. whether it takes an anthropocentric or an ecocentric perspective on the ecological system
iii. whether it is an action-oriented or an analysis-oriented framework.

These analysis frameworks of SESs were further expanded and organised by Cumming (2014) into following the five categories,

a) assessment-oriented frameworks: these frameworks help the society to think about a system in a structured way. They are used to outline key characteristics of a socio-ecological system with the aim of describing it.
b) action-oriented frameworks: these frameworks suggest a particular program of action by a well-established set of actors in response to a certain problem. They are centred on applying remedies rather than establishing the causes of the problems.
c) hypothesis-oriented frameworks: these frameworks are often quite particular, centering on pairs of variables or clearly defined theoretical concerns/questions.
d) problem-oriented frameworks: these frameworks initiate and facilitate the process of solving a problem. They focus on the processes of identifying the problem and problem solving, other than prescribing the actual actions that are to be taken. They are also concerned with applying the theory in specific instances through collective procedures.
e) theory-oriented or overarching frameworks: these frameworks attempt to describe and connect different pieces of theory within a certain area of analysis.

2.2.1.1 The DPSIR Framework

The Pressure-State- Response (PSR) framework, as shown in Figure 2.2, was proposed in the late 1970s, and promoted by the Organization for Economic Cooperation and Development in the early 1990s for its environmental monitoring (Smith et al., 2016). The PSR was then re-evaluated and extended to the Pressure-State-Impact-Response (PSIR) framework to include the improved understanding of causes and suitable responses to impacts of human activities on the environment along the causal-effect chain (Binder et al., 2013).

In the late 1990s, the EU then adopted the Driver-Pressure-State-Impact-Response (DPSIR) framework as an overall mechanism for analysing environmental problems (Smith et al., 2016). Cumming (2014) classified the DPSIR framework as an action-oriented framework, that has been central to conceptualising marine environment issues and translating those to stakeholders, environmental managers and researchers (Smith et al., 2016).

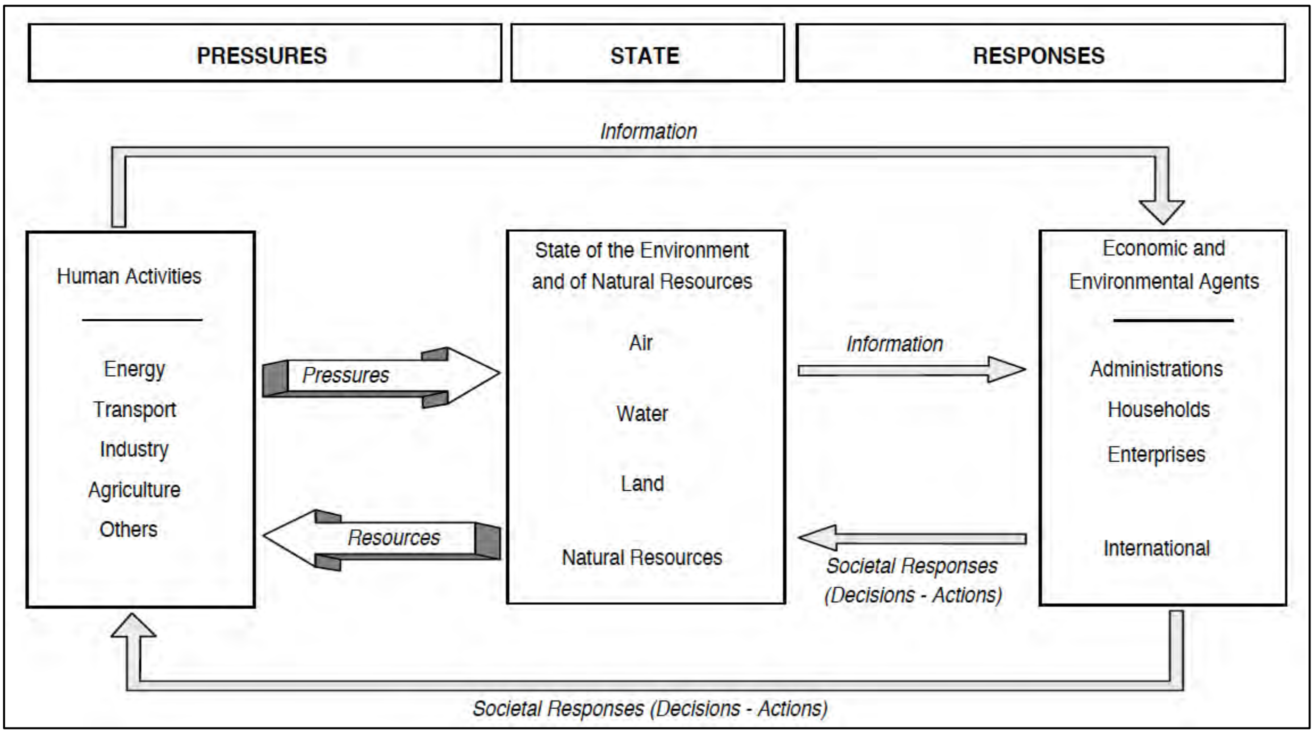


Figure 2. 2: PSR Framework (Smith 2016 citing OECD, 1993).

The DPSIR Framework provides a basic view of large-scale influences on the marine system (Agardy et al., 2005). The DPSIR framework has been applied broadly in Integrated Environmental Assessment such as coastal zones (Palmer et al., 2011; Delgado et al., 2021b; Labianca et al., 2021) water (Baer & Lehmann, 2012; Delgado et al., 2021a), Biological Conservation (Roura-Pascual et al., 2009), marine systems (Perry et al., 2010; Atkins et al., 2011), MPA (Ojeda-Martínez et al., 2009) and to support MSP (Furlan et al., 2020), with DIPSI (Driver-Pressure-State-Impact) adopted by (Gimpel et al., 2013) in MSP studies.

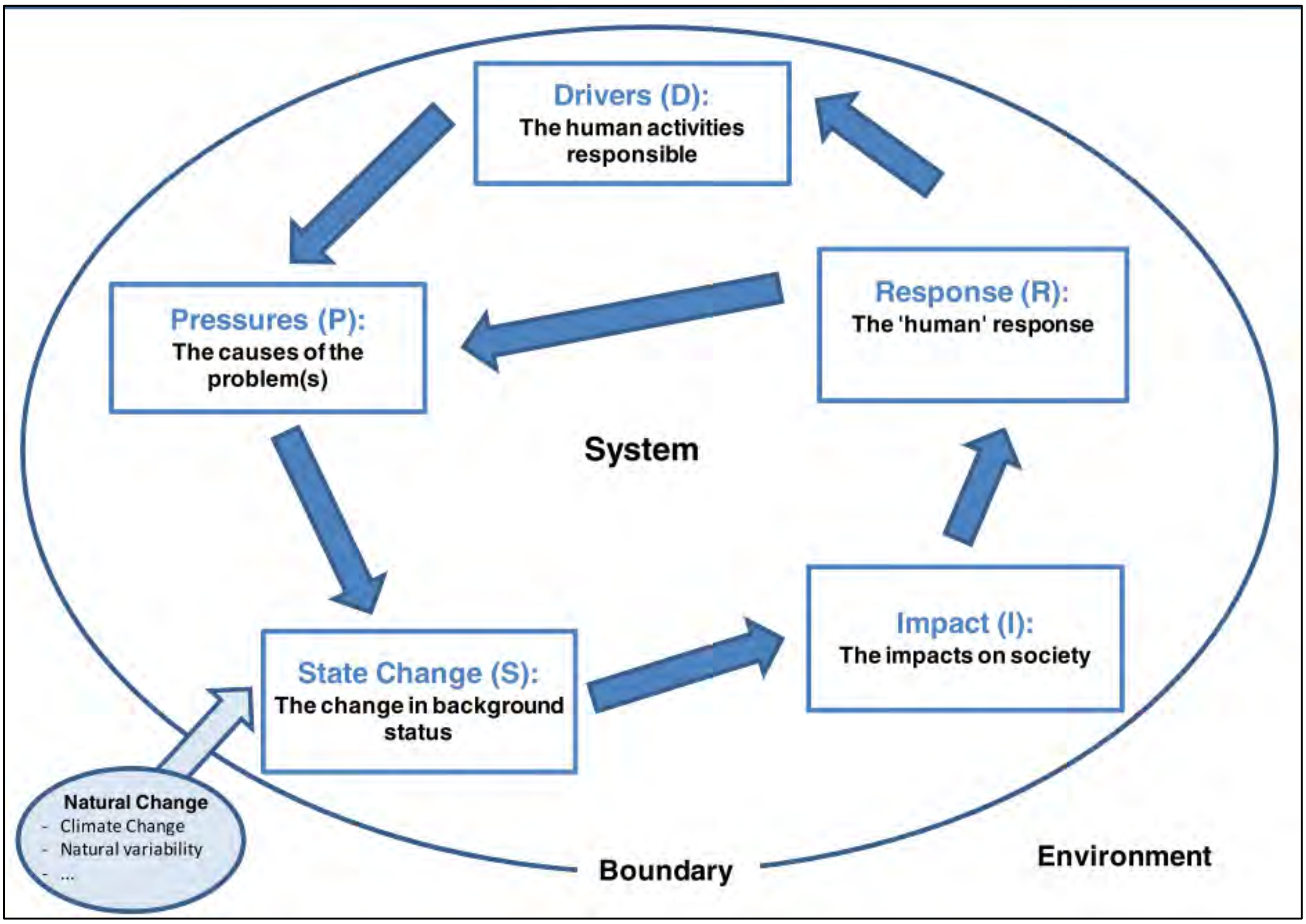


Figure 2. 3: Components of the DPSIR Framework as a cycle and system in the environment (Atkins et al., 2011).

2.3 Literature Review

Understanding the impact, both direct and indirect, of human activities on the marine environment is essential in defining the human-derived pressures and assessing the distribution and intensity of the activities on the marine environment. This research looks at how the continuous interaction with the use of the ocean's resources impacts the marine environment, which can either be direct or indirect. Therefore, the purpose of reviewing this literature is to gain an understanding of the issues surrounding the human impact of human activity on the marine environment.

2.3.1 Human interactions with the marine environment

The description of the social system starts with the people (Berkes & Folke, 1998). The use of the ocean's valuable services and resources by humans is increasing globally, resulting in pressures that change the marine ecosystems and their functionality (Parravicini et al., 2012). The users have modified the oceans through direct and indirect uses resulting in the destruction of natural habitats and a change of species composition. The increase in human reliance on marine environments is enabled by the technological advances that allow marine resources to be accessed and exploited (Benn et al., 2010).

The analysis of interactions requires a focus on feedback mechanisms (Berkes & Folke, 1998). Understanding how humans interact with the Marine environment is important, as it helps us with the assessment of impacts of human activities on the environments and the formulation of marine management plans. The interaction of human activities with the ecosystems is through drivers of change, often referred to as "stressors" (Selkoe et al., 2009). Human activities have an impact on the marine environment through chemical, biological and physical changes (Ban & Alder, 2008). Assessing the relationships between human activities and their ecological impacts, as well as their distribution is essential in managing the marine ecosystems in a way that increases socio-economic benefits while reducing the degradation of the ecosystems (Selkoe et al., 2009). Human activities have various intensities of impact on ecological ecosystems, as well as in their distribution across the ocean (Halpern et al., 2008).

2.3.1.1 Drivers of marine ecosystem change

Climate change has been identified as a key global driver of marine ecosystem change (Gissi et al., 2021; United Nations, 2019), as it impacts all dynamics of marine biodiversity at multiple spatial and temporal scales (IPCC, 2019). Additional global drivers of marine ecosystem change were identified as overfishing, marine pollution, change in sediment load, introduction of alien species (Gissi et al., 2021; United Nations, 2019), shipping and cultural services (IPCC, 2019).

Within the South African context, Mead et al. (2013) identified the following human-induced drivers of global coastal change: regional climate change, species introduced to coastal waters, coastal development, changes in specific ecosystems caused by invasive species, the exploitation of marine resources as well as pollution. Similar regional drivers of change were identified in a study by Moloney et al. (2013) as fishing, climate change, pollution, ocean acidification and mining.

A regional scale study by Sink et al. (2012), identified 27 different anthropogenic activities and drivers of ecosystem change and mapped the cumulative pressures that impact South Africa's marine environment. The study by Sink et al. (2012) was refined in 2018, whereby 31 human activities were mapped. The improvements that were made to the 2018 NBA were the fine scale mapping of the pressures and addition of a few more pressures into the assessment (Sink et al., 2019). As a result, this research project will refine and use the methodology at a local scale and high resolution for the marine spatial plan of Algoa Bay, thereby adding to and improving the existing data.

Assessing the relationships between human activities , their ecological impacts and their distribution is essential in managing the marine ecosystems in a way that increases socio-economic benefits while reducing the degradation of the ecosystems (Selkoe et al., 2009). Branch & Branch (2018) illustrated the interactions of humans with the marine environment in Figure 2.4.

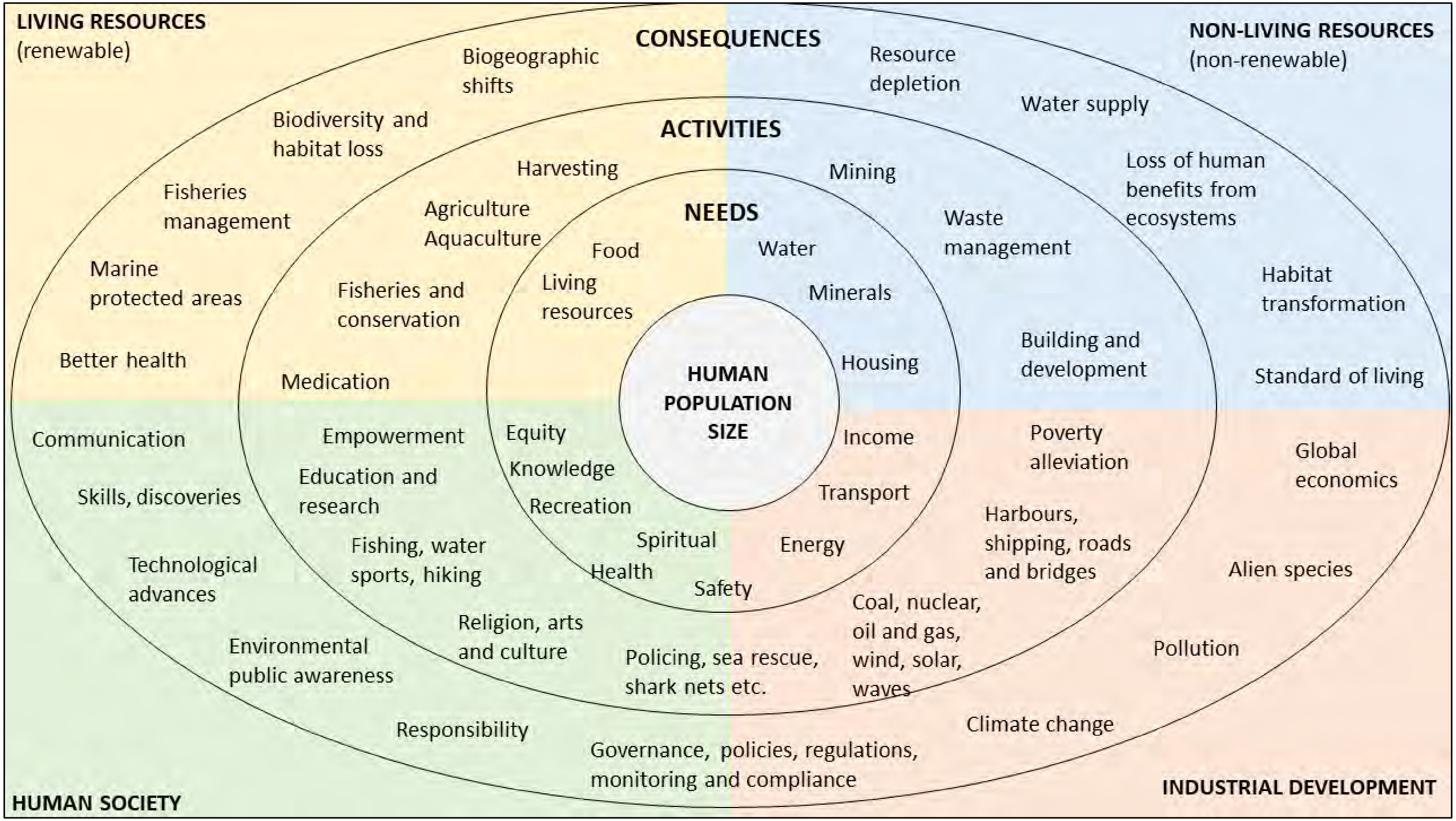


Figure 2. 4: Interactions of humans with the environment (Branch & Branch, 2018).

Early literature by Hodgson (1999) identified that there is a poor understanding of how marine ecosystems respond to human activities on a regional and global scale. Our understanding was improved by Halpern et al. (2008), who determined the ecological impacts of human activities on the oceans. The method of converting human activities into “ecosystem-specific” habitats is vital in determining the ecological impact of human activities on the oceans (Halpern et al., 2008).

2.3.2 The impact of human uses on the marine ecosystems

Human uses exert a wide range of pressures on marine ecosystems, often resulting in the loss of species and degradation of habitats (Dailianis et al., 2018). Over time, there has been a decline in marine services and resources (Ban et al., 2013a). A study by Osterblom et al. (2016) revealed that with the complexity of human uses on the ocean, the marine environment remains severely impacted, resulting in a loss of resilience. A few studies have highlighted a positive relationship between pollution and decreases in diversity and abundance (Johnston & Roberts, 2009; McKinley and Johnston, 2010) and changes in some functional and ecological groups (Henriques et al., 2013; Oug et al., 2012).

2.3.3 Integrating Social Knowledge into the management of the marine environment

2.3.3.1 The society’s perception of pressures and impacts on the marine environment

Local-level systems and traditional resource management systems can improve the management of ecosystems (Berkes & Folke, 1998). Incorporating different knowledge systems is important in planning, designing and implementing management of the marine environment. Berkes & Folke (1998: 4) defined Traditional ecological knowledge (TEK) a s a “cumulative body of knowledge and beliefs, handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment; used here as a subset of indigenous knowledge”.

Indigenous knowledge (IK) was defined as “local knowledge held by indigenous peoples, or local knowledge unique to a given culture or society; used here interchangeably with traditional knowledge.” (Berkes & Folke, 1998). Perera et al.'s (2012: 3) definition of experts involves four key categories of individuals, namely; “scientists, who conduct research and publish their knowledge formally; practitioners, who apply scientific knowledge management but typically do not conduct research and publish their knowledge formally; stakeholders, who have an interest in the outcome of applying ecological knowledge to inform conservation or resource extraction issues; and elders of local societies (aboriginal or other) who are rich sources of traditional knowledge". Expert knowledge will be used in this study to describe all forms of knowledge as described by Perera et al. (2012).

Various scholars have investigated the public perceptions of the marine environment (Gkargkavouzi et al., 2019; Jefferson et al., 2014; Lotze et al., 2018; Manson et al., 2021). (Jefferson et al., 2014) emphasized that a challenge in studies on public perceptions of the marine environment is that they do not provide a societal definition of marine health, nor do they identify how to connect ecological and societal perspectives of marine health.

Gkargkavouzi et al. (2019) revealed that a review of public perceptions within the marine context identified pollution, farming and fishing and climate change as top threats. Gkargkavouzi et al. (2019) noted that these perceptions could most likely be attributed to media campaigns with a focus on conservation-related issues.

Jefferson et al.'s (2014) study on the public perceptions of subtidal species and marine health revealed litter as the greatest threat and indicator of the poor health of the marine ecosystem. Jefferson et al. (2014) highlighted that a challenge in achieving increased and higher quality public engagement with marine issues is the spatial and cognitive disconnection between society and the marine environment.

2.3.3.2 Adding social data into cumulative impact mapping

Knowledge of pressure sources and impacts on ecosystems is important not only for a better understanding of the ecosystem responses to pressures but also in order to formulate effective prevention or management measures (Batista et al., 2014). Expert knowledge is an example of a human dimension used to assess the impact of human uses on the marine environment where empirical data is scarce in impact assessments (Jones et al., 2018). While the assessment and management of marine resources have focused on the biophysical environment - which is extensively mapped due to the spatial component - the human dimensions have remained undocumented in the spatial analysis (St. Martin & Hall-Arber, 2008).

A study by St. Martin & Hall-Arber (2008) examined how the social landscape of the marine systems are being included in MSP. The study suggests that including spatial analytical techniques and participatory research such as interviews and workshops will result in essential layers of qualitative information that will help with MSP since GIS is limited in representing social processes.

However, St. Martin & Hall-Arber (2008) warned that without the knowledge of the human landscapes in the marine environment, there would be continuous resistance to the management of the marine environment. The advantage of combining spatial data and quantitative expert input provides a systematic foundation for ecosystem-based management (EBM) as it uses a holistic approach in assessing the impacts of human uses on the marine environment (Teck et al., 2010).

2.3.4 Ecosystem Management

2.3.4.1 Ecosystem-based management as an approach for marine spatial planning

Ecosystem-based management (EBM) involves managing the ecosystem, taking into consideration all components, pressures and impacts (Olsen et al., 2014). This approach has grown consistently over the last number of decades as part of natural resource management (Curtin & Prellezo, 2010). Curtin & Prellezo (2010) highlighted that EBM broadened the scope of traditional resource management to consider a wide range of ecological, human and environmental factors in using and exploiting marine resources.

An example of this ecosystem-based management approach is Marine Spatial Planning (MSP). MSP provides a practical approach that deals with issues of multiple uses and multiple cumulative impacts on the ocean (Olsen et al., 2014). MSP is a plan that informs the spatial distribution of marine activities to support current and future uses of the marine environment and maintain ecosystem resources to meet economic, ecological and social objectives (Ban et al., 2013b).

The importance of protecting and conserving the marine environment is to introduce a framework that looks at the management of the environment and human uses that can have an impact on the threatened and declining marine resources (Peckett et al., 2014). Peckett et al. (2014) suggest that a MSP can be helpful in protecting a portion of biodiversity in the most efficient way that will reduce the potential conflict with other sea users. Combining ecological and human use data is vital in identifying overlapping biodiversity conservation and multiple-use interests for the sea (Ban et al., 2013b). Peckett et al. (2014) identified an issue in marine planning: the availability of biological species data and detailed habitat maps for the marine environment.

2.3.4.2 Assessing the cumulative impacts of human uses

Quantifying and understanding the impacts through mapping their spatial distribution is essential in evaluating the conflicting human uses of the oceans as well as protecting the ocean's ecosystems (Halpern et al., 2008). According to Halpern et al. (2008), the mapping of human uses as cumulative pressures will improve the spatial management of human uses.
The spatial patterns and overlaps of threats are required in an effective regional-scale marine plan (Selkoe et al., 2009). In their study, Selkoe et al. (2009) emphasised that mapping cumulative human impacts requires collecting three types of data:

(1) maps of the intensity of human uses and stressors,

(2) habitat/ecosystem maps,

(3) ecosystem vulnerability weights on how ecosystems are affected by each stressor.

Cumulative pressure mapping provides valuable information on spatial patterns of human impacts as well as the marine ecosystem's carrying capacity. Therefore, this tool is extremely useful in management approaches to MSP as it can point decision-makers in the direction of where reductions in human pressures should be (Fernandes et al., 2017). Cumulative impact mapping requires human stressor distribution and intensity maps, marine ecosystem maps and vulnerability stress weight scores (Selkoe et al., 2009; Kappel & Halpern, 2012).

In their study, Clarke Murray et al. (2015b) argued that the limitation in mapping cumulative impacts is the absence of good, update-to-date and high-resolution datasets. Because of these limitations, analysis often includes uneven human activity data with different timescales and resolutions. Even with the limitations highlighted, Clarke Murray et al. (2015b) state that cumulative pressure mapping remains essential and useful for effective regulation and management of human uses as well as identifying areas of restoration and areas for protection. Figure 2.4 shows different projects (global and local) followed and modified using the standardised method by Halpern et al. (2007; 2008) in managing the marine environment.

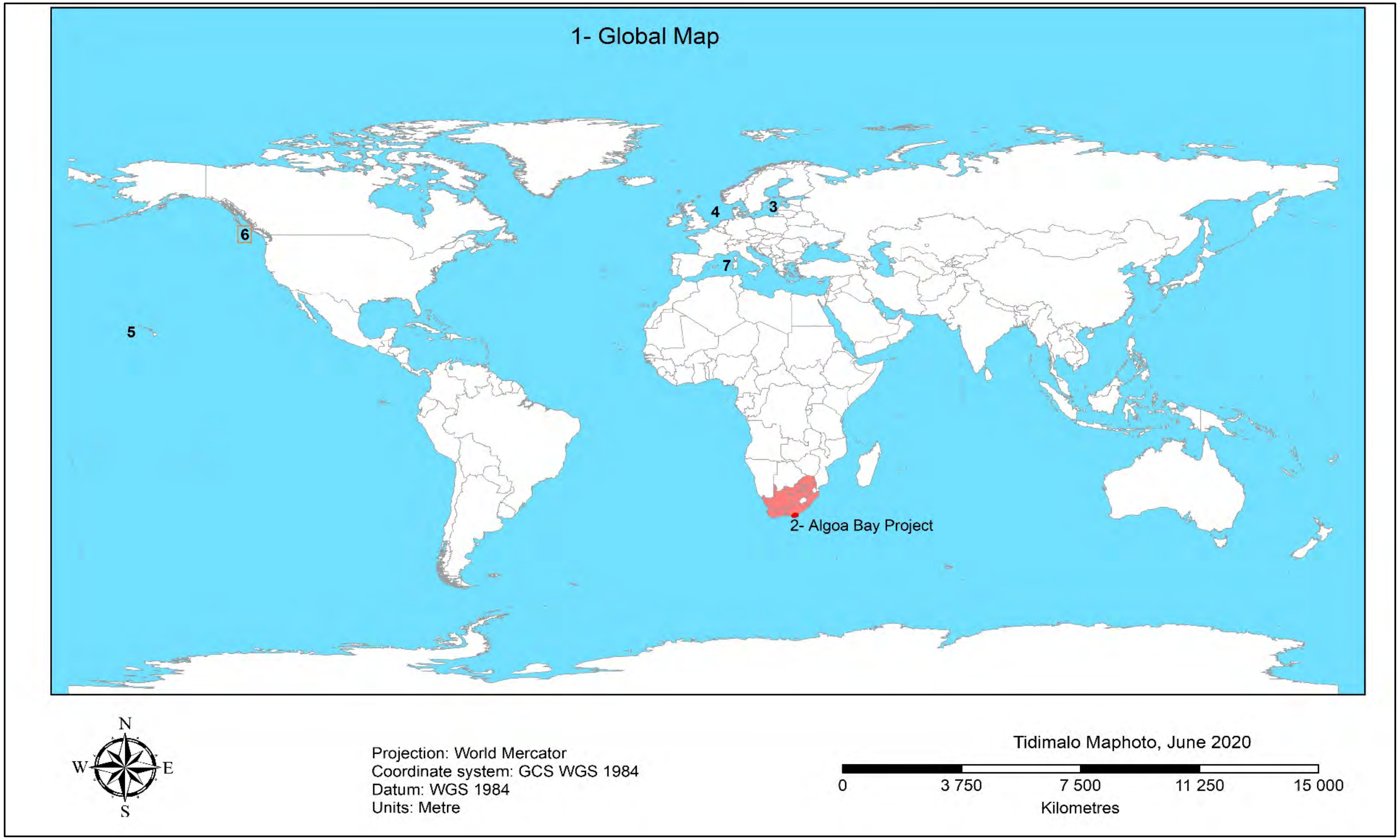


Figure 2. 5: International and local products that have used the standardised method by Halpern *et al*. (2007; 2008) to map human impacts on the marine environment. 1. Global scale (Halpern *et al*., 2008); 2. South Africa- National Biodiversity Assessment (Sink *et al*., 2012; Sink et al., 2019); 3. Baltic Sea (HELCOM, 2010; Korpinen *et al*., 2012); 4.Northern Sea (Andersen & Stock, 2013; Menegon *et al*., 2018); 5. Hawaiian Islands (Selkoe *et al*., 2009) ; 6. Canada's Pacific water (Ban *et al*., 2010); 7. Ligurian Sea- North West Mediterranean (Parravicini *et al*., 2012).

2.3.5 Tools used for managing the marine environment

2.3.5.1 The use of GIS in ocean management

Advances in ecological and planning software have made it possible to carry out analysis for conservation (Baldwin et al., 2014). In the past decade, GIS-based conservation planning tools have rapidly escalated with increasing computing ability (Baldwin et al., 2014).
Quan et al. (2001) define GIS as a computer-based tool used to analyse and map spatially referenced data. The tool has the ability to transform data and present knowledge in various formats to support decision-making processes (Quan et al., 2001). GIS based approaches provide a tool for interdisciplinary studies, whereby spatial data from environmental, physical, socio-economic and ecological disciplines can be integrated (Furlan et al., 2020) to examine spatial relationships of human uses and their interactions with the marine environment, which is beneficial to MSP (St. Martin & Hall-Arber, 2008).

Parravicini et al., 2012 used GIS to understand the relationship amongst conflicting human uses on the coast. Their GIS approach was proven effective in modelling complex interactions among multiple pressures and predicting future scenarios.

A study by Henriques et al. (2017) successfully used GIS to support the planning and development of an ecosystem-based conservation plan for a coastal region in Portugal. The study was undertaken to establish a spatial plan that would help define Aquaculture Management Areas (AMAs) on the south coast of Portugal. Ecological and socio-economic data were used to assess and reduce the conflict of uses in ecologically sensitive areas. The study was also successful in reducing the conflict between AMAs and fishing and avoiding conflict with the allocation of offshore aquacultures over sensitive habitats (Henriques et al., 2017).

Furlan et al., 2020 developed a GIS-based Network to evaluate the probability of marine cumulative impacts, under various climate and management scenarios. Their GIS-based approach was considered an operational tool for adaptive marine management.

GIS has also been applied broadly within the marine environment in mapping marine mammal biodiversity (Davidson et al., 2012); marine species distribution and habitat preference (Choi et al., 2011; Melly et al., 2017); habitat mapping (Bravo & Grant, 2020; Cogan et al., 2009).

2.3.5.2 The role of GIS and decision support tools in MSP

Since human pressures and coastal ecosystems have a spatial component, mapping and cartography are essential in analysing and managing the ocean (Henriques et al., 2017; Parravicini et al., 2012). The maps of these features and activities can be used to assess the conflict and compatibilities between human uses and the environment (Henriques et al., 2017).

GIS can help identify options for areas that require management (Ban & Alder, 2008). Gissi & de Vivero (2016) also highlighted the importance of managing data through technologies such as GIS, Decision Support Systems and Scenario Analysis Techniques to support implementing a structured MSP.

Common products that are produced from using GIS for conservation are:

(1) Atlas of marine ecological values and human uses and

(2) analyses that identify areas of high/low conservation values (Ban & Alder, 2008).

2.3.5.3 Issues associated with the use of GIS in resource management

While GIS has been useful in assessing human uses and their impacts on the marine environment, a few concerns are associated with its use. One of the concerns is the involvement of humans in GIS technology.

Quan et al. (2001) outline the following concerns that one may come across:

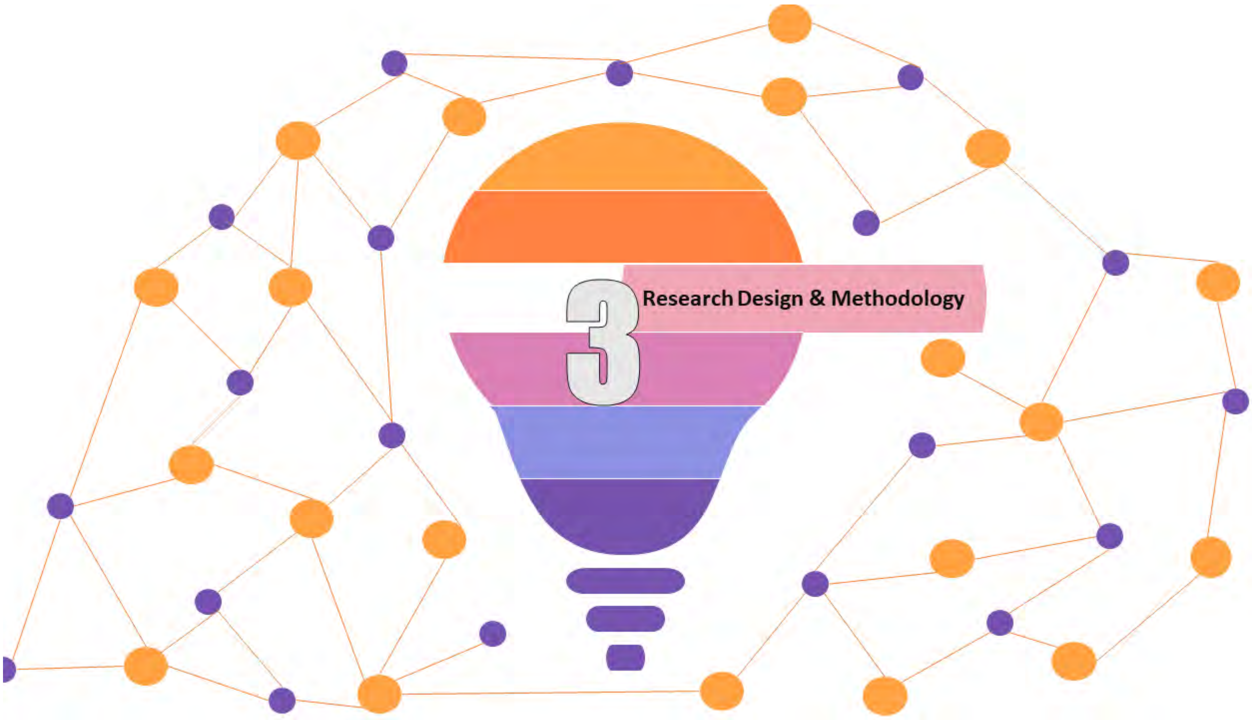
- The security of involved communities may be compromised if the supplied information is used without the participants' knowledge or understanding.
- Issues with integrating data based on datasets that have different spatial resolutions, formats and levels of accuracy.

2.3.5.4 Stakeholder engagement

GIS helps integrate biophysical and social datasets to allow multi-disciplinary analyses in order to understand and answer natural resource management questions (Quan et al., 2001). Stakeholder engagement is an essential component of MSP and it ensures that spatial uses are accounted for and that the interests of different persons are included in planning decisions (Quan et al., 2001). Participatory mapping is one method in GIS (which involves stakeholders) and is useful for investigating the community's perceptions of the spatial uses of social and natural resources (Quan et al., 2001).

2.4 Gaps in the Literature

It is evident from the studies that there has been a rapid increase in human use of the marine environment. The literature review suggests that many studies have been carried out to study the cumulative impacts of human uses on the marine environment throughout the world (Halpern, 2008; Halpern, 2015). Despite continuous research on cumulative impacts, there is little research in South Africa on integrating social data with biodiversity data to quantify the impacts of human uses. With that said, geospatial technologies such as GIS allows for such quantification to help decision-makers with management options.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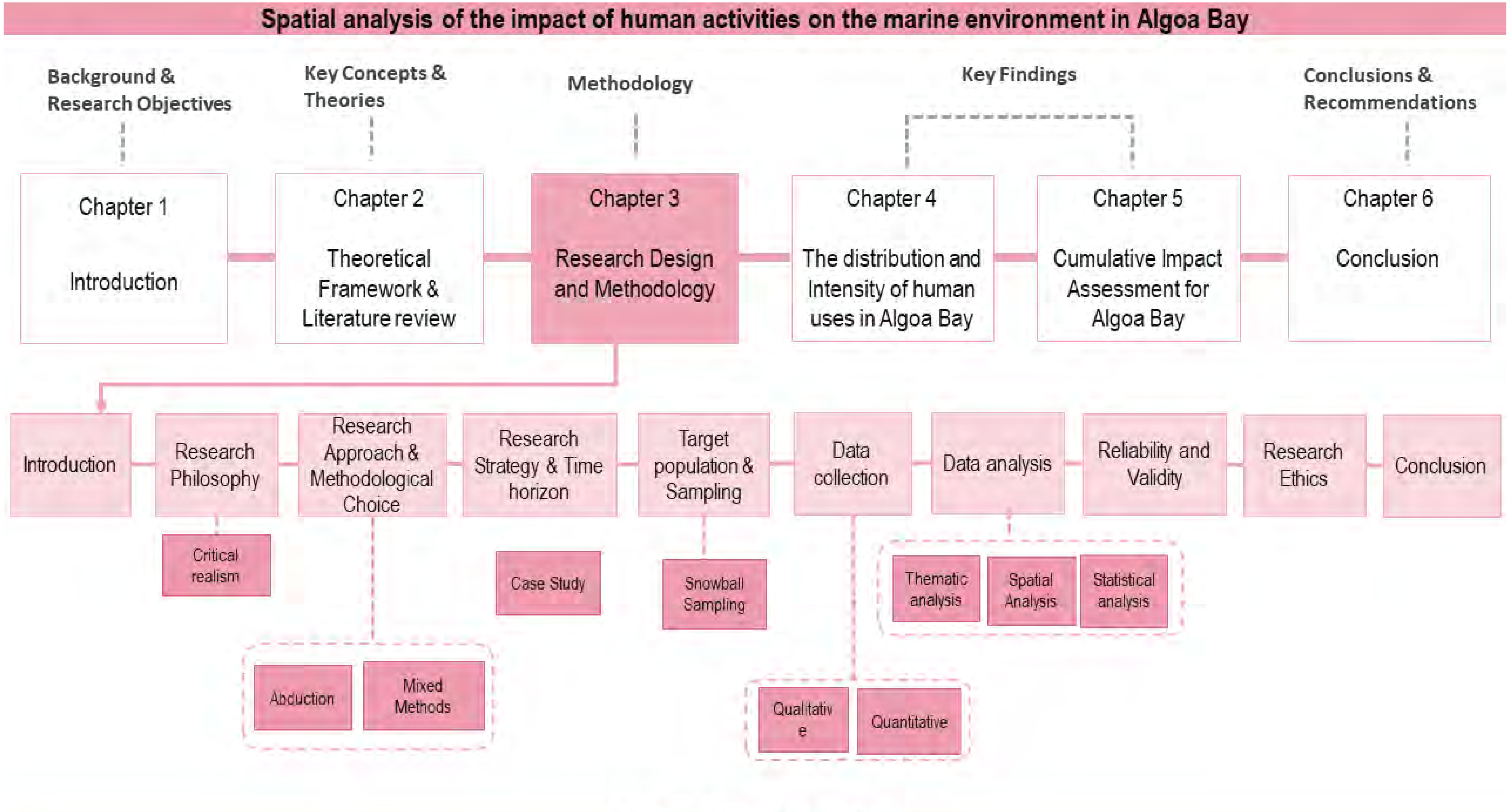
Research Design & Methodology



Chapter Three Overview

3. RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

Creswell & Creswell (2018) identify research design as the plan and process of the research that runs from a wide range of assumptions that are then narrowed down to comprehensive methods of collecting data, leading to its analysis and interpretation.

This chapter presents the research design, methodology and analysis steps undertaken for this study. In elaborating the design, this study uses the research onion scheme developed by Saunders et al. (2019), as shown in Figure 3.1. The aim of the study was to investigate the spatial distribution of human activities and their impacts on the Algoa Bay marine environment. The overall research design adopted mixed methods using a case study approach for the Algoa Bay study area. The following sections will be structured based on each "slice of the onion," starting from the research philosophies layer.

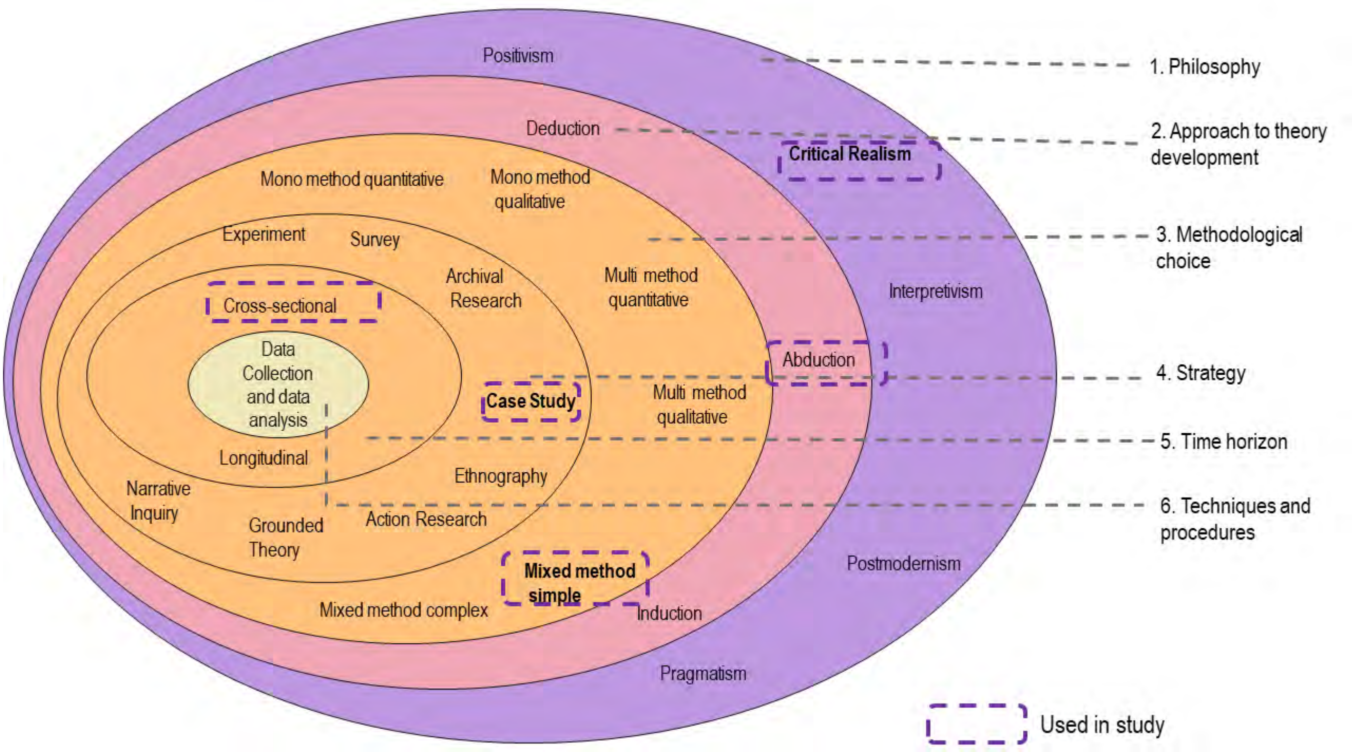


Figure 3. 1: Research onion steps adapted in this study (Saunders et al., 2019).

3.2 Research Philosophy

Research philosophy describes a system of assumptions and beliefs about knowledge development (Saunders et al., 2019). This study investigates the spatial distribution of human activities and their impacts on the Algoa Bay marine environment. This leads to exploring the research questions through the lens of critical realism.

Kitchin & Tate (2000) define critical realism as a philosophy that investigates the underlying mechanisms of social relations and identifies the building blocks of reality. Saunders et al. (2019) emphasize that critical realist scholars focus on explaining what is experienced and seen and they aim to be aware of the socio-cultural background and experiences that might influence the research to be objective and minimize biases.

Five philosophical assumptions that ground the critical realism research philosophy are summarised below:

i. Ontological assumptions of critical realism – the nature of reality

Certain aspects of reality are seen as real and they exist independently of interpretation by people (du Plooy-Cilliers, 2014). The interactions between human use on the marine environment and the associated impacts cannot be understood outside of the context of the DPSIR framework. The DPSIR Framework provides a basic view of large-scale influences on the marine system (Agardy et al., 2005). As a result, the ontological questions that allow the researcher to understand the context of the interactions between humans and the marine environment are:

- What is the marine environment like?
- What are the human activities taking place in Algoa bay?
- What are the impacts of the activities on the marine environment?

ii. Epistemological assumptions of critical realism- the nature of knowledge

Critical realists view knowledge as something to be considered within its social and historical context, where knowledge is transitive, meaning that it can change (Saunders et al., 2019). Following Saunders et al. (2019), epistemological questions of the study will be:

- What contributions to knowledge can be made?
- What constitutes good data?

iii. Metatheoretical assumptions of critical realism

Critical realists emphasize change; therefore, they maintain that there should be practical and should include a plan for change, providing people with resources to assist them with understanding and questioning (du Plooy-Cilliers, 2014). In this study, the socio-ecological systems theory was used as a theoretical basis, with the lens of the DPSIR framework, in order to understand the impact and the interactions of humans with the marine environment.

iv. Methodological assumptions of critical realism

The multidimensional reality of critical realism can be investigated from different angles to inform the beliefs of critical realism, where no single method can provide definite results about given research objectives (du Plooy-Cilliers, 2014). As a result, research methods proposed for critical realists tend to use mixed methods research (Saunders et al., 2019).

v. Axiological assumptions of critical realism

Axiology recognizes that research is not only "value-laden," but there are deeply-rooted biases present that shape the research's narrative (Creswell & Creswell, 2018). du Plooy-Cilliers (2014) asserts that critical realists acknowledge a degree of subjectivism in their research, where they further emphasize that it is impossible to do research that is free of values. Saunders et al. (2019) propose the following Axiological questions:

- How should the participant's values be dealt with?
- What is the role of values in research?

3.3 Research Approach

According to Creswell & Creswell (2018), the research approach is determined based on the research problem. The research problem that this study is addressing is the lack of understanding of the impacts of human activities in Algoa bay. An abductive approach is concerned with collecting data to identify themes, explore a phenomenon, explain patterns and generate a new / modify an existing theory tested through additional data collection (Saunders et al., 2019). The abduction approach combines both induction (moving from data to theory) and deduction (moving from theory to data) by moving back and forth (Saunders et al., 2019). Saunders et al. (2019) assert that an abductive approach is most likely to be underpinned by critical realism.

3.4 Methodological Choice

Tashakkori & Creswell (2007) define mixed methods design as research in which data is collected and analysed and findings are integrated to draw inferences using both quantitative and qualitative methods. This type of design brings together qualitative and quantitative methods to answer the research question(s) while allowing the researcher to reach well-substantiated research conclusions and increase the study's validity (Creswell & Creswell, 2018). The core assumption of this form of inquiry is that the integration of qualitative and quantitative data yields additional insight beyond the information provided by either the quantitative or qualitative data alone (Creswell & Creswell, 2018). Creswell & Creswell (2018) argue against viewing quantitative and qualitative research as opposites, advising that they should be viewed as representing different ends of a spectrum, in the middle of which mixed methods are positioned.

This study is aligned towards a triangulation design due to the simultaneous data collection and integration. Triangulation mixed-methods uses merging integration, where qualitative data is merged with the numerical information acquired from quantitative data. There is a concurrent but separate collection and analysis of qualitative and quantitative data within the triangulation mixed methods design (Creswell & Creswell, 2018).

3.4.1 The Strength of a Mixed-Method Approach

The employment of a mixed-methods approach in this study is based on the recognition that marine issues resulting from human activities can be understood through a combination of quantitative and qualitative data.

Combining the methods and data will bring about a more comprehensive understanding of the research questions and provide a more detailed understanding of the particular space of the global marine ecosystem, that is Algoa Bay. Hawthorne (2017) highlights that combining the methods allows the researcher to uncover and explore meanings that would not be possible using only one approach. Browne-Nuñez & Jonker (2008) state that an approach that uses mixed methods will strengthen and improve the study results. This research emphasises the generation of data, specifically GIS data, that can be used in other stages of the Algoa Bay MSP Project.

3.5 Research Strategy and Time horizon

The research strategy adopted in this study is a case study. According to Creswell & Creswell (2018), a case study is a strategy to deeply explore a program, process or event that is bounded in activity and time by using various data collection methods to gather detailed information. Case studies allow researchers to link small actions of individuals to large scale processes and structures (Neuman, 2014). As a result, the case study approach would allow the researcher to learn about the different views of various stakeholders regarding the human uses and associated impacts of the pressures of the marine environment in Algoa Bay. The case study approach is suitable where the research addresses explanatory or descriptive questions and aims to produce a first-hand, in-depth understanding of events and people (Yin, 2018)

Based on the research strategy used, a choice of mixed-methods and cross-sectional time horizon was seen to be most suitable for this study. This study was conducted using various methods at one moment in time, not in a series of time frames.

3.5.1 Case Study Description: Algoa Bay

Algoa Bay, which is situated between the Cape Padrone (33°46′ S, 26°28′E) and Cape Recife (34°02′ S, 25°42′E), is centrally located within the warm-temperate Agulhas Bioregion in the province of the Eastern Cape of South Africa and is the largest and best formed logarithmic-spiral bay on the Cape south coast (Bremner, 1983). The pelagic ecosystem environment in the Agulhas ecoregion is currently vulnerable to anthropogenic threats, while the coastal ecosystem environment status ranges from vulnerable to critically endangered (Sink et al., 2019). The bay is mapped in figure 1.2.

3.5.1.1 Biophysical Characteristics

a. Coast and islands

Algoa Bay is the largest embayment on the south cape coast (Goschen & Schumann, 2011). The coastline of Algoa Bay consists of distinct geographical features such as the Alexandria Dunefield, which is 120km^2 in area and lies on the northern boundaries of the Bay (Watson et al., 1996). Bird Island is situated southwest of Cape Padrone, with the islands of St Croix, Brenton and Jahleel, situated a few kilometres offshore and between the mouths of the Swartkops and Sundays Rivers, the two large, perennial rivers that drain into Algoa Bay (Klages et al., 2003).

b. Oceanography

Algoa Bay is in the transition zone between the Agulhas and the Benguela currents. The flow of the current is southwest along the continental shelf of South Africa's east coast (Goschen & Schumann, 2011). The surface water in the southwest area of the Bay is cold in winter and warm in summer as compared to the north-eastern side (Goschen & Schumann, 2011). The distinguished oceanographic feature in Algoa Bay is the Agulhas Current that carries warm tropical water south-westwards past the south coast of South Africa (Goschen & Schumann, 2011).

c. Rivers and estuaries

Five estuaries drain into the Algoa Bay Marine Environment. The Swartkops and Sundays Rivers are two large perennial systems with permanently open estuaries into Algoa Bay (Bremner, 1991). The Baakens and Papenkuils estuaries are situated within the city of Port Elizabeth and are temporarily open/closed estuaries (Whitfield 2000). The salt work operation has transformed the Coega estuary in the nearby area (Lemley et al., 2019). The Sundays River has a catchment area of 20 729 km^2, with an estuary approximately 21km long, bordering the Alexandria Dunefield (Harrison & Whitfield, 1990). The Sundays estuary is an important recreational area, particularly for anglers (Whitfield & Baliwe, 2013). The Swartkops river has a catchment area of 1 354 $km^{2,}$ with an estuary approximately 16.4 km long, north of Port Elizabeth (Baird et al., 1986). The Swartkops estuary is ecologically viable even with the urban developments and artificial obstructions along the river (Whitfield & Baliwe, 2013).

Climate and weather

The Algoa Bay's weather is primarily controlled by high-pressure systems as well as cold fronts and coastal lows, which are associated with high winds, cloud cover and rainfall (Goschen & Schumann, 2011). Port Elizabeth experiences intra and inter-annual variability, with an average of 545mm rainfall annually (Figure 3.2). October and November months receives the highest rain (Figure 3.2) Average daily air temperatures range from a minimum of 14°C to 21°C.

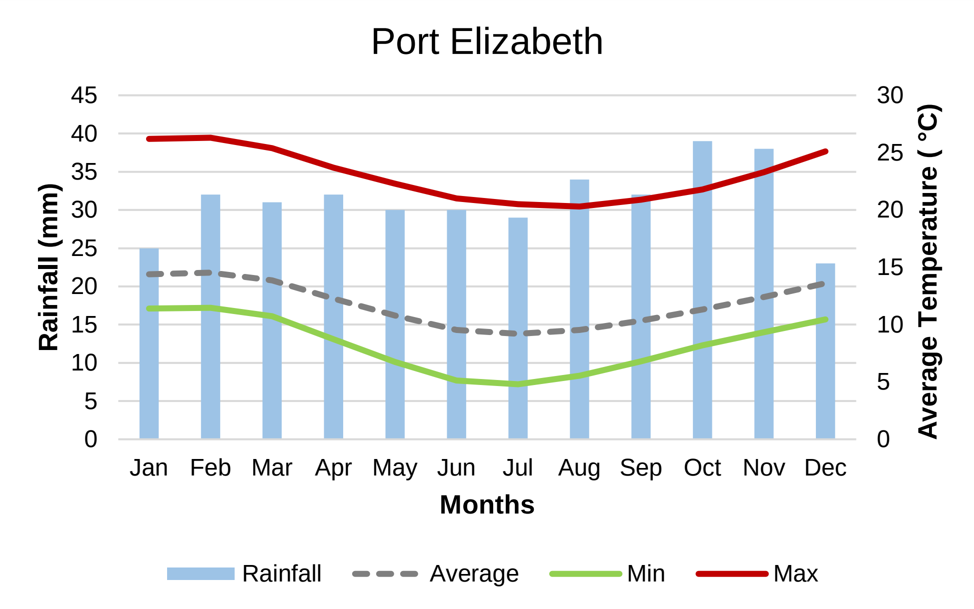


Figure 3. 2: Monthly rainfall and temperatures for Algoa Bay (Schulze et al., 2007)

d. <u>Marine Ecosystems</u>

i. Coastal ecosystems

The classification of coast types is based on substrate geology, grain size and wave exposure (Sink et al., 2019). According to Harris et al. (2011), the extent of different coast types reflects the dominance of sandy beaches and mixed shores. The coast of Algoa Bay is classified as a logarithmic spiral bay (Sink et al., 2019). The logarithmic spiral bay forms as a result of refraction caused by an approaching wave and diffraction by an upcoast headland bypass (LeBlond, 1979)

ii. Inshore ecosystems

Inshore ecosystems range from the subtidal coast type boundary (-5m bathymetric contour) to the offshore boundary (-30m bathymetric contour). Unconsolidated inshore ecosystems include sandy, gravel and muddy habitat types, whereas inshore reefs and hard grounds consist of two main types of inshore rocky habitat types (Sink et al., 2019).

iii. Island ecosystems

Within the Agulhas ecoregion, there are two Islands (the Bird Island and St Croix Island groups) classified as 'major' islands based on their conservation importance in terms of the land-breeding predator colonies they support (Sink et al., 2019).

iv. Offshore Benthic Ecosystems

The unconsolidated shelf is the most diverse ecosystem group with 16 different habitat types recognised in the South African marine environment (Sink et al., 2011). This results from the many different sediment types (determined by grain size) and finer-scale depth and biogeographic patterns. Sandy shelf habitat types have the greatest extent, with muddy, gravel and mixed sediment habitat types constituting smaller areas (Sink et al., 2019).

Algoa Bay’s marine ecosystems are illustrated in Figure 3.3.

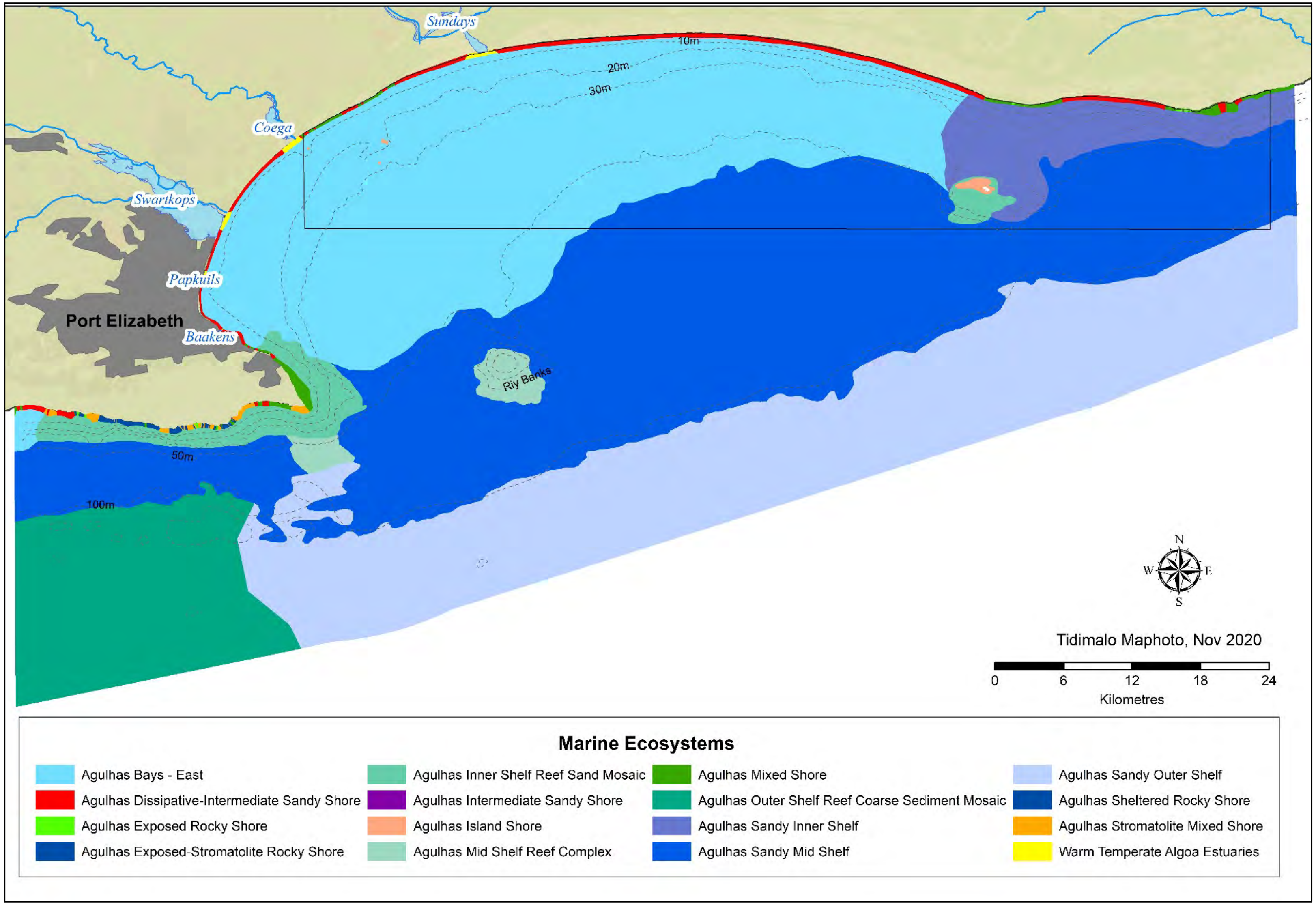


Figure 3. 3: Marine Ecosystems in Algoa Bay (Source of data: Sink et al., 2019).

3.5.1.2 Biological characteristics

Algo Bay has a rich endemic biodiversity of invertebrates, fish, and seaweeds (Dorrington et al., 2018). A brief description of some of the biological characteristics are provided (and not limited to) below.

Algoa Bay's rocky shores and sandy beach are recognized for their abundant marine life (Klages et al., 2003). The patterns of zonation of the marine organisms on rocky shores are a result of the variation in environmental variables across the shore, which influences the organism that occupy each section of the shore (Branch & Branch, 2018). The sandy beach in Algoa Bay is occupied by approximately 25 species of marine invertebrates, of which sandmussles are commonly known (Klages et al., 2003).

Algoa Bay's surf zones are important habitats for larval fishes with estuarine dependent species dominating the communities (Strydom and d'Hotman, 2005)

The two island groups (St Croix Island and Bird Island) in Algoa Bay serve as breeding and nursing grounds seabirds such as the Cape Cormorant, Cape Gannet and the African Penguin (Klages, 2003).

Melly et al. (2017) observed the following distribution of whale and dolphin species in Algoa Bay :

- Eubalaena australis (Southern Right whales) were distributed in the inshore areas of Algoa Bay between Port Elizabeth (PE) Port and past the Sundays River.
- Megaptera novaeangliae (Humpback whales) occupied the Riy banks and the two island groups.
- Balaenoptera brydei (Bryde's whales) were distributed in the offshore areas of the western half of Algoa Bay.
- Sousa plumbea (Humpback dolphins) were distributed in the inshore areas of Algoa Bay between PE Port and past the Sundays River.
- Tursiops aduncus (Bottlenose dolphins) were distributed in the inshore areas of Algoa Bay.

3.5.1.3 Socio-Ecological Characteristics

a. Social Dynamics in Algoa Bay

i. Population in Nelson Mandela Bay Municipality

The population for the NMBM was estimated at 1 264 340 in 2016 (ESSECC, 2017). The largest population by race is the black population, with more black females than males. A summary of the population by race for the NMBM for 2016 is provided in Figure 3.4.

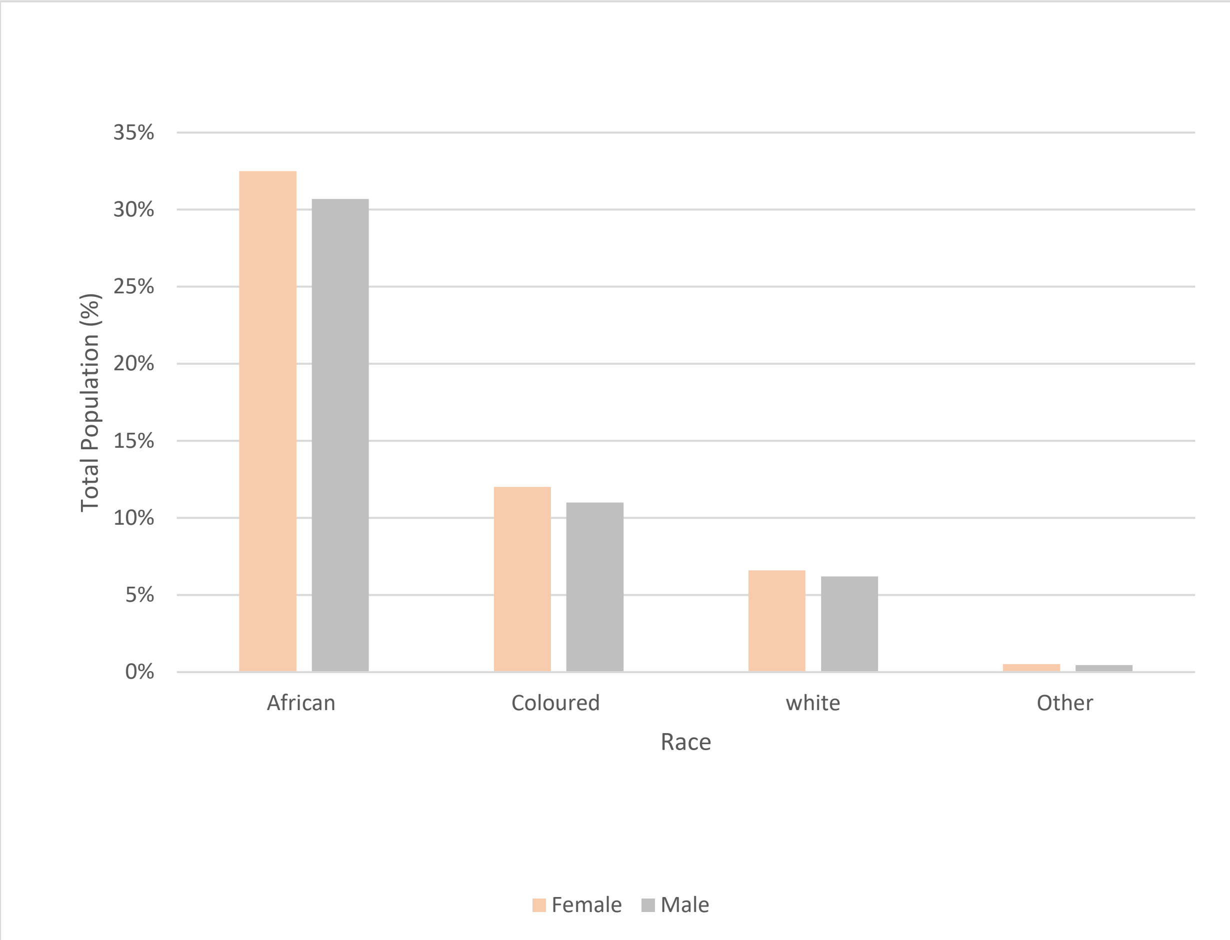


Figure 3. 4: Total population by gender per race (Source of data: Stats SA, 2016).

ii. Population in the Eastern Cape Province (Year 2016)

The Nelson Mandela Bay Municipality has the second-highest total population count when compared with the rest of the municipalities in the Eastern Cape. The population density of Nelson Mandela Bay is 588 persons/km² (ESSECC, 2017). The distribution of population density in the Eastern Cape is shown in Figure 3.5.

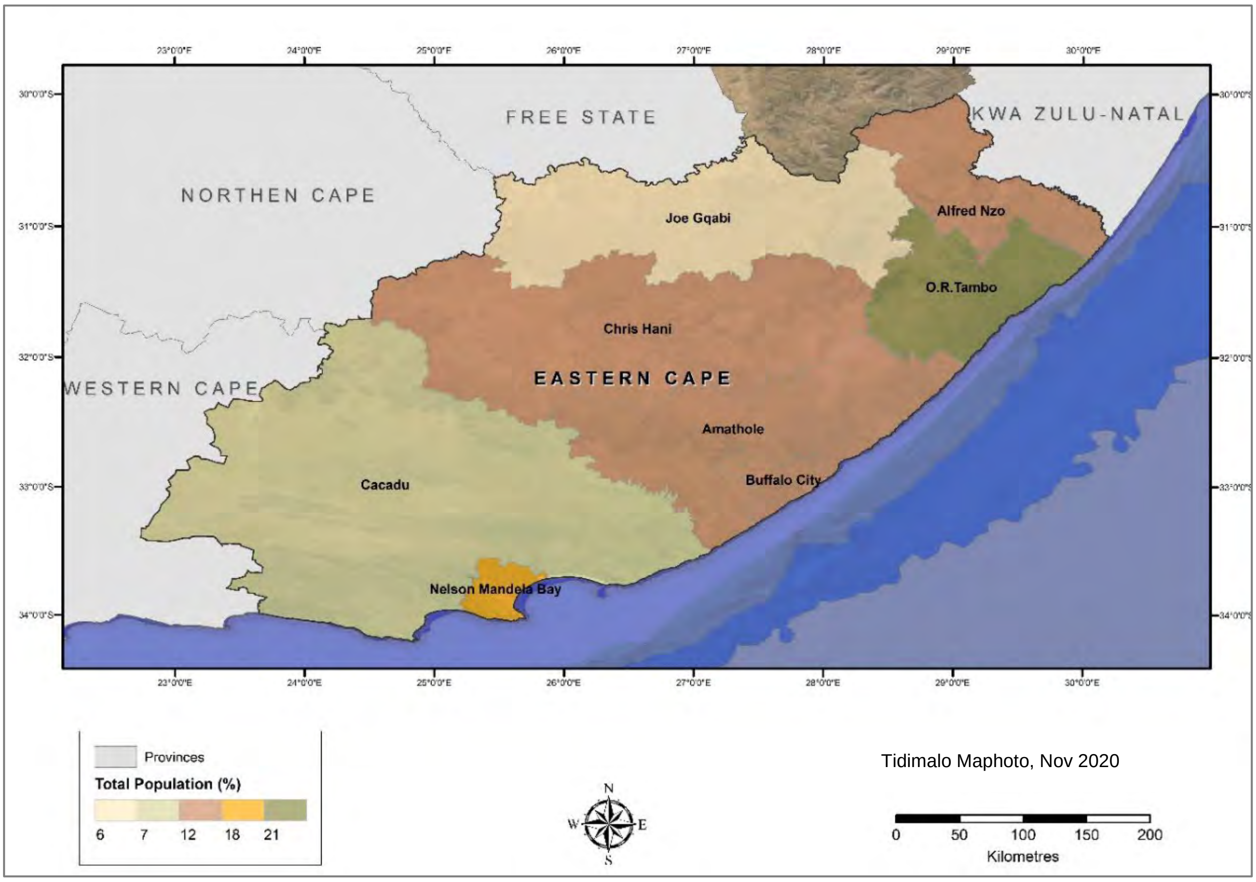


Figure 3. 5: The distribution of population density in the Eastern Cape (Source of data: Stats SA, 2016).

Most of the households in Nelson Mandela Bay are "very formal" dwellings, with 10% of the dwelling unit type being informal (ESSECC, 2017).

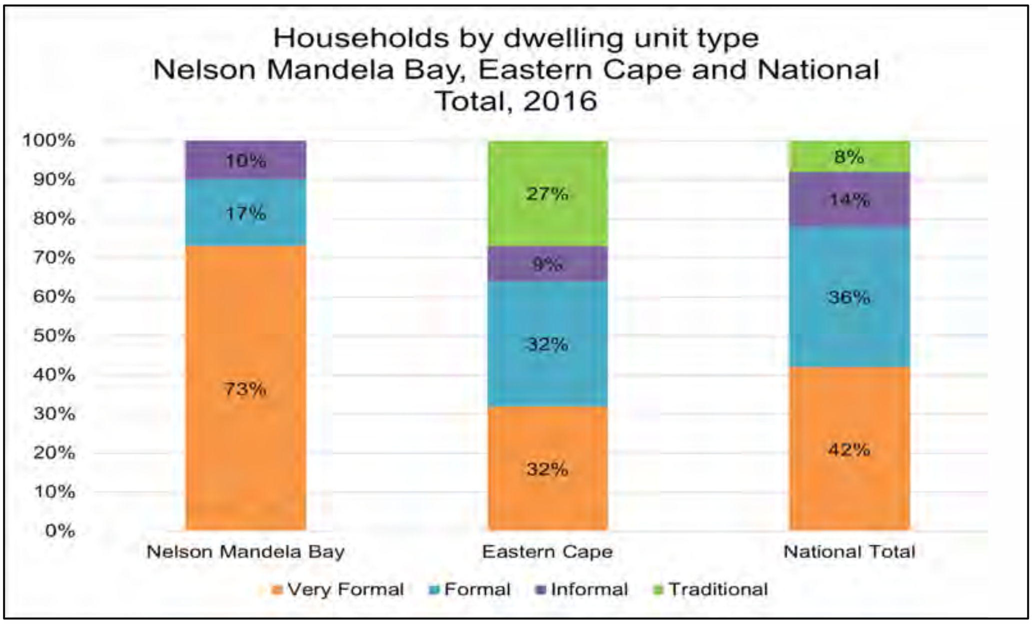


Figure 3. 6: Types of household dwelling in Nelson Mandela Bay Municipality. (Source of data ESSECC, 2017).

b. Economic Dynamics in Algoa Bay

i. Economic Drivers

Ocean related activities in Algoa Bay are a critical component of the regional economy. Port Elizabeth (PE) is the economic hub of the region, with an emphasis on manufacturing, commercial and industrial activities (Klages, 2003). The main economic drivers are the automotive industry and the beneficiation of raw materials. Both these activities produce goods for export. A large variety of marine fish and shellfish species are commercially exploited along the Port. The Nelson Mandela Bay Municipality (NMBM) has a seaport (Port of Port Elizabeth and Port of Ngqura) and an automotive manufacturing centre which are the economic engines of the city, together with the community services and transport sector (ESSECC, 2017).

The Port of Port Elizabeth is a multi-cargo port that handles dry bulk, bulk liquid, general cargo and container cargo. In contrast, the Port of Ngqura handles container, dry and liquid bulk vessels as well as accommodating rig repairs (Coega Development Corporation, 2016). The Coega Industrial Development Zone (IDZ), which is located within the study area, is an industrial development complex (known as a Special Economic Zone). It provides employment to the population and contributes to the economic growth of the Bay (Coega Development Corporation, 2016)

ii. Tourism in Algoa Bay

The Nelson Mandela Bay Municipality (NMBM) is a gateway to the Eastern Cape Province with an excellent tourism infrastructure for visitor arrivals and departures (Klages, 2003). The tourism value of Port Elizabeth is largely focused on the coast (Algoa Bay Project, 2019). The Port Elizabeth airport, harbour and railway station are located within a radius of 5 km of the centre of Port Elizabeth, surrounded by a cluster of hotels and other alternative accommodation (Klages, 2003). Algoa Bay has invested in the blue economy through biodiversity-based at-sea tourism experiences, which include sea cruises that offer whale, dolphin and African penguin watching and shark cage diving at Bird Island (Algoa Bay Project, 2019). Leisure tourists who travel to see the sardine run attract a range of special interest travellers to Algoa Bay (Joubert and Poole, 2018).

c. Ecological importance of Algoa Bay

Algoa Bay has high diversity of habitats, seabirds and marine organisms, which are of ecological importance in the Agulhas Bioregion (Chalmers, 2012). Knowledge of the extent and distribution of biodiversity, the ecosystem processes that sustain this biodiversity and the human use that threaten it is an important component of a biophysical plan (Algoa Bay Project, 2019). Algoa Bay is, therefore, a suitable case study, given the substantial body of biophysical data that exist for the area, the diversity of ecosystems and species and the range of human uses competing for space in the bay (Algoa Bay Project, 2019). There is a need for management of the coastal and pelagic environment in this region to allow for the sustainable use of the resources for humans and the environment. In response to this need, the Algoa Bay Project was established in 2017 to develop the first Marine Spatial Plan (MSP) in South Africa (Dorrington et al., 2018).

3.6 Research Techniques and Procedures

3.6.1 Data collection

Based on the principle of case study strategy, qualitative and quantitative data were collected during the same phase of the research process. The purpose of collecting both qualitative and quantitative data was to acquire different but complementary data on the same topic (Creswell & Creswell, 2018). Figure 3.8 summarizes the data collected using primary and secondary data collection.

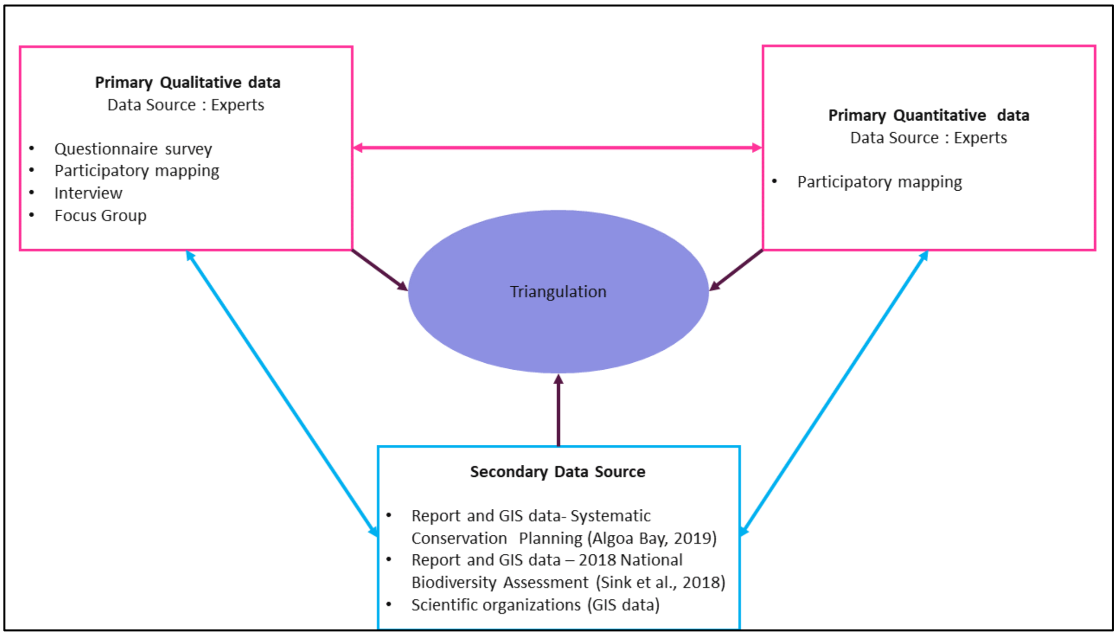


Figure 3. 7: Data sources and collection.

3.6.1.1 Primary Data Collection

a. Questionnaire Survey

Questionnaire surveys are useful in collecting a large amount of data from a large number of participants in a short space of time (Bryman, 2012). Questionnaire surveys are useful as they quantify and simplify responses and participants are normally more willing to tick boxes (du Plooy-Cilliers & Cronje, 2014). A questionnaire survey was designed and prepared and modified from (Halpern et al., 2007) to suit the objectives of the project. The questionnaire was designed to ask for contributions of 'expert knowledge' to an exercise in mapping the Algoa Bay marine ecosystem pressures and to reflect the extensive knowledge of this ecosystem through expert mapping (Attached in Appendix 7). The questionnaire surveys were distributed to various groups of people who were deemed as being relevant for this study based on their experience and knowledge (the sampling method and target population is explained further in section 3.7).

b. Participatory GIS

Participatory GIS was used to collect spatial data from experts. Participatory GIS, Public participation GIS and Volunteered Geographic Information (VGI) are terms used for social and participatory research methods of collecting spatial information (Brown *et al*., 2017). The participatory approach is beneficial in facilitating the need to address socio-environmental issues and promote knowledge (Littaye et al., 2016). Two options were provided to the experts for mapping the marine issues as a result of human activities. The first option was to complete the mapping exercise using the hardcopy map attached to the questionnaire. The second option was to complete the mapping exercise on Google Earth.

i. Traditional Mapping

An A2 printed map was provided to the experts (experts defined in section 3.7.1), together with an A4 map attached to the questionnaire (two different maps sizes were used to provide a clear representation of the study area, especially on the A2 map). Each expert was requested to indicate the spatial location (on the A4 map) of the marine issues that they had listed in the questionnaire survey. Participants were provided with different colour pens so that they could mark different marine issues.

ii. Digital mapping on Google Earth

This mapping option was done by experts who completed the questionnaire survey online and sent it through to the researcher via email. The folder "marine issues" with the study area boundary was generated in Google Earth and sent in "KML" format. Experts were requested to add polygons and placemarks within the study area boundary as per the instructions attached in the questionnaire.

c. Interviews with Local Citizens

Semi-structured interviews offer the researcher the benefit of the structure while allowing the researcher to avoid being strictly confined to the structure (Bryman, 2012). Semi-structured interview questions were formulated, which focused on views from a socio-economic perspective. The questions were based on socio-economic activities and related issues in the Bay. During the interview, follow up questions were asked for clarity on some responses (Attached in Appendix 8).

d. Focus Groups

Strydom and Bezuidenhout (2014) define a focus group as a group interview used to determine the behaviour, attitudes and preferences of participants interviewed simultaneously by a facilitator. Focus groups normally consist of one investigator and several participants in one session (Adams & Cox, 2008). Strydom and Bezuidenhout (2014) note that focus groups are advantageous as they allow for different viewpoints and collect evidence about participants' opinions. Focus groups provide an opportunity to stimulate a large amount of interaction on a topic in a short period by providing in-depth information and direct evidence regarding the participants' experiences (Strydom & Bezuidenhout, 2014).

A focus group was organised with five local small-scale and commercial fishermen to gain their perceptions and insight into the human uses and potential impacts of uses in Algoa Bay. Their availability determined the choice of fishermen on the day of the focus group. Adams & Cox (2008) state that a focus group should be between a minimum of three and a maximum of eight participants. The overall aim of the research was explained to the fishermen. The questions were prepared in English and asked in IsiXhosa with the help of a research assistant (Attached in Appendix 9).

Permission to record the interviews was requested. The researcher made notes while the research assistant was asking questions. While focus group discussions have many advantages, Strydom & Bezuidenhout (2014) warn that the researcher should not try to force their opinions on the participants into the researcher's desired outcome.

3.6.1.2 Secondary Data Collection

Secondary data were collected from the following:

- the Systematic Conservation report (Algoa Bay Project, 2019)
- the 2011 and 2018 National Biodiversity Assessment (Sink et al., 2012; 2019)
- GIS datasets from scientific organisations.

The type of GIS data acquired was on the different human uses in the Algoa Bay marine environment. The sources of data are summarised in Appendix 1.

3.7 Target Population and Sampling

3.7.1 Target population

The target population for this study were professional and non-professional contributors of knowledge that relates to the marine environment. Figure 3.10 shows the different groups of participants in the study. The participants were referred to as experts. According to Galloway (2013), experts are people with specialised knowledge gained from formal training, direct personal experience and reflection.

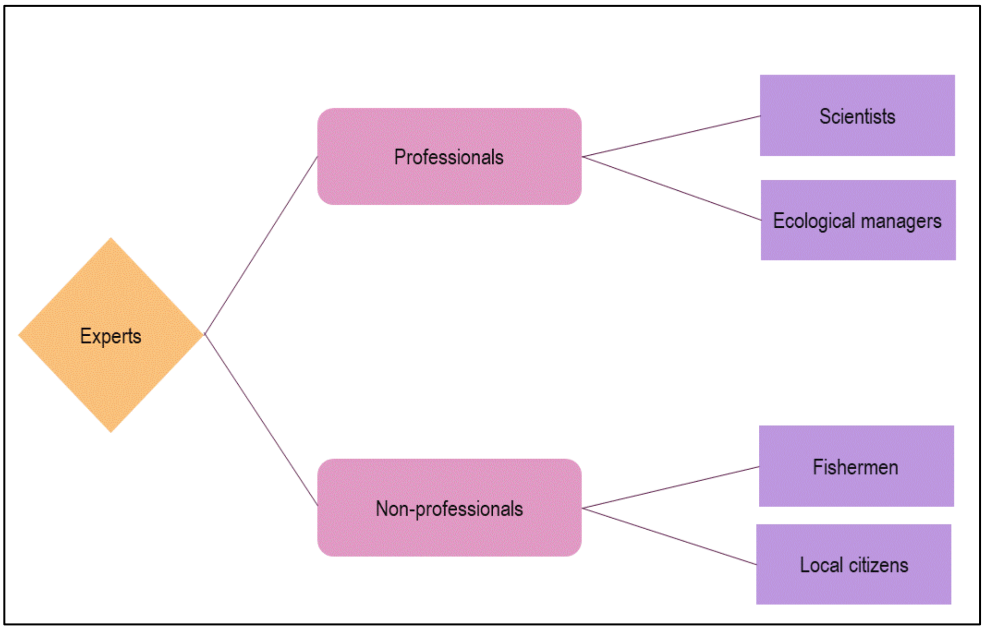


Figure 3. 8: Different groups of participants in the study.

3.7.1.1 Expert Recruitment

Experts were defined as individuals who had knowledge and experience regarding Algoa Bay and were aware of the environmental issues. Experts differ from each other according to the knowledge they contribute, the information they provide and spatial representation (Galloway, 2013). In this study, most of the experts were located in Algoa Bay. Some of the experts from outside the study area had previously worked in the Algoa Bay marine environment, thus having knowledge of the bay and understanding the various activities that occur.

3.7.2 Sampling

Saunders et al. (2019) define this sampling as the deliberate selection of particular units that are suitable to answer research questions. A non-probable sample of participants was selected using snowball sampling. In non-probability sampling, the exact number of elements in the population is unknown, which means that the likelihood of selecting any one member of the population is unknown (Saunders et al., 2019).

Snowball sampling is used when it is almost impossible to determine the population of the study. Snowball sampling makes use of referrals to increase the sample size, whereby the key informants provide suggestions of participants who fit the requirements of the study (Creswell & Creswell, 2018). As a result, key informants were approached and asked to suggest participants who may be interested or have knowledge of the topic.

3.7.2.1 Sample Size

A snowball sampling approach was used to identify research participants from key informants. In order to create reliable results, seventy experts were targeted and approached to take part in the study. Thirty-eight (38) responses were received, resulting in a response rate of 46%. From the 38 responses, twenty-nine (29) participants filled in the questionnaire survey. Face-to-face meetings were set up with the participants to complete the questionnaire and participate in the expert mapping exercise. Some participants opted for an email to be sent to them instead of having a face-to-face meeting. Four (4) participants were interviewed and five (5) participants were part of the focus group interview.

3.8 Pilot Study

A pilot study is conducted to reflect all plans of the study and validate the study's feasibility (In, 2017). In (2017) further emphasizes the importance of conducting a pilot study by highlighting that it is useful in determining the sample size of the study and assessing aspects that are useful in the study. A draft version of the questionnaire survey was used in a pilot study to obtain verbal feedback on the questions. The data collected was used to improve and correct the validity of the questionnaire surveys. The participant was also one of the key informants who suggested other research participants to assist with acquiring information through a snowball approach.

3.9 Data analysis

3.9.1 Qualitative Data Analysis

Qualitative content analysis was chosen as a method for analysing qualitative data. Qualitative content analysis is when themes and patterns are identified in the text (Bezuidenhout and Cronje, 2014). Microsoft Word (Microsoft® Office) was used to record and capture the answers from the interviews. In order to understand the data, the recorded data were exported to NVivo software for further analysis; this software was used as it provides consistency and replicability.

An inductive coding approach (Bezuidenhout & Cronje, 2014) was used where the researcher allowed for codes to emerge from a thorough examination of the text. The codes created were reduced based on the themes that emerged from the answers through constant comparison. The questions that were asked guided the codes that were assigned. Data were structured into themes to identify patterns.

The steps for qualitative data analysis by Creswell & Guetterman (2018) were followed and summarised in Figure 3.12.

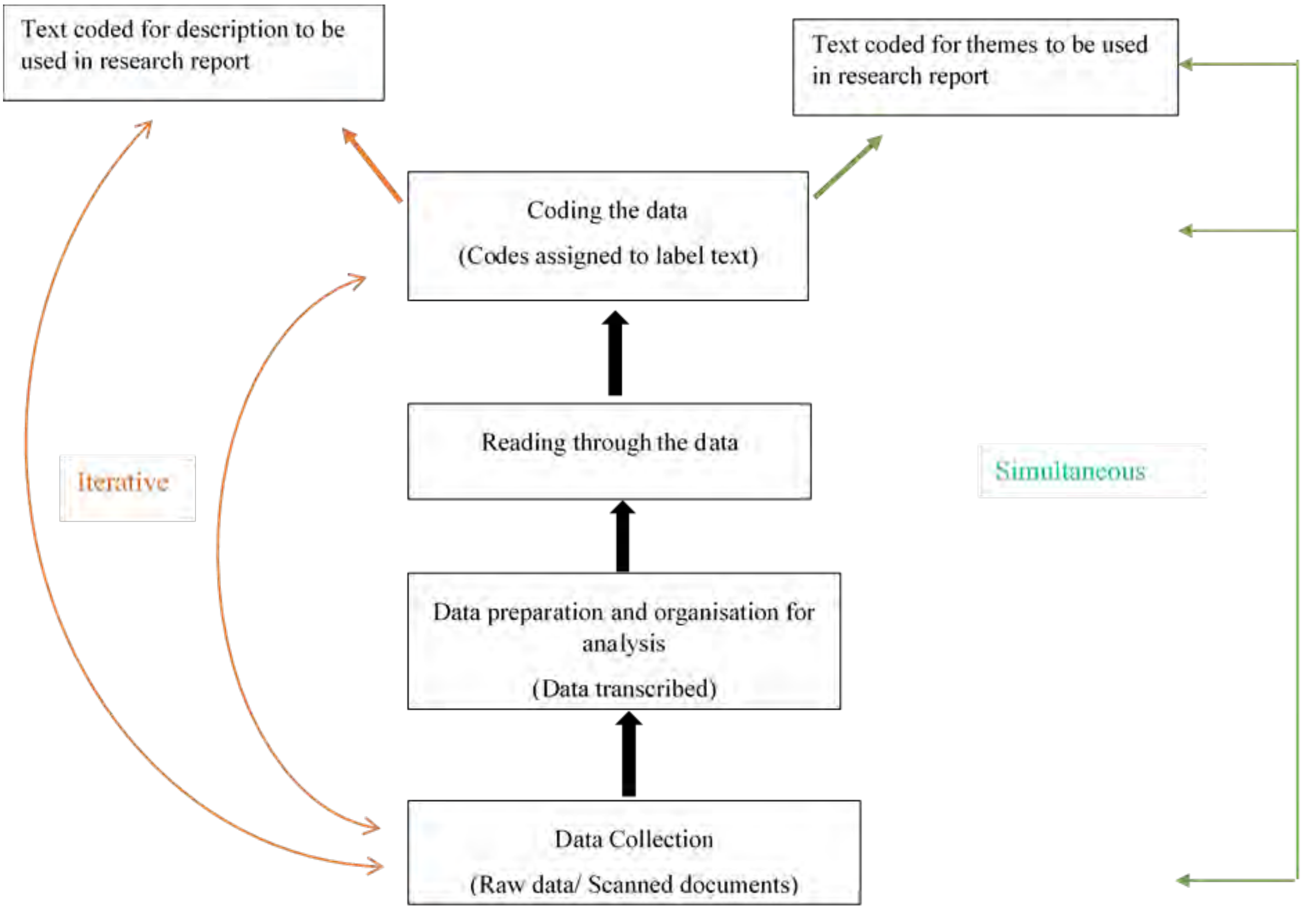


Figure 3. 9: An overview of the qualitative data analysis (Source: Creswell & Guetterman, 2018).

3.9.2 Spatial Analysis

Spatial analyses were done using ArcGIS 10.8 software. The spatial reference adopted an Albers Equal Area Conic Projection with standard parallels -24°S and -33°S and a central meridian of 25°E referenced to the WGS84 datum. This was in line with the projection used in the SCP (Algoa Bay Project, 2019). The spatial distribution of human pressures and ecosystems, which were scored according to the impact of the pressures on the marine environment, were combined into a GIS model (in ArcGIS) to map the cumulative impacts. These followed methods developed by Halpern et al. (2007). The assessment focused on the current state of the Algoa Bay marine environment. As a result, only existing human activity data is used and not potential threat data. The data sources for the layers are summarised in Appendix 1. Detailed analyses are presented in Chapters 4 and 5.

3.9.3 Statistical Analysis

Microsoft Excel was used for the statistical analysis of data. Detailed analyses are presented in Chapters 4 and 5. Basic statistical calculations were carried out in exploring patterns in the quantitative data.

3.10 Reliability and validity

Reliability deals with the repeatability of findings, while validity deals with the credibility or believability of the research (Bryman, 2012). In this study, reliability and validity were achieved by:

- conducting a pilot of the questionnaire with an expert that was familiar with the study area and research field. Based on the pilot study, the questionnaire survey was revised for final implementation
- the questionnaire survey was developed in line with a previous study by Halpern et al., 2007.

3.11 Research Ethics: Key Considerations

Since this study involves human subjects and sensitive data collection, ethical clearance was granted from the Rhodes University Science Faculty Ethics Committee (SCI2018 / 044).
Concerning research ethics, Creswell & Creswell (2018) reminds researchers to be aware of the following:

- Informed consent
- Privacy, confidentiality and anonymity
- Voluntary participation

3.11.1 Informed consent

Informed consent was received from all participants. Participants were informed of the purpose of the study, as well as their roles in the study. Consent was both verbal and written

3.11.2 Privacy, Confidentiality and Anonymity

The participants' privacy, confidentiality and anonymity were maintained by removing identifying characteristics and assigning codes to their responses.

3.11.3 Voluntary Participation

Participants were informed that their participation was voluntary and that they could opt out of the research at any time.

3.12 Conclusion

In this case study, mixed-methods study of the impact of human activities on the Algoa Bay marine environment, qualitative and quantitative data were collected to answer the research questions identified. Quantitative data were analysed using statistical and spatial analysis, while qualitative data were analysed through thematic content analysis by identifying themes. Appropriate steps were taken to ensure the reliability and validity of findings from this mixed-methods study. Research ethics were properly observed in this study. The overall process of this study can be seen in Figure 3.13.

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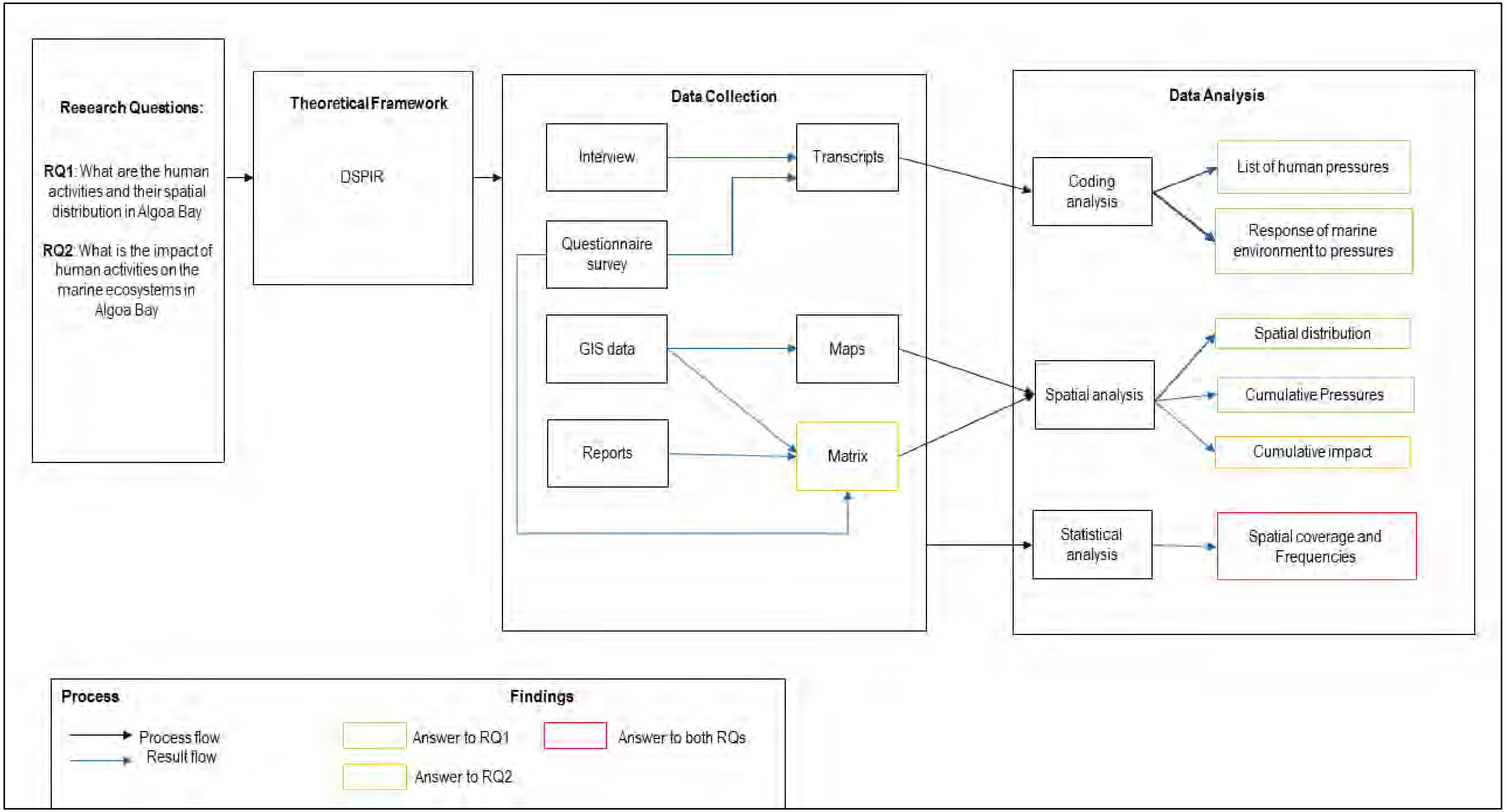
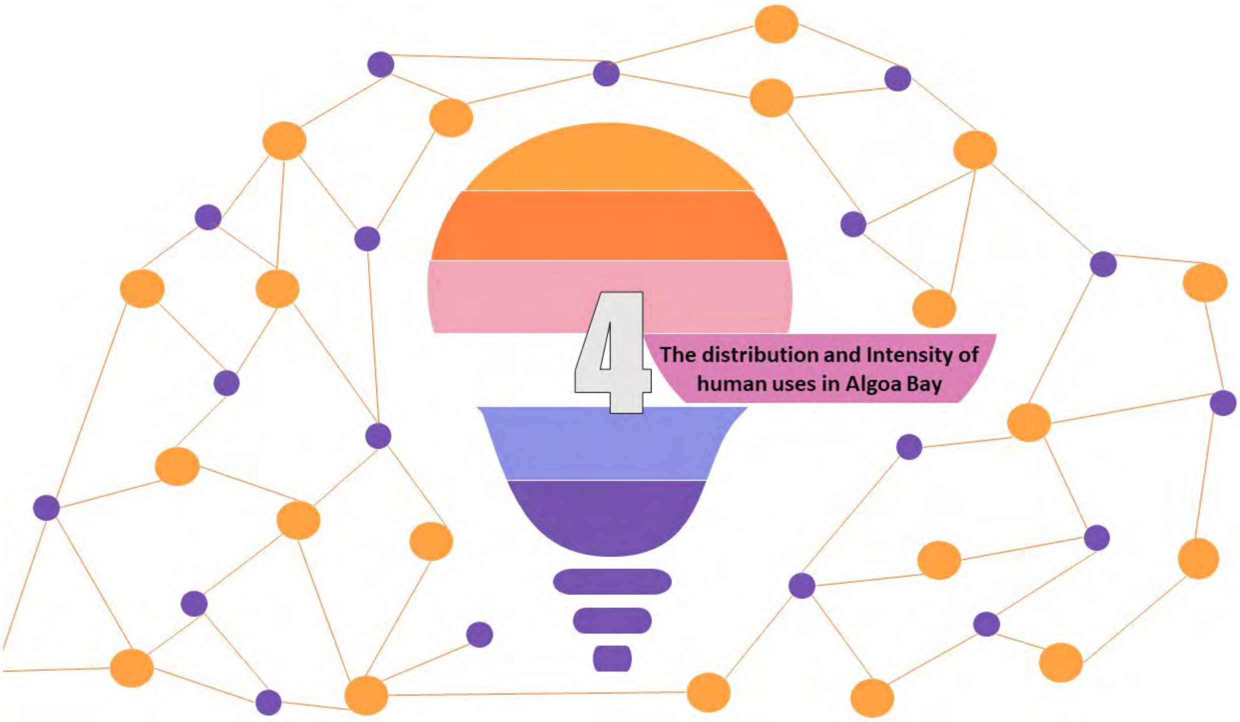
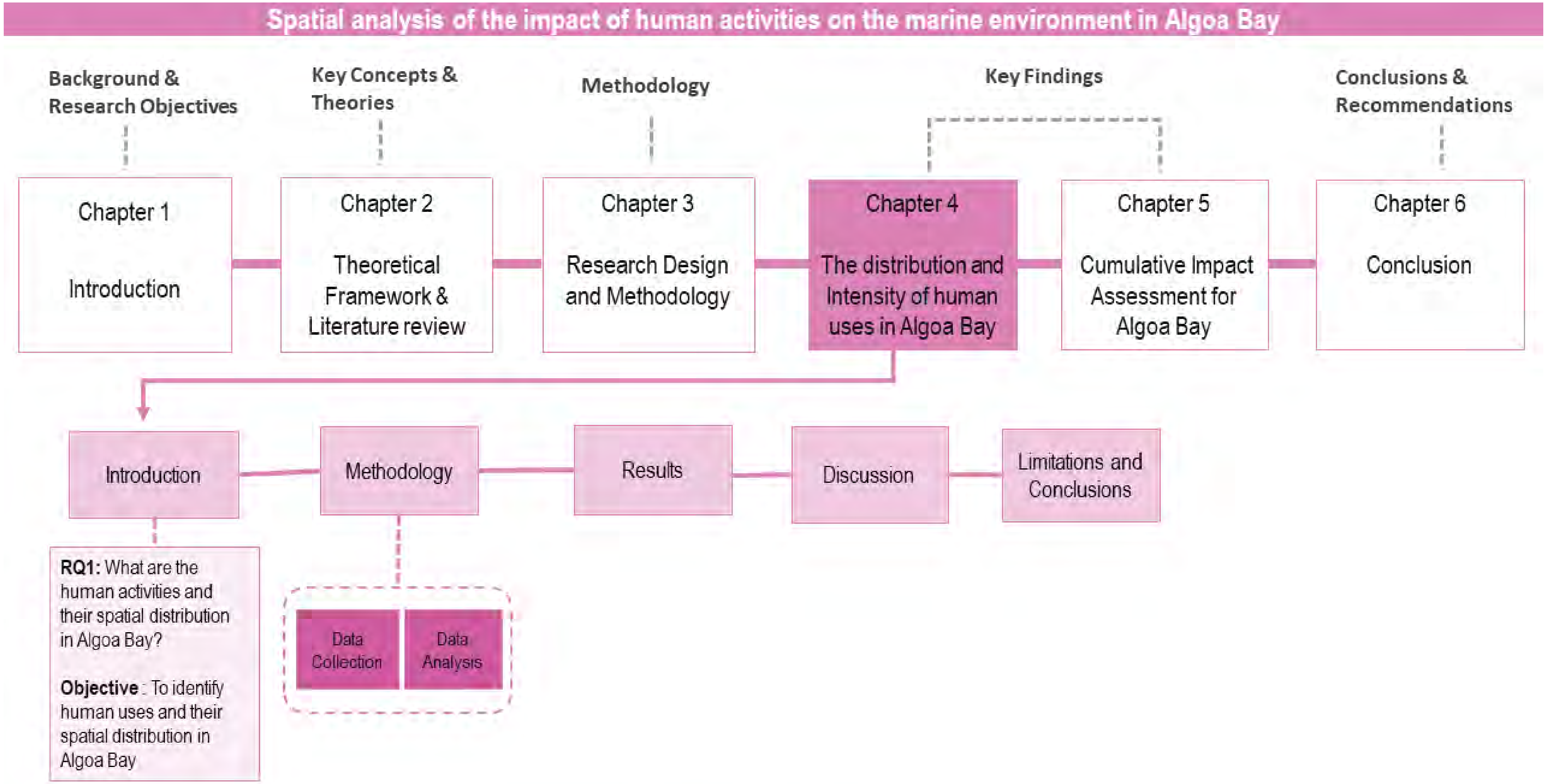


Figure 3. 10: Research design and methodology summary for the study.


4
The distribution and Intensity of human uses in Algoa Bay



Chapter Four Overview

4. THE DISTRIBUTION AND INTENSITY OF HUMAN USES IN ALGOA BAY

4.1 Introduction

4.1.1 The marine environment, human uses and marine spatial planning

The marine environment provides humans with many ecosystem goods and services such as climate buffering, oxygen production, food resources, tourism and recreation, mining, shipping and pharmaceuticals (Ansong et al., 2017). Additionally, the marine environment provides jobs connected to the ocean, providing a source of livelihood for coastal communities (Liquete et al., 2013). Unsustainable use, ocean warming, acidification and pollution are now threatening the ocean's ability to provide the ecosystem services upon which humans depend (Leslie, 2005).

Since access to the marine environment is often unrestricted, there is potential for the unsustainable use of resources as well as conflicts between ocean users (Ehler & Douvere, 2009). Increasing population growth has resulted in more demand and less supply of these resources (Branch & Branch, 2018). The oceans now have decreased capacity to provide sustainable resources (Neumann et al., 2017). Spatial representation of human activities in the ocean and an assessment of the relative impacts associated with these activities are important in monitoring, mitigating, and reducing negative impacts. Marine spatial planning (MSP) approaches can assist with this mitigation and promote healthy oceans and sustainable blue economies (Dailianis et al., 2018).

Ehler & Douvere (2009) define MSP as "a public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic and social objectives that are usually specified through a political process". MSP is considered to be a "suitable" management option which is a "spatially explicit" process that accounts for the management of multiple pressures (Parravicini et al., 2012). MSP informs the spatial delineation of marine activities to support sustainable current and future uses of the marine environment while attempting to maintain ecosystem services to meet economic, ecological and social objectives (Ban et al., 2013b)

To fulfil the effective development of MSP, Ehler and Douvere (2009) outlined the ten steps which must be undertaken, with an emphasis that MSP can produce various environmental, economic and social benefits when properly developed. Figure 4.1 frames the study by addressing steps 4 and 5 from Ehler & Douvere (2009). Step 4 involves identifying relevant stakeholders as a way to achieve multiple objectives and reflect various perspectives on the uses, conflicts and opportunities occurring in the MSP area of study. Step 5 involves collating and mapping human uses and pressures in the area of study (Ehler & Douvere, 2009).

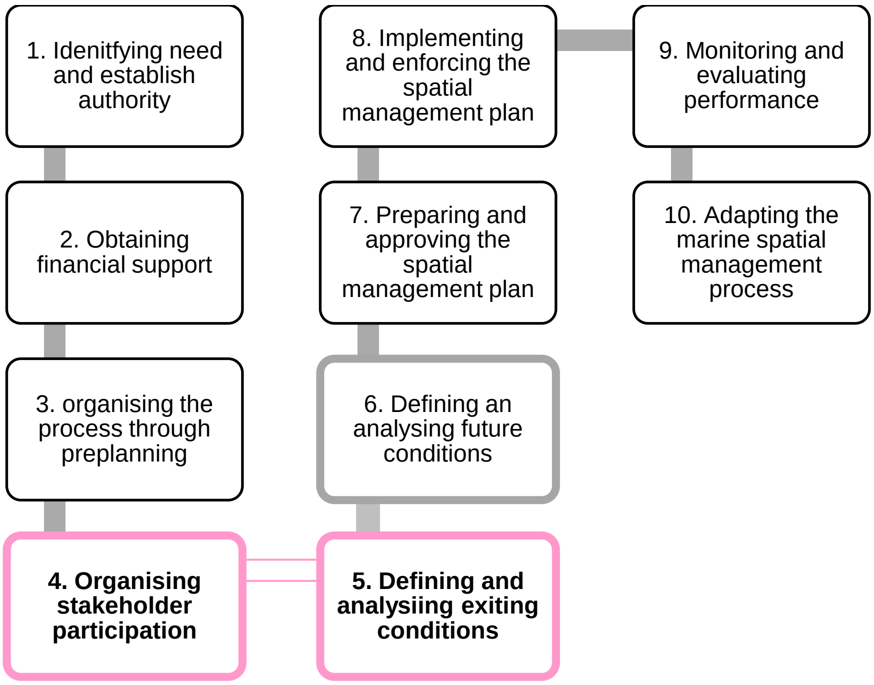


Figure 4. 1: Steps in MSP (Source: Ehler and Douvere, 2009).

4.1.2 <u>Participation and GIS</u>

Understanding how spatial plans can conserve important species and ecosystems that support the needs of the various stakeholders is important in achieving goals for managing the marine environment (Levine and Feinholz, 2015). Advancements in GIS-based tools have allowed for the rise in techniques used to combine quantitative and qualitative data into maps of stakeholder uses to support spatial planning (Stelzenmüller et al., 2013).

The information from stakeholders can be collected through participatory mapping methods to result in multiple levels of information such as social uses, ecological patterns and concerns (Levine & Feinholz, 2015). Participatory GIS, Public participation GIS and Volunteered Geographic Information (VGI) are terms used for social and participatory research methods of collecting spatial information (Brown et al., 2017).

In this study, the participatory method of collecting spatial information will be referred to as participatory GIS. Participatory GIS aims to identify attributes of a place that range on a scale from subjective perceptions of the place to objective location based on the participant's knowledge and experience in the study area (such as human uses and behaviours) (Brown et al., 2017). Littaye et al. (2016) emphasised that the participatory approach is beneficial in facilitating the need to address socio-environmental issues and promote knowledge.

4.1.3 Expert Knowledge

Perera et al.'s (2012:3) definition of experts involves key categories of individuals, namely;

- "**scientists**, who conduct research and publish their knowledge formally
- **practitioners**, who apply scientific knowledge management but typically do not conduct research and publish their knowledge formally
- **stakeholders**, who have an interest in the outcome of applying ecological knowledge to inform conservation or resource extraction issues; and elders of local societies (aboriginal or other) who are rich sources of traditional knowledge."

Expert knowledge can be a valuable source of information to supplement existing geographic information (Aswani & Lauer, 2006; Goodchild & Li, 2012). Expert knowledge can also provide information that may be difficult to observe directly (Uusitalo et al., 2016). In addition, including community participation and local knowledge in the decision-making process of a management plan is key to obtaining more comprehensive information and developing successful management plans (Levine & Feinholz, 2015).

Cowling et al. (2003) emphasize that using expert knowledge in conservation planning involves challenges such as data being biased towards the experts' fields of expertise on locations and taxa. Using scientific data and expert knowledge can lead to the production of gap-filling knowledge in the scientific understanding and development of priorities for management plans (Noble et al., 2020).

The research objective of this Chapter is to identify and map the spatial extents and intensities of human pressures in Algoa Bay to assist with the development of a MSP for the bay (Dorrington et al., 2018). This will build onto the information collated by the 2018 NBA (Sink et al., 2019) and the Algoa Bay Project (2019).

The Algoa Bay Systematic Conservation Planning (SCP) report (Algoa Bay Project 2019) collected all available data on human uses in Algoa Bay. Some of the data layers included expert data, which provided a base for this research. This study will build onto the existing data by expanding the knowledge base, including more stakeholders, integrating as many uses as possible and building a holistic picture of the uses of the ocean. The data provided from this Chapter are used in the next Chapter to develop a map of cumulative impacts.

4.2 Methodology

The method followed in this Chapter was derived from the Algoa Bay Project (2019), where expert mapping and existing data were used to produce a cumulative pressure layer of human uses for conservation planning purposes to feed into a marine spatial plan for the bay.

4.2.1 Data Collection

Primary data were obtained from questionnaire surveys, interviews, focus groups and expert mapping. Secondary data were obtained from the 2018 NBA (Sink et al., 2019) and SCP (Algoa Bay Project, 2019) reports and through GIS datasets from scientific organizations. Appendix 1 summarises the data sources from scientific organizations. Figure 4.2 summarises the data collection methods that were used to address the research question: What are the human activities and their spatial distributions in Algoa Bay?

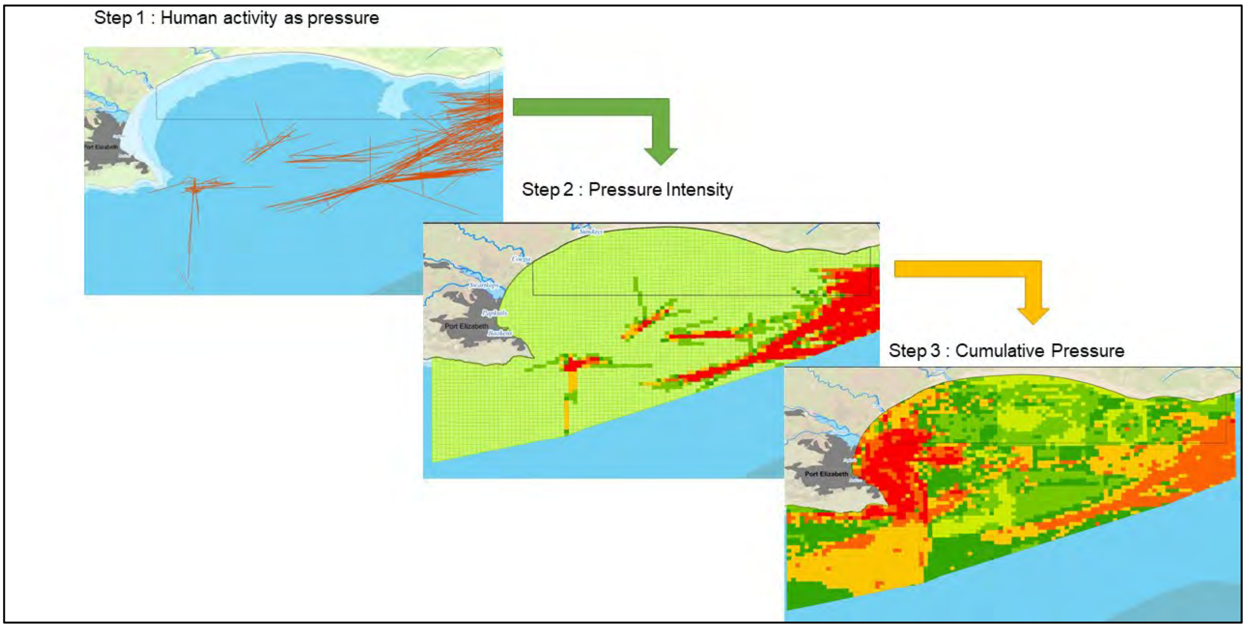


Figure 4. 2: Schematic presentation of the steps followed in data analysis. Step 1 shows only one of the seventeen pressure layers used in the analysis. Step 2 shows the transformation of the pressure layer to show its intensity and step 3 shows the sum of the seventeen pressure intensity layers.

4.2.2 Spatial Analysis

This study used the 1km^2 planning units that were created for the SCP report (Algoa Bay Project, 2019). This planning unit size was chosen for Algoa Bay because it matched the varying resolutions of different spatial datasets and was used in expert mapping conducted for the Algoa Bay Project (2019). The Algoa Bay planning unit included source data from the National Biodiversity Assessment (NBA) report (Sink et al., 2019), which included data for cumulative pressure. Source data in the planning unit included the SCP data (7 pressures summarised in Table 4.1). The NBA and SCP data were in the same planning units as the Algoa Bay planning units and spatial conversions were not necessary. Contents of the GIS data layers used for analysis are summarised in Table 4.1.

Table 4. 1: Data layers used for calculating cumulative pressures per planning unit in Algoa Bay.

Source	Data layer	Number of layers	Weighting
National Biodiversity Assessment (Sink ***et al***., 2019)	Cumulative pressure layer which incorporated: -Coastal development -Coastal disturbance -Wastewater discharge -Invasive alien species -Recreational and subsistence fisheries, -Industrial fisheries -Small pelagic fisheries	1	3x
Systematic conservation planning report (Algoa Bay Project, 2019)	Individual layers for different human uses: -Shipping intensity -Shipping lanes -Dredge dumping -Squid -Inshore trawl -Shark longline -Line fishing	7	1x
Scientific Organizations (Attached in Appendix 1)	Individual layers for different human uses: -Nutrient enrichment: Dissolved Inorganic Nitrogen (DIN) -Nutrient enrichment: Dissolved Inorganic Phosphorus (DIP) -Outfalls - Recreational activities -Research monitoring -Anchorage -Mariculture	7	1x
Expert mapping	Individual layers for different human uses: -Ballast water discharge -Abalone poaching	2	1x
		Total layers: 17	

NB: The rows summarise the source data that were used to calculate cumulative pressures. The data layer column summarises the layers that were included in the analysis. The weighting column refers to the weight that was given to each layer when calculating the cumulative pressure. The cumulative pressure data from the National Biodiversity Assessment were given a weight of three times more than the other layers, as was done in the SCP (Algoa Bay Project, 2019).

The researcher was involved in the collection of data (between November 2018- September 2020) for the following layers: ballast water discharge, abalone poaching, Dissolved Inorganic Nitrogen (DIN), Dissolved Inorganic Phosphorus (DIP), outfalls, recreational activities, research monitoring, anchorages and mariculture as well as development thereof for use in the Algoa Bay Project.

4.2.2.1 Expert mapping

The maps from the questionnaire survey (Appendix 7) were scanned as images and processed in ArcMap. The Georeferencing Tool was used to geo-reference the scanned image and digitize the human uses that were delineated. Data collected from Google Earth were converted from Keyhole Markup Language (KML) format to shapefiles in ArcGIS.

All the new data generated from the experts were then collated to present the overall distribution of marine activities as one map. Where data were absent, data from expert mapping was used (e.g. ballast water discharge). These data were validated by assessing the knowledge base of the expert who provided the data. Data from experts with scientific backgrounds and experience working in the study area were retained.

4.2.2.2 Pressure Intensity

Data layers were summarised into the Planning Units (PUs) using the Intersection tool in ArcGIS. For polygon datasets, such as anchorage, the percentage coverage of a pressure polygon in a planning unit was used as a measure of intensity; thus, 100% coverage meant that the intensity was 100 and a 50% coverage meant that the intensity was 50. For point datasets, such as recreational activities, the number of points present in a PU was used to determine the intensity of the pressure. For point data indicating diffusion into the sea, such as outfalls and nutrient enrichment, adjacent PUs were picked to highlight the intensity of the point based on the output volume value given in the dataset. These layers were then scaled from 0-100.

4.2.2.3 Spatial coverage

The planning unit layer was exported to Microsoft Excel, where the spatial coverage of the activities (SCP data, scientific data and expert data) was determined by calculating the percentage coverage within the planning unit.

4.2.2.4 Cumulative pressure

In order to calculate the 2020 cumulative pressure, a new field was added to the planning unit layer. The cumulative pressure value for each planning unit (Cp) was calculated by adding all the 17 layers (summarized in Table 4.1) together as shown below:

$$Cp = \sum_{(i=1)}^{n} \boldsymbol{NBA(x3) + SCP + Sci + Exp}$$

Where:

The $\boldsymbol{NBA(x3)}$ layer reflected data for the 2018 cumulative pressure, scaled from 0 - 100 and multiplied by three according to the same method described by the Algoa Bay Project (2019). The $\boldsymbol{SCP}$ field included the seven layers from the SCP project (refer to Table 4.1). The $\boldsymbol{Sci}$ field included seven layers from scientific organisations, as summarized in Table 4.1 and Appendix 1. The $\boldsymbol{Exp}$ field included two layers that were collected from expert mapping. All data layers were scaled from 0-100 (this scale was based on the percentage cover of a pressure in the planning unit). Figure 4.3 summarises the steps followed in ArcGIS for the development of a cumulative pressures layer.

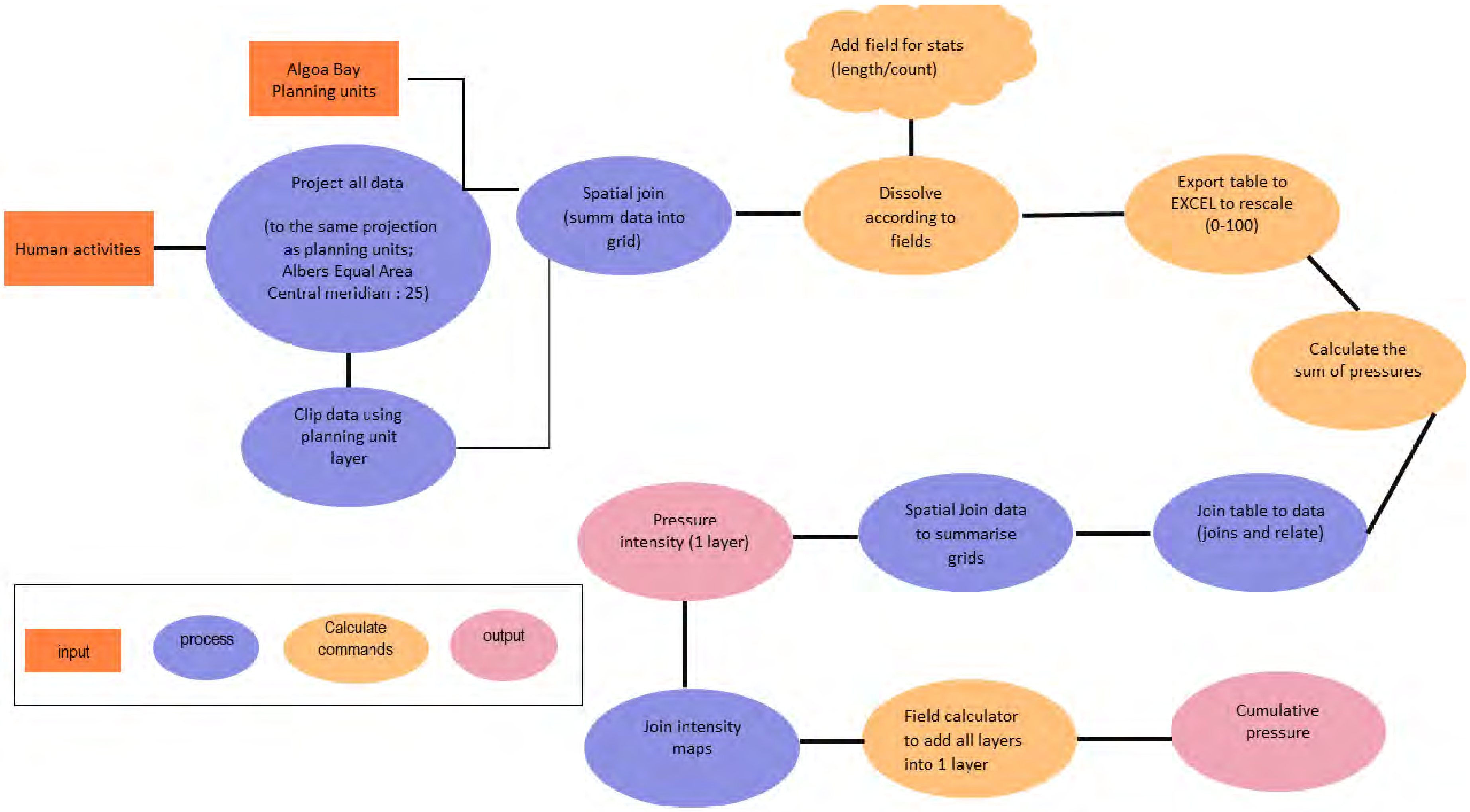


Figure 4. 3: Cartographic model of the process used in ArcGIS for the development of a cumulative pressures layer for Algoa Bay.

4.2.3 Qualitative Data Analysis

Microsoft Excel and NVivo 11 (QSR International) were used for thematic analysis of the qualitative data. The thematic content analysis identifies themes and patterns in the text (Bezuidenhout and Cronje, 2014). Microsoft Excel was used to record and capture all qualitative data from the questionnaire survey, interviews and focus group. In order to understand the data, the recorded data were imported to NVivo 11 software for further analysis, using the import wizard option. This software was used as it provides consistency and replicability. An inductive coding approach (Bezuidenhout & Cronje, 2014) was used where the researcher allowed for codes to emerge from a thorough examination of the text.

Analysing the open-ended questions from the questionnaire survey as well as the interview and focus group data involved a method of thematic content analysis. The auto code option was used to code data from the Microsoft Excel file imported into NVivo automatically. When NVivo creates codes, it refers to them as nodes. NVivo created nodes for each of the questions (Columns in Microsoft Excel). The nodes were edited by reducing the repetition of words through grouping based on common themes that emerged from participant statements. This structure allowed for queries in NVivo to be run that identified patterns based on thematic statements. The text search query was done to find patterns that emerged from the theme. Data visualisation was done by creating word clouds and word trees from relevant questions. Figure 4.4 represents the steps that were followed in the analysis of qualitative data.

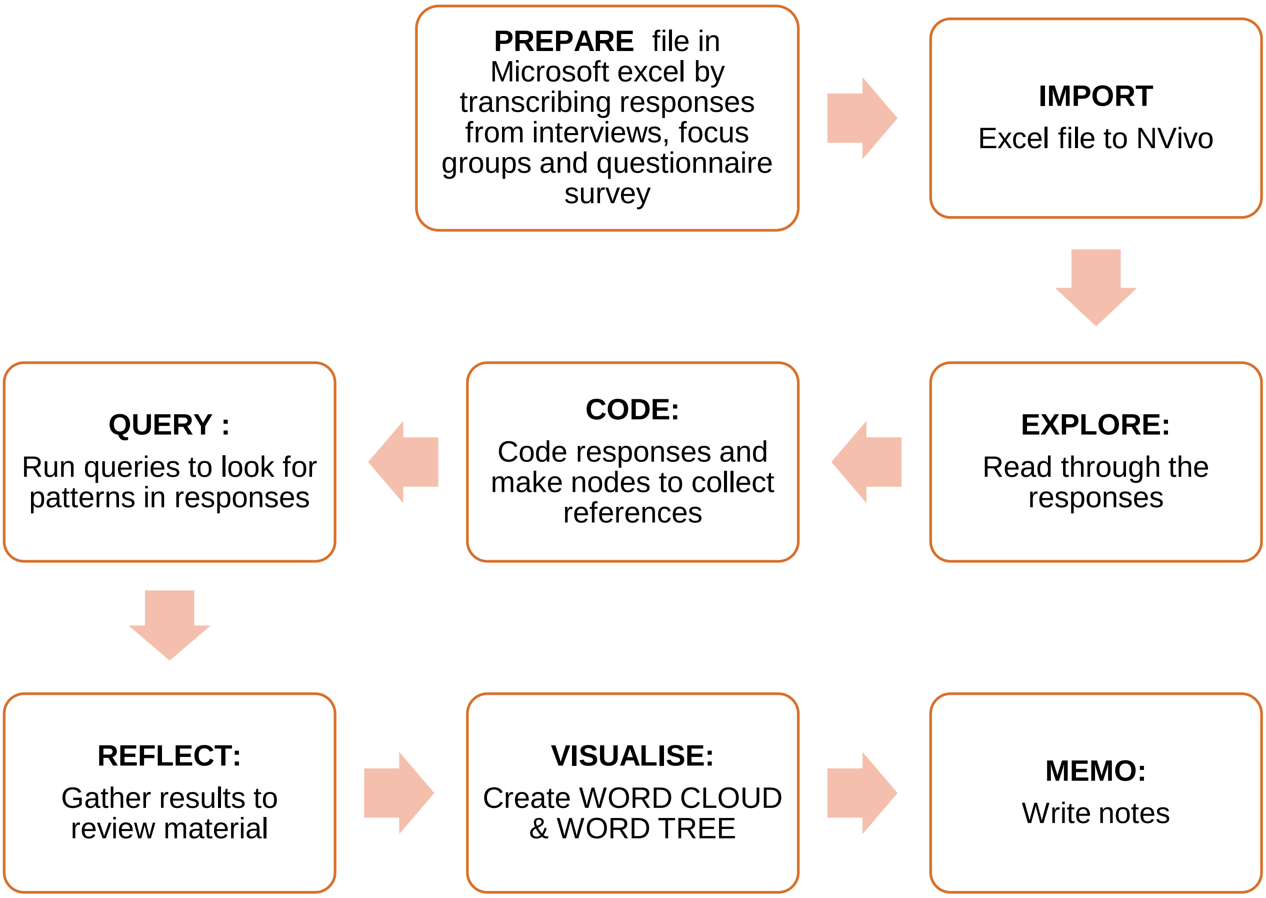


Figure 4. 4: Steps taken when conducting qualitative data analysis (NVivo Help, 2020).

4.3 Results

4.3.1 Spatial distributions of Human Activities

There is a wide distribution of human activities in Algoa Bay, as shown in Figure 4.5. Most activities take place closer to the coast in the inshore environment. Inshore trawling has a large spatial extent when compared with other human activities. Research monitoring is also widely distributed across the marine environment.

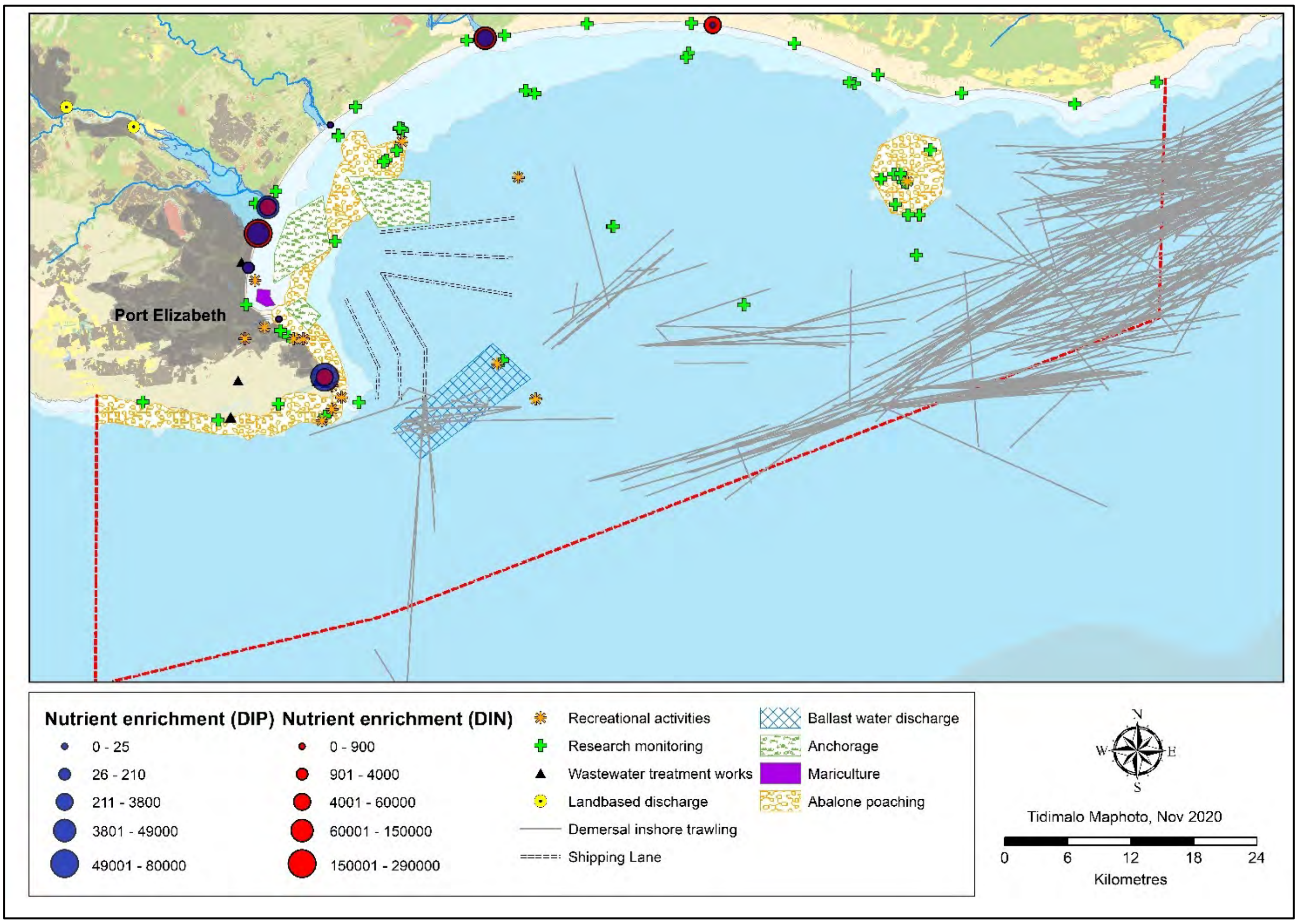


Figure 4. 5: The spatial distribution of selected human uses in Algoa Bay. Data used in producing this map do not include 2018 NBA and 2019 SCP data since data from the 2019 SCP were already summarised into grids. As a result, only GIS data collected from expert mapping and scientific organizations were used. *(*Data sources are summarised in Appendix 1).

4.3.2 Spatial coverage and Intensities of human activities

Figure 4.6 shows a concentration of shipping activities (anchorage, shipping lanes and shipping intensity) around the harbours and close to the economic centre. The mapped shipping activities have high intensities with only a few low intensities. Shipping intensity shows the greatest spatial coverage within the planning units.

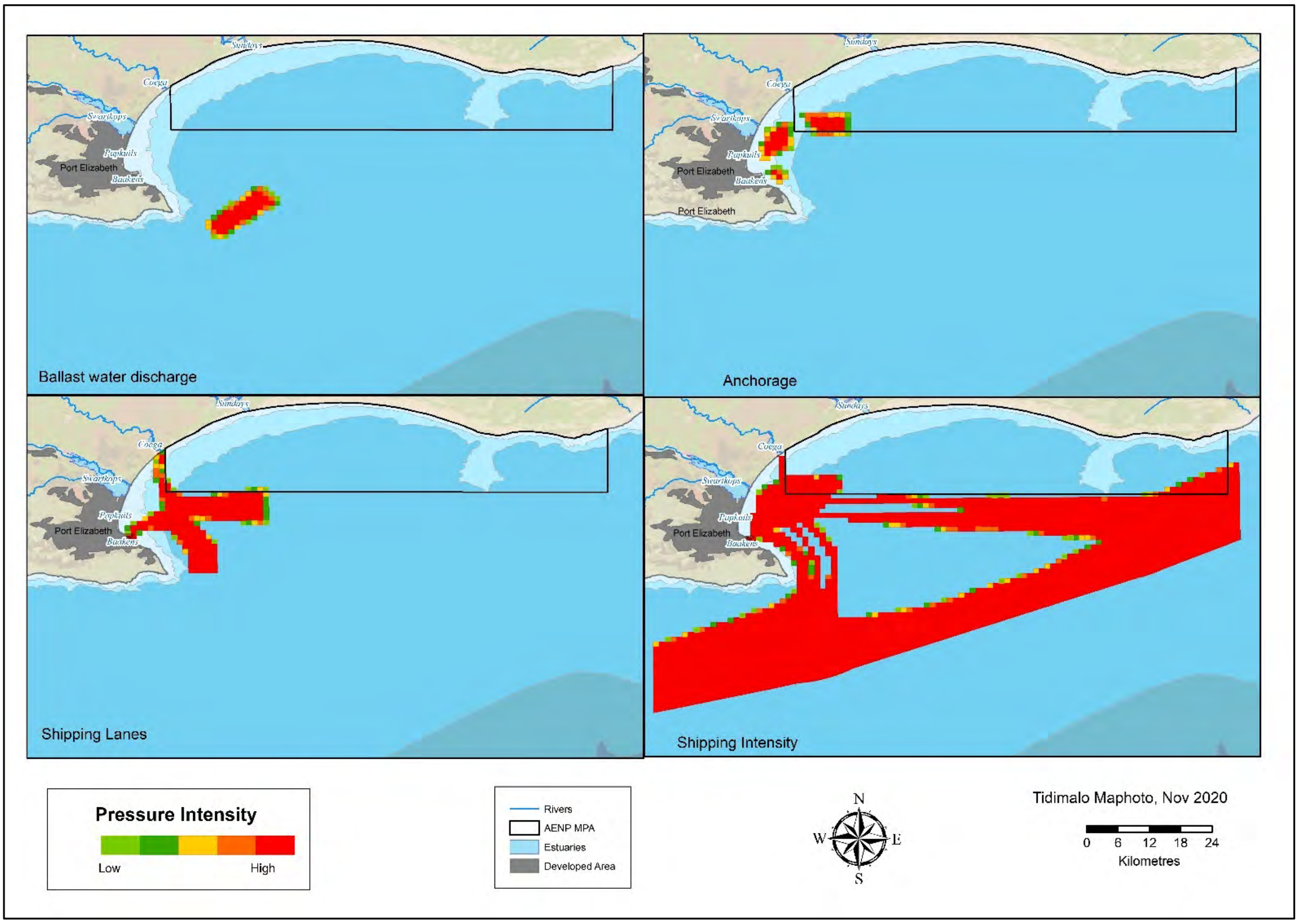


Figure 4. 6: The distribution and intensity of shipping activities in Algoa Bay (Source of data: Algoa Bay Project, 2019). a) Ballast water discharge, b) Anchorage, c) Shipping lanes and d) Shipping intensity. The data scale ranged from 1-100 and equal intervals of 20 were used as a classification method in ArcGIS to display the data. Cells with 0 values were removed from the display.

Different fishing activities occur across the bay, as shown in Figure 4.7 and all occur with high intensities. Trawling occurs in the deeper waters and the high-pressure intensities can be seen concentrated in the offshore marine environment. At the same time, squid fishing occurs closer to the shore. Shark longline fishing shows high intensity throughout much of the bay. Line fishing has the least intensity compared with other fishing activities, with a moderate spread across the bay. Shark longline shows the greatest spatial extent within the planning units, followed by trawling.

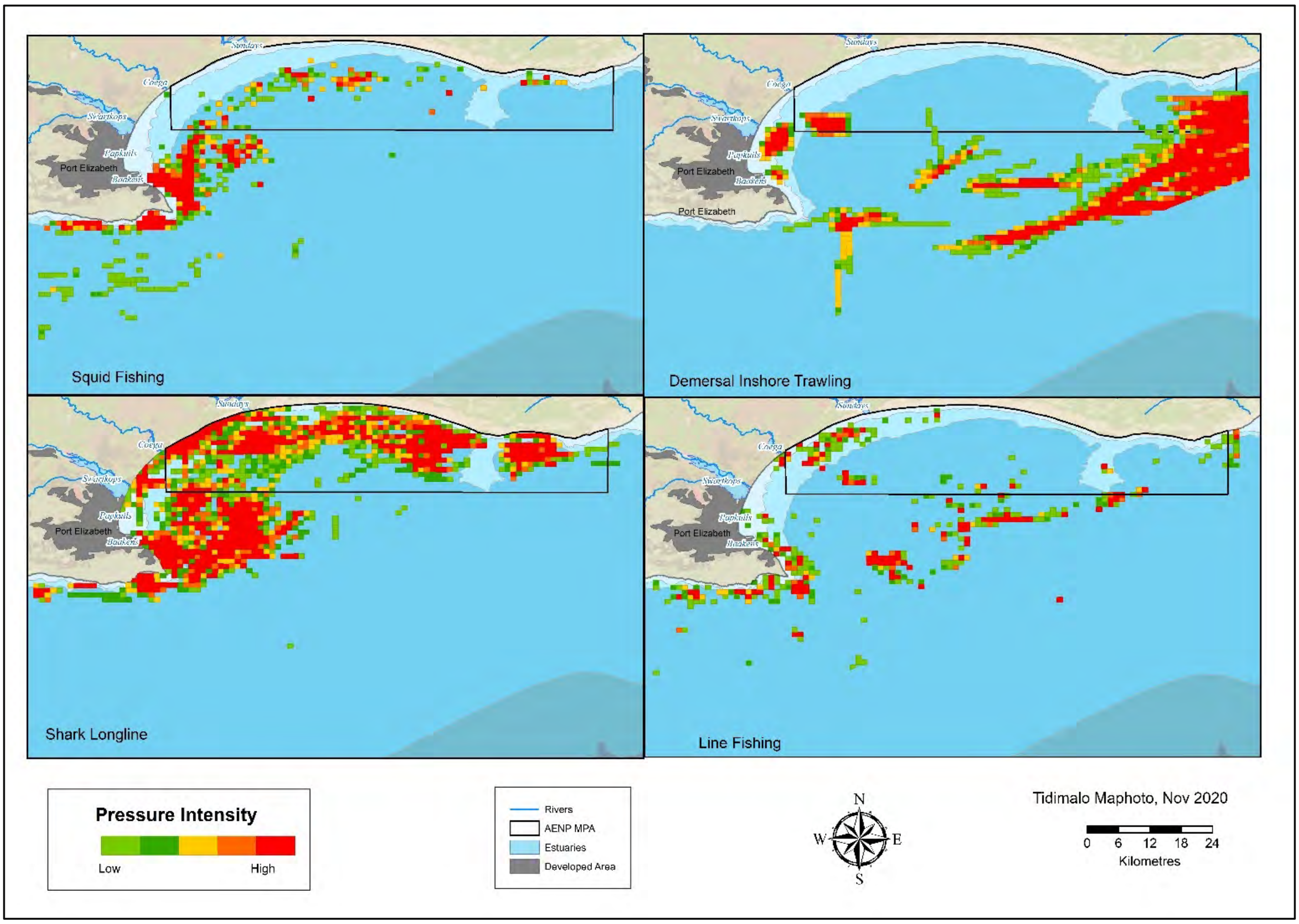


Figure 4. 7: The distribution and intensity of fishing activities in Algoa Bay. (Source of data: Algoa Bay Project, 2019). a) Squid fishing, b) Demersal inshore trawling, c) Shark longline, and d) Line fishing. The data scale ranged from 1-100 and equal intervals of 20 were used as a classification method in ArcGIS to display the data. Cells with 0 values were removed from the display.

Figure 4.8 illustrates fewer areas of high-pressure intensities for sources of pollution. Dissolved inorganic nitrogen (a) has the highest intensity in the Baakens estuary and moderate intensities in the Papkuils and Swartkops estuaries. Dissolved inorganic phosphate (b) shows the highest intensity in the Papkuils estuary and moderate intensity in the Sundays estuary. Dredge dumping (d) reflects high-pressure intensities closer to the Port of Ngqura harbour.

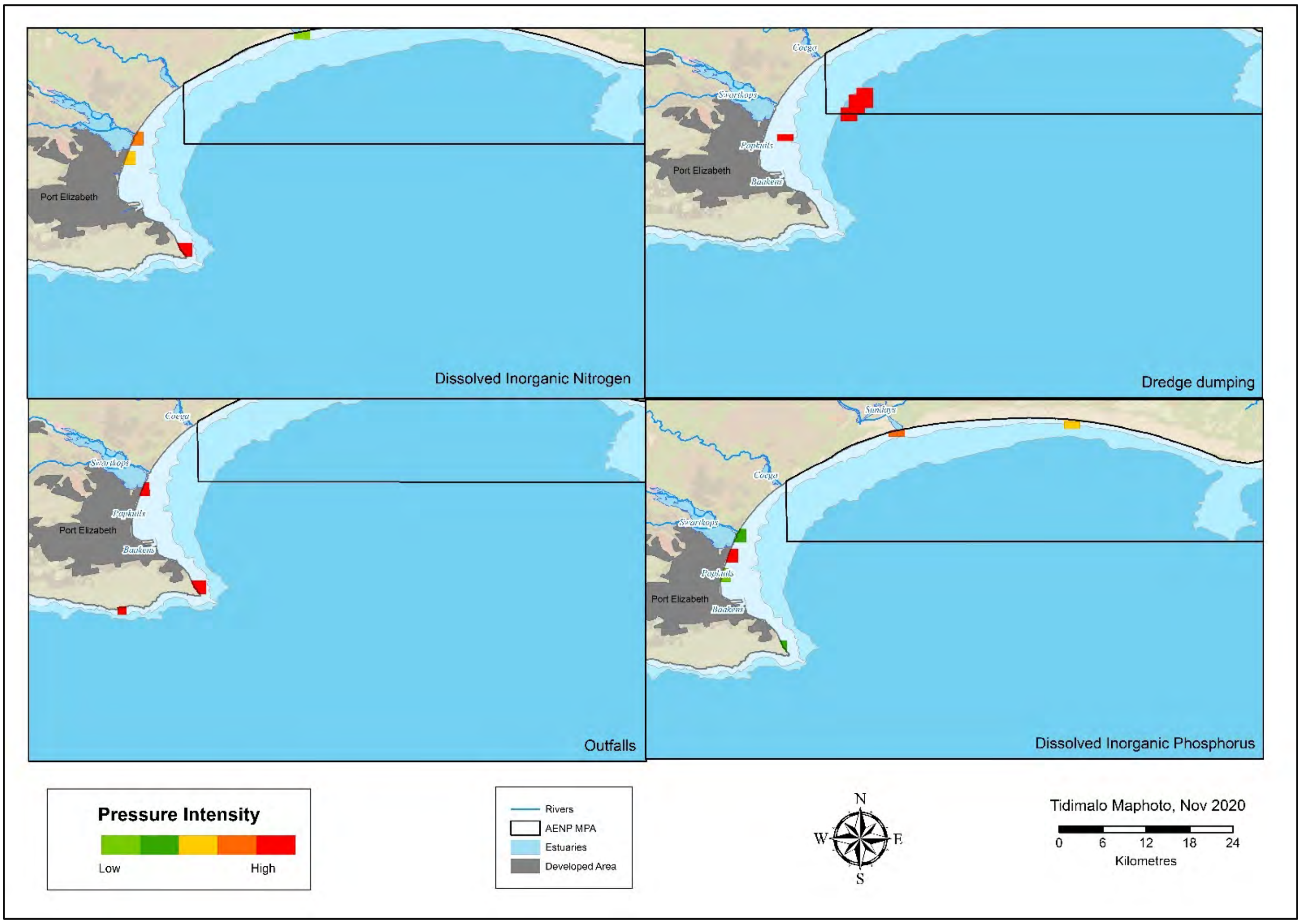


Figure 4. 8: The distribution and intensity of sources of pollution and dredge dumping in Algoa Bay. a) Dissolved Inorganic Nitrogen, b) Dredge dumping, c) Outfalls and d) Dissolved Inorganic Phosphorus. (Data sources are summarised in Appendix 1). The data scale ranged from 1-100 and equal intervals of 20 were used as a classification method in ArcGIS to display the data. Cells with 0 values were removed from the display.

Figure 4.9 shows a concentration of few high-pressure intensity for mariculture (a) closer to the Port of Port Elizabeth. Abalone poaching (b) show high-pressure intensities on the western side of the bay and Bird Island. Research monitoring (c) and Recreational activities (d) reflect a dispersed pattern with low-pressure intensities.

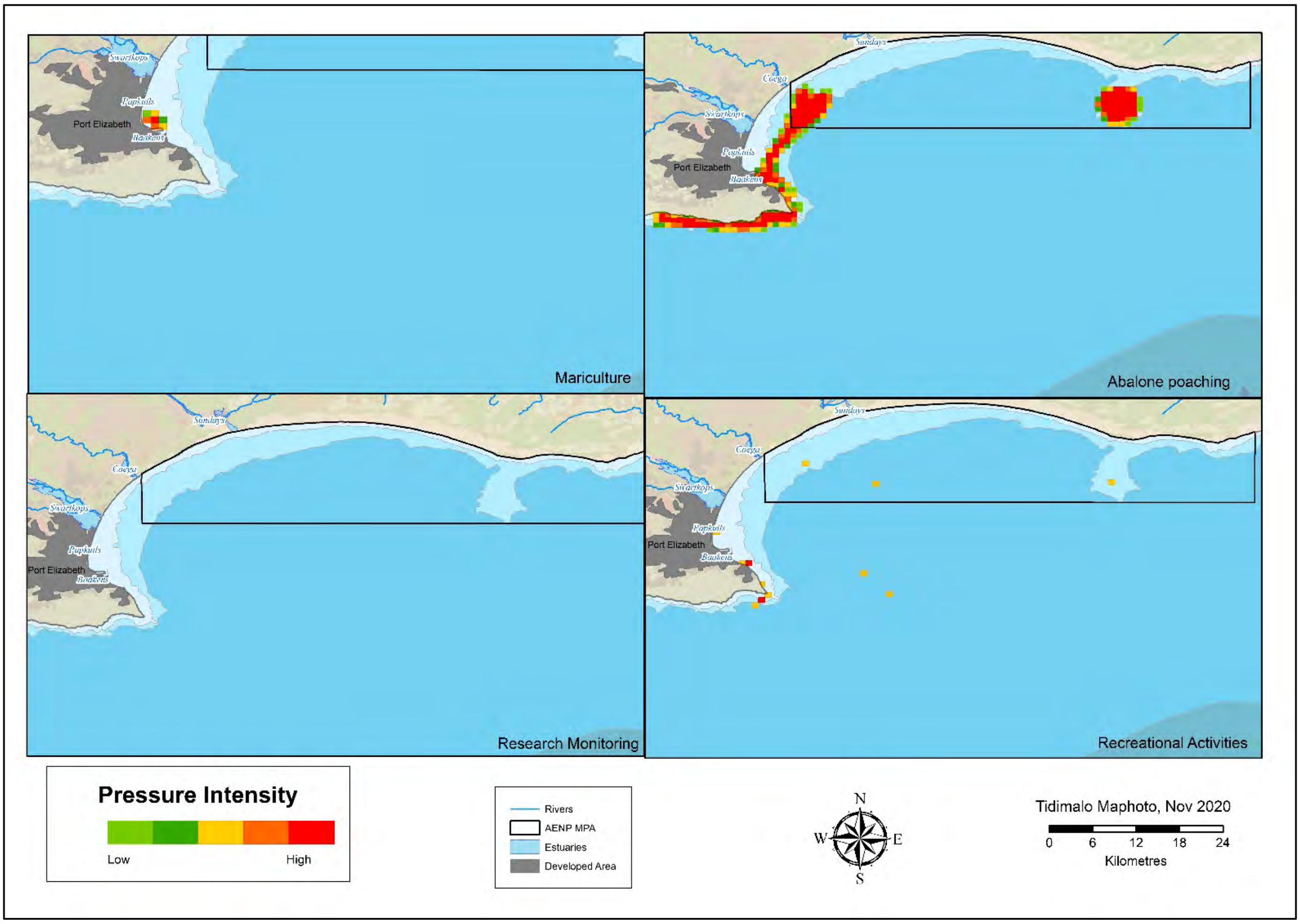


Figure 4. 9: The distribution and intensity of a) mariculture, b) abalone poaching, c) research monitoring and d) recreational activities in Algoa Bay (Source of data: Expert mapping). The data scale ranged from 1-100 and equal intervals of 20 were used as a classification method in ArcGIS to display the data. Cells with 0 values were removed from the display.

According to Figure 4.10, the activities with the greatest spatial coverage within the planning unit are shipping, shark longline and trawling. In comparison, activities with the least spatial coverage are dredge dumping, recreational activities, outfalls and mariculture. The activities with the highest spatial coverage also have high intensities, as previously shown in Figure 4.7 and Figure 4.8.

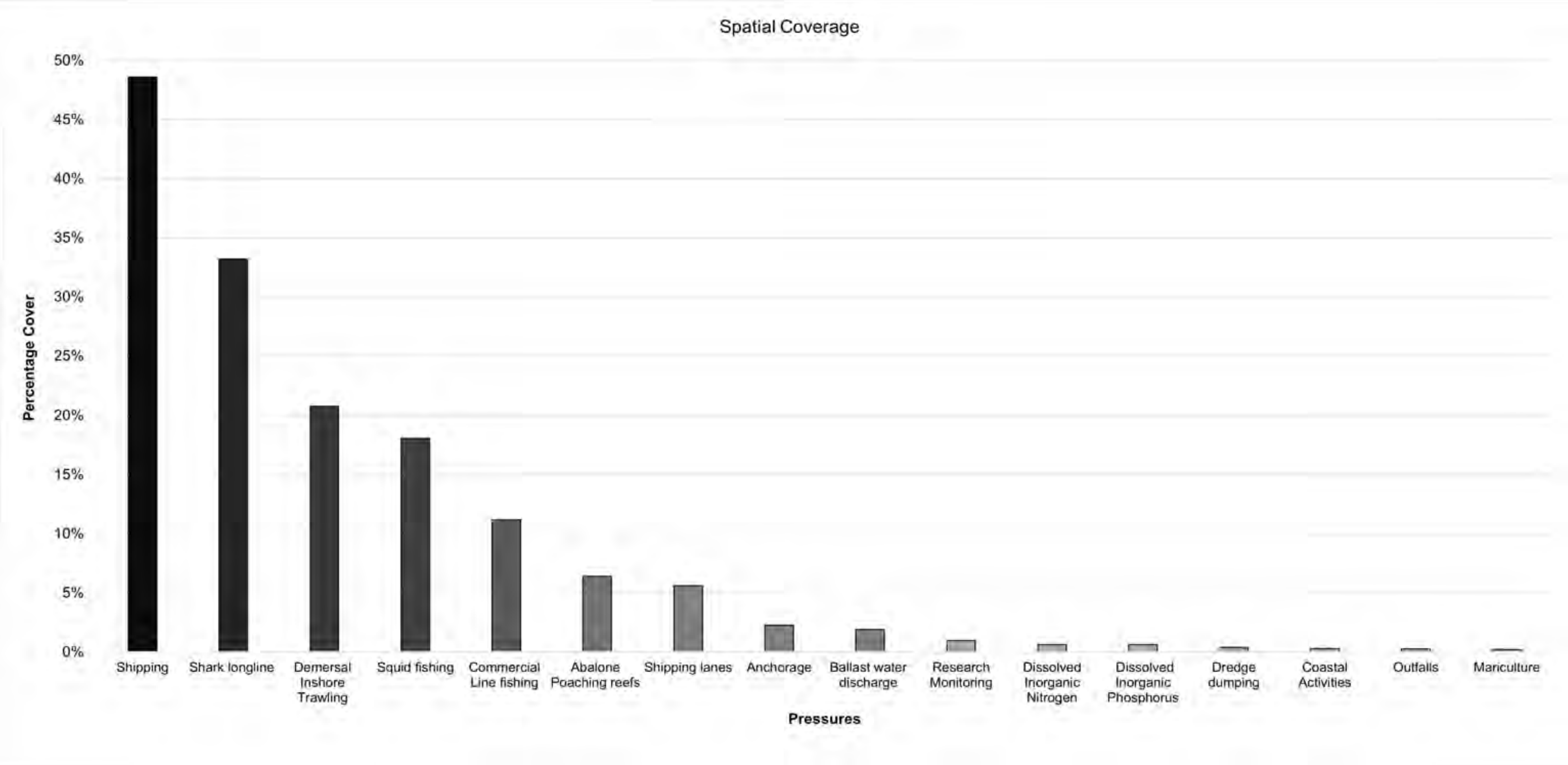


Figure 4. 10: The spatial coverage of the human pressures. The calculation was based on the percentage coverage of individual activity data layers within the planning unit layer.

4.4 Cumulative pressures

4.4.1 The 2018 NBA Cumulative pressures

Figure 4.11 illustrates the spatial patterns of cumulative pressures mapped by the 2018 NBA Sink et al. (2019). This cumulative pressure map included the following layers: coastal development, coastal disturbance, wastewater discharge, invasive alien species, the range of recreational and subsistence fisheries and industrial fisheries.

The highest cumulative pressure is present closer to the coast on the western side of the bay, where activities such as shipping take place and the south of the bay, where fishing activities such as poaching of abalone occur.

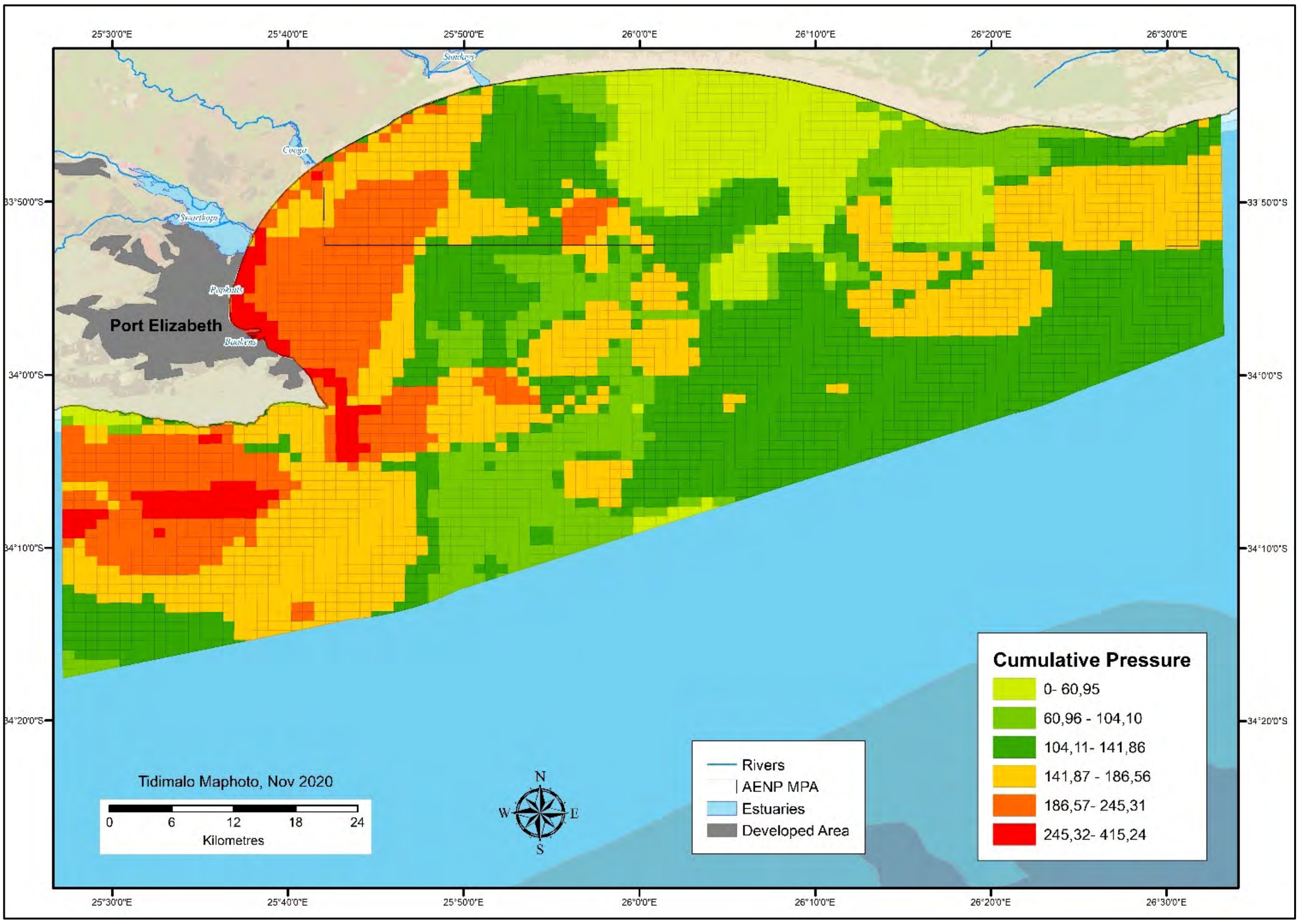


Figure 4. 11: The 2018 NBA Cumulative Pressures (Source of data: Sink et al., 2019). Natural breaks were used as a classification method in ArcGIS to display the data.

4.4.2 The 2019 SCP Cumulative Pressures

Figure 4.12 illustrates the spatial patterns of cumulative pressures mapped by the Algoa Bay Project (2019). The cumulative pressure layer included data from the 2018 NBA cumulative layer, as well as seven individual layers for the following human uses: shipping intensity, shipping lanes, dredge dumping, squid, inshore trawl, shark longline, line fishing.

The spatial patterns of the cumulative pressures reflect high cumulative pressures on the western side of the bay, close to harbours and four estuaries.

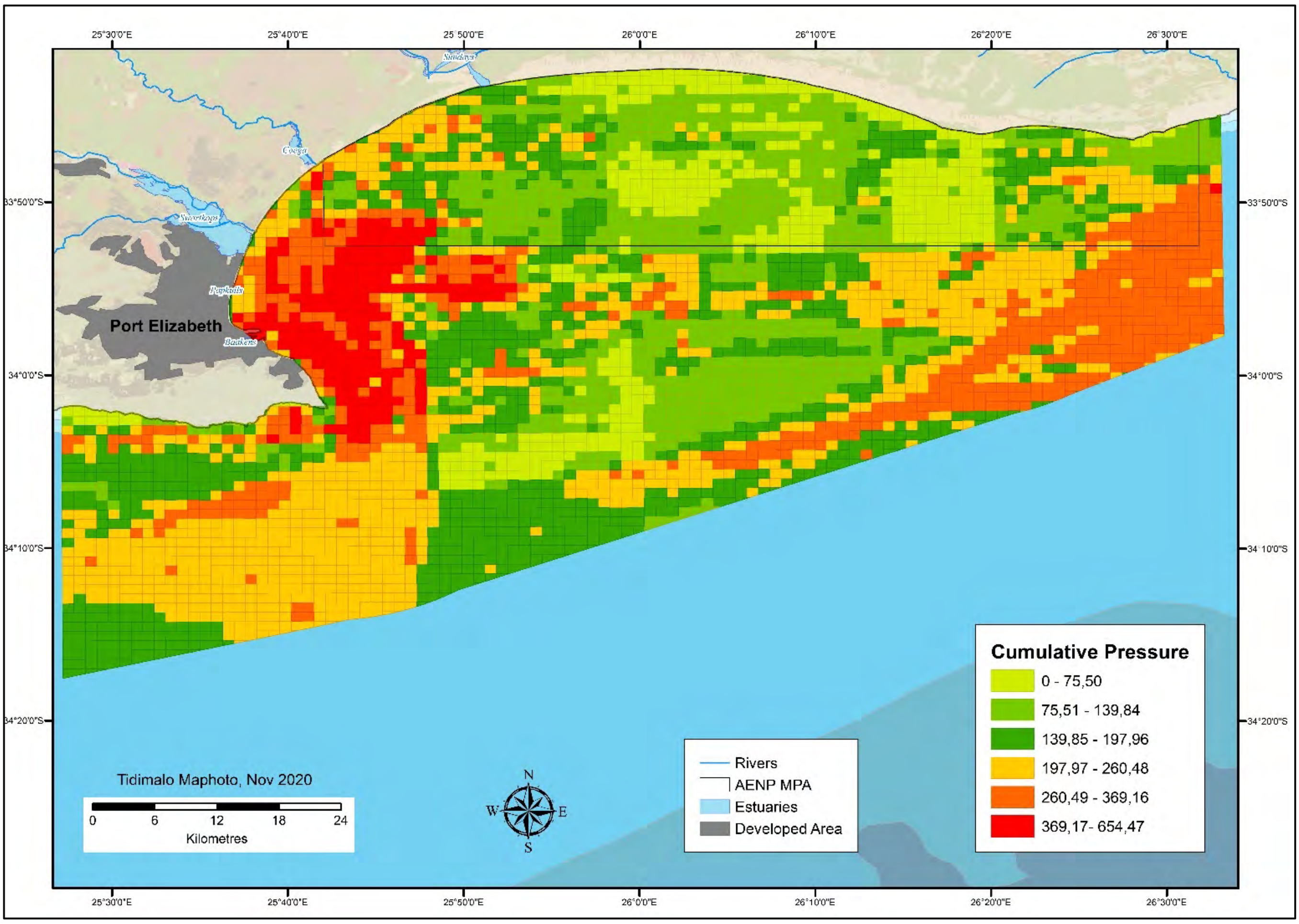


Figure 4. 12: Spatial patterns of the 2019 SCP cumulative pressures (Source of data: Algoa Bay Project, 2019). Natural breaks were used as a classification method in ArcGIS to display the data.

4.4.3 The 2020 Cumulative Pressures

Figure 4.13 illustrates the spatial patterns of cumulative pressures mapped for this study in 2020. Higher cumulative pressures are concentrated closer to the harbours, on the western side of the bay. The high cumulative pressures result from activities with high intensities, such as shipping, fishing. The eastern side of the coast shows the least cumulative pressures. The intermediate to high cumulative pressures can be observed in the offshore marine environment, mostly driven by high intensities (such as shark longline fishing and demersal inshore trawling, as previously shown in Figure 4.7). Low cumulative pressures are dispersed around the rest of the marine environment.

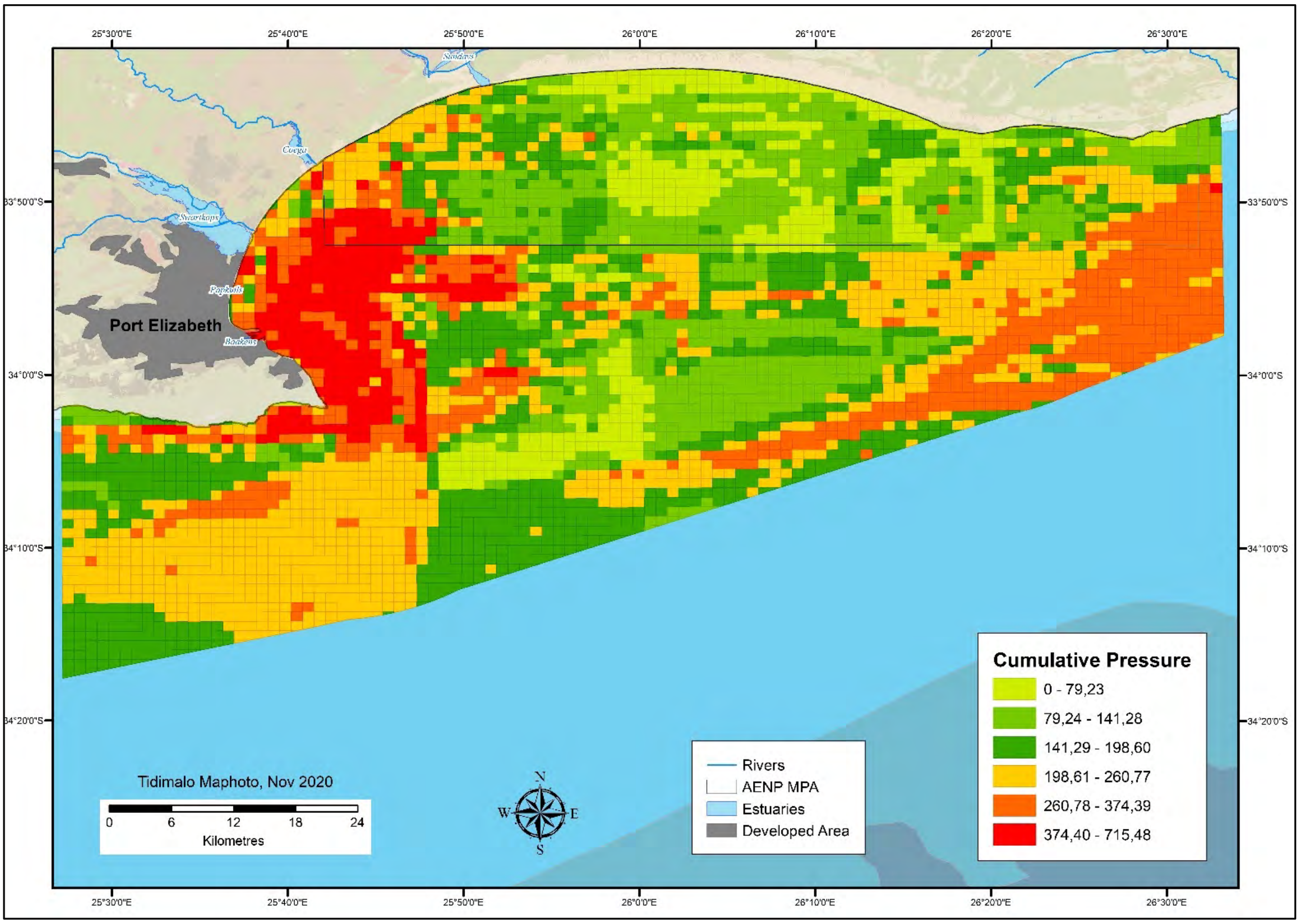


Figure 4. 13: Spatial patterns of cumulative pressures for human pressures in Algoa Bay, mapped from a combination of the 2018 NBA data (Sink et al., 2019), the Algoa Bay SCP (Algoa Bay Project, 2019), data collected from expert mapping as well as from scientific organisations (Appendix 1). Natural breaks were used as a classification method in ArcGIS to display the data.

4.5 Qualitative analysis

4.5.1 Perception of experts of the human activities

Figure 4.14 illustrates the human activities that were identified by experts when qualitative data were collected. Pollution was frequently mentioned as the activity causing pressure on the Algoa Bay marine environment. Fishing was the second frequently mentioned activity, followed by shipping. The other activities that experts mentioned had the least frequencies.

Figure 4. 14: Perception of human uses in Algoa Bay by experts. Text size indicates the frequency of words identified by experts (Source: Qualitative data).

4.5.2 Response of marine environment to human activities

In exploring the activities that occur in the marine environment, six themes emerged from the question regarding the response of the environment to human activities. The themes are summarised in Figure 4.15. Experts gave mixed reviews on how the environment will respond to human pressures.

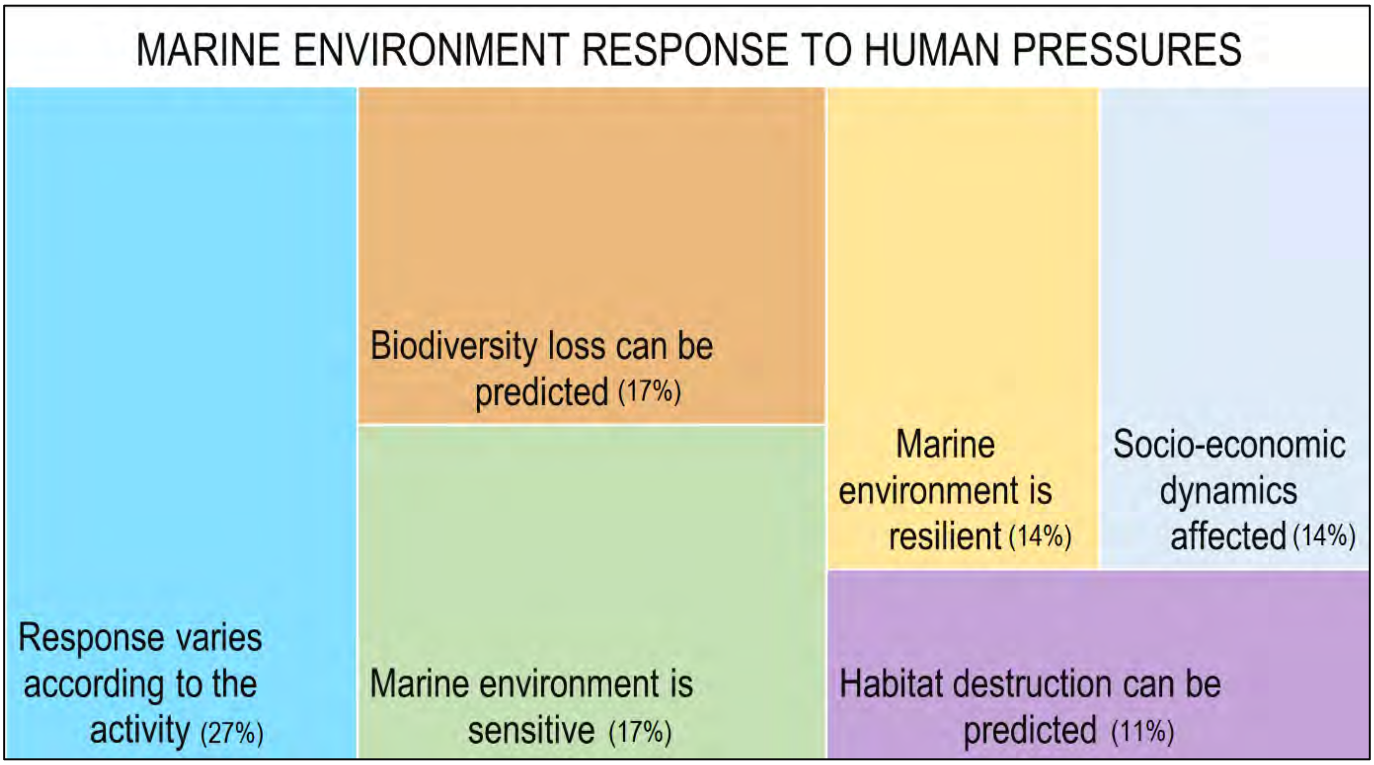


Figure 4. 15: Themes that emerged from thematic content analysis. The block size indicates the frequency of statements within the identified themes (Source: Qualitative data).

4.5.2.1 Theme 1: Response varies according to the activity.

Some experts expressed that the response of the marine environment varies based on the impact, as stated below :

"Response to disturbance will vary and it also depends on the frequency and amplitude of the disturbance, and the inherent properties of that disturbance itself…… through evolutionary time, environments recover from disturbance events inevitably, but, it is unreasonable to expect the recovered state to be the same or similar to the pre-disturbance state (sic)"

This was further supported by another expert as quoted below:

"We often don't see the response because it happens below the surface. I don't think we actually know how different plants and animals respond to many of these impacts. Also, during some periods, species will be more vulnerable to anthropogenic activities than others."

4.5.2.2 Theme 2: Biodiversity loss can be predicted.

Biodiversity loss was also mentioned as a consequence of increased pressure on the marine environment, highlighted in the comment below:

"The introduction of alien organisms by shipping can have a negative impact on the ecosystem as the introduced species might dominate and compete with the native organisms."

4.5.2.3 Theme 3: Marine environment is resilient.

An expert expressed that the marine environment was relatively resilient to disturbances and can absorb a certain level of pressure before showing any clear response. One expert made a particularly insightful comment:

"Algoa Bay is, to an extent, a resilient environment owing to its dynamic oceanography and proximity to exposed shores to the north-east. However, due to the sheltered nature of the south-western sector of the bay (metropolitan and industrial hub), coupled with the potential intensification of industrialisation, shipping, aquaculture and other anthropogenic activities projected for this region, the bay will likely undergo altered states of resilience, becoming more stressed as a result."

4.5.2.4 Theme 4: Marine environment is sensitive.

This theme emerged from the statement below, as expressed by an expert:

"The marine environment in Algoa Bay is sensitive. When the resource is heavily impacted, it may reach a tipping point and change."
An expert pointed out that the marine environment is sensitive to the impacts of the human activities

"The environment is not resilient to the impacts of the human activities. Fish and bait species are renewable (sic) resources, but overexploitation is not sustainable; harbours have led to permanent habitat alterations; pollution introduces toxins -harmful to various biota. Debris/litter needs alteration to avoid long term impacts."

4.5.2.5 Theme 5: Socio-economic dynamics affected.

While most of the responses focused on the impacts of the human activities on the marine environment, one participant pointed out that the impacts go beyond the environment, affecting the socio-economic dynamics of the bay:

[“From a tourism perspective, the marine environment will not attract tourists . Instead of giving life, it will be dangerous for swimming, fish consumption and also affects the economy in terms of the fish being exported to other countries.”]

What the researcher understood from the above statement is that as a result of the increased impacts of human activities on the marine environment, the bay will no longer attract tourists which will affect food provision and the economy of the area.

4.5.2.6 Theme 6: Habitat destruction can be predicted.

The perspective of experts on habitat destruction was attributed to shipping activities in the marine environment, as stated by a participant:

“The Coega harbour development resulted in quite extensive habitat destruction and restructuring”.

4.6 Discussion

The research objective of this chapter was to identify and map the spatial extents and intensities of human pressures in Algoa Bay, building on the information collated by the Algoa Bay Project (2019). The methodology employed to answer the questions related to the objective was through the lens of both quantitative and qualitative data collection and data analysis.

The spatial distribution and intensities of human activities were analysed from data provided the following sources: the 2018 NBA (Sink et al., 2019), the Algoa Bay Systematic Conservation Planning (Algoa Bay Project, 2019), scientific organizations (see Table 4.1 and Appendix 1) as well as through data collected from expert mapping.

4.6.1 Spatial distributions of Human Activities

This study used Perera et al.'s (2012) definition of experts; this ensured that various groups of individuals were represented. As a result, scientists, practitioners and stakeholders had knowledge of the activities they mapped, based on their work and experiences (Perera et al., 2012).

The value of expert data successfully filled data gaps and did not contradict the quantitative data. The data provided from expert mapping matched the scientific data that was already available. The work from this study brought additional data that could be used for planning, as it provided some data that is not otherwise available. The new data layers were: ballast water discharge, abalone poaching, Dissolved Inorganic Nitrogen (DIN), Dissolved Inorganic Phosphorus (DIP), outfalls, recreational activities, research monitoring, anchorages and mariculture

The spatial distribution of human activities is concentrated in the marine ecosystems closer to the coast and two harbours (Clarke Murray et al., 2015a). A similar trend in the concentration of human activities was found in Ban & Alder (2008) and Moreno et al. (2012). The harbour is associated with increased coastal development, and it is a point of access to the sea (Sink et al., 2019).

According to Ban & Alder (2008), the shallow continental shelf is extensively used by humans. Activities with the greatest spatial coverage were shipping and fishing (specifically longline fishing and trawling). These activities also had the highest intensities. The activities with the lowest spatial coverage had low intensities.

4.6.2 Cumulative pressures of the human activities

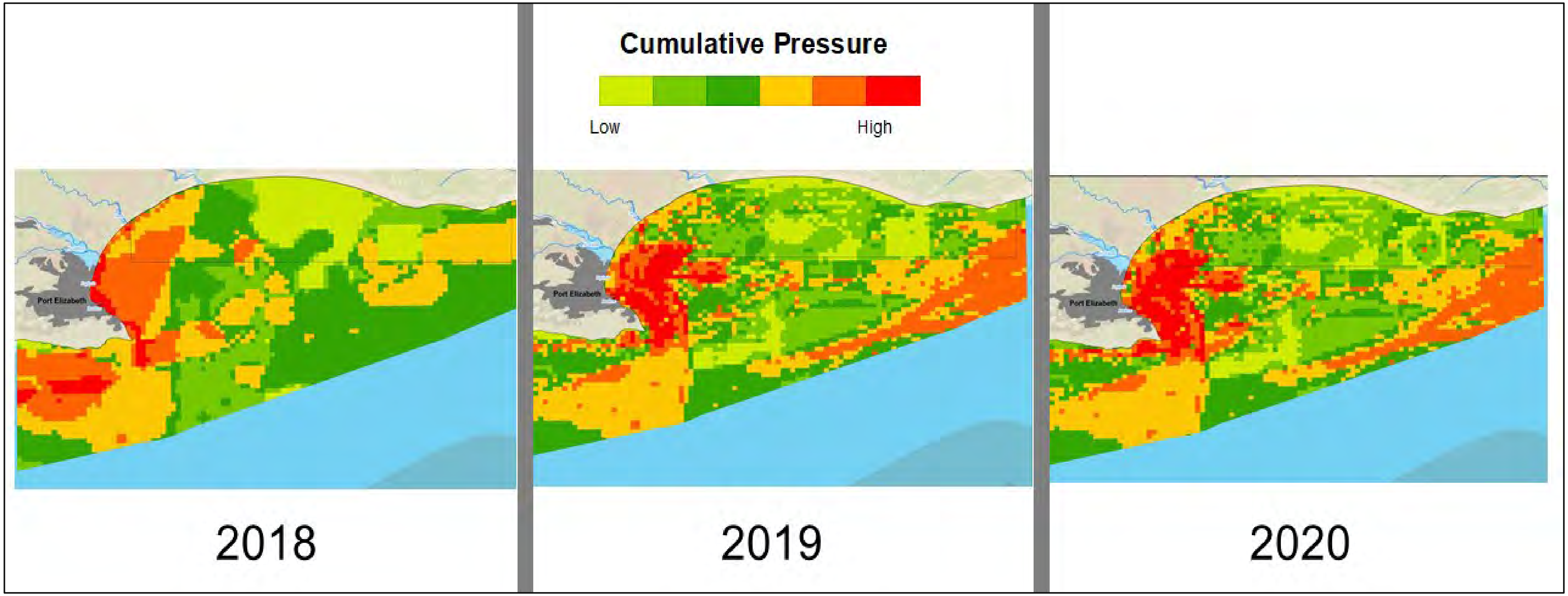


Figure 4. 16: Cumulative pressures of the human uses from 2018-2020. Sources: 2018 cumulative pressure (Sink et al., 2019); 2019 cumulative pressure (Algoa Bay Project, 2019); 2020 cumulative pressure (Researcher: Tidimalo Maphoto).

Due to a lack of pressure data, pressures were quantified as human uses. Although a temporal scale was not considered when collecting the spatial data, there is a shift from fairly high to very high cumulative pressure in the western side of Algoa Bay (close to Port Elizabeth) when comparing the cumulative pressures for the different years. This may be due to more data added to the calculation that was not available when the NBA and the SCP studies were conducted. However, the highest cumulative impacts can be seen on the western side of the bay, which is closer to the harbour as well as the city centre.

The 2018 cumulative pressures show the greatest coverage of intermediate to high cumulative pressures across the years, with the least coverage of low cumulative pressures (Figure 4.17). Both the 2019 and 2020 cumulative pressures are comparable with slight differences in cumulative pressures. Intermediate cumulative pressures showed the greatest spatial extent, while high cumulative impact showed the least spatial extent in Algoa Bay for the three years Figure 4.17).

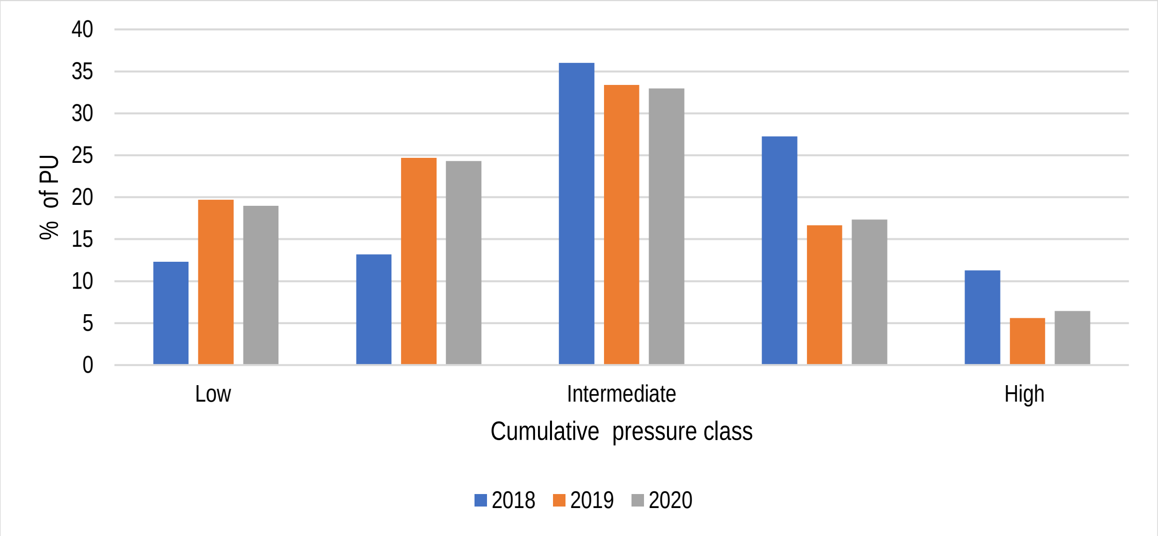


Figure 4. 17: Percentage of PU (Planning Units) per cumulative pressure class. Sources: 2018 cumulative pressure (Sink et al., 2019); 2019 cumulative pressure (Algoa Bay Project, 2019); 2020 cumulative pressure (Researcher: Tidimalo Maphoto).

4.6.3 Perception of experts of the human activities

Based on the emphasis from the questionnaire survey, three areas of concern were identified as pollution, fishing activities and shipping activities. This supports the results from a few studies (Batista et al., 2014; Gkargkavouzi et al., 2020) although, the degrees of intensities of the pressures were varying.

4.6.3.1 Pollution

The ocean has long been used as a sink for many outlets of pollution based on the assumption that marine pollution diffuses seawards, and the impacts will be low given the vast size of the ocean (Branch & Branch, 2018). As noted by Moloney et al. (2013), pollution in the marine environment results from point and diffuse sources. This study only mapped point sources of pollution in the form of land-based discharge and wastewater treatment works (Figure 4.11).
The pollution identified is related to increasing populations and urbanisation. The Nelson Mandela Bay Municipality (NMBM) has the second-highest population in the Eastern Cape, as previously stated in chapter 3. The points of pollution were distributed close to the settlements in NMBM. It is likely that there are also diffuse sources of pollution along the urban coastal front. In particular, informal settlements drain into the estuaries and the non-perennial rivers. There is industrial development along the port of Ngqura and the Central Business District (CBD). The activities that are related to pollution accumulate near big cities. This accumulation of pollution near big cities is a result of the location of wastewater and industrial water discharge (Moreno et al., 2012).

4.6.3.2 Fishing activities

South Africa’s marine resources have experienced a long history of intense, persistent fishing pressure (Blamey et al., 2015). The pressures of fishing have increased with increased populations (Moloney et al., 2013). Fishing had the greatest spatial extent when compared with the rest of the human uses (Figure 4.10). In a study by Benn et al. (2010), bottom trawling had the greatest extent compared with the rest of the other human uses. A similar trend was also noticed in a study by Ban and Alder (2008).

4.6.3.3 Shipping activities

Shipping activities were mapped from data on the spatial distributions of the disposal of dredged material, the anchorage of ships, and the shipping lanes for the ships coming into and out of the bay. Shipping activities are a major part of the Port Elizabeth economy, as previously discussed in chapter 3. The concentration of these activities is closer to the harbours and the city centre (Figure 4.9). Harbours are points of entry to the sea, and they are the critical drivers of cumulative impacts on the marine environment (Sink et al., 2019).

4.6.3.4 Response of marine environment to human activities

The expert and non-expert data were insightful, as they provided empirical data based on the knowledge of the experts. The thematic content analysis of the qualitative data revealed mixed perspectives from experts. Ecological statements were recognised by a high proportion of experts as for Jefferson (2014). Most experts indicated that the response of the ocean would vary depending on the activity and its intensity. Others shared that biodiversity loss can be predicted, making it easier to manage, while some argued that the marine environment is sensitive to the impacts of human activities. Other perspectives from experts included comments on the socio-economic dynamics being affected, the marine environment being resilient, and habitat destruction as a result. This study has built onto the existing data by expanding the knowledge base, including more stakeholders, integrating as many uses as possible, and bringing a holistic picture of the uses of the ocean in Algoa Bay.

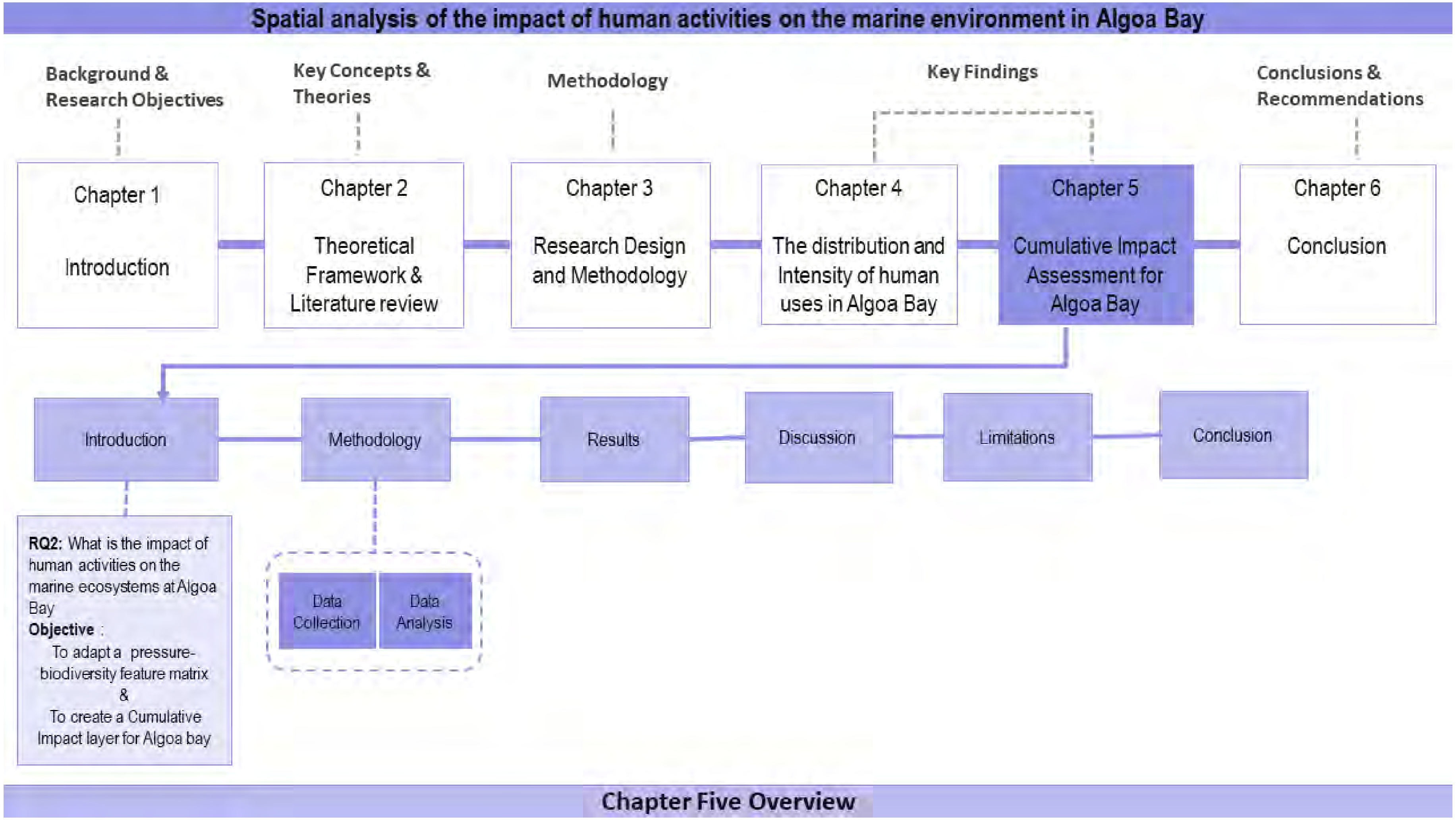
4.7 Limitations and Conclusions

The main limitations of this chapter relate to the collection of data, and the resolution and availability of the GIS data. Some of the stakeholders approached were reluctant to be part of the research, and some did not return the questionnaires survey. As a result, only the stakeholders that were available to take part in the study were included as participants. This limitation can be overcome by aiming for a larger sample size. The return of questionnaire surveys might still be a challenge since participants were not forced to take part in the study. Access to some spatial data was a challenge as some sectors were reluctant and sceptical to share data on the human uses that take place in Algoa Bay. Some sectors did not want to become part of a planning process, resulting in disadvantaging other sectors should their data be shared.

This limitation affected the spatial analysis, as it included only existing spatial data and data that was mapped by experts. Some of the data were at a low resolution because they were captured at a national scale. As a result, these data were clipped to match the extent of the study area. This clipping did not, however, change the resolution of the data. Data on small pelagics and bunkering were not included in the analysis because these data were not available to the Algoa Bay Project (2019) and were thus not included in the data provided to the researcher. In addition, regional climate change (Mead et al., 2013) and harmful algal blooms (HABs) drive the ocean health of the bay as noted by Lemley et al. (2019). The researcher recognises that both the regional climate change and HABs can place marine systems under a lot of pressure. However, Climate change was not mapped due to the unavailability and complexity of the data and HABs were not mapped as the data was not available at the time of study.

The results of this Chapter suggest that the Algoa Bay marine environment is under pressure from shipping and fishing activities and pollution, as shown in Figure 4.10, which have great spatial coverage and intensities. The next steps that will be taken will include applying the data from this chapter in a Cumulative Impact Assessment (CIA).


5
Cumulative Impact Assessment for Algoa Bay


Spatial analysis of the impact of human activities on the marine environment in Algoa Bay
Background & Research Objectives
Key Concepts & Theories
Methodology
Key Findings
Conclusions & Recommendations
Chapter 1
Introduction
Chapter 2
Theoretical Framework & Literature review
Chapter 3
Research Design and Methodology
Chapter 4
The distribution and Intensity of human uses in Algoa Bay
Chapter 5
Cumulative Impact Assessment for Algoa Bay
Chapter 6
Conclusion
Introduction
Methodology
Results
Discussion
Limitations
Conclusion
RQ2: What is the impact of human activities on the marine ecosystems at Algoa Bay
Objective :
To adapt a pressure-biodiversity feature matrix
&
To create a Cumulative Impact layer for Algoa bay
Data Collection
Data Analysis
Chapter Five Overview

5. CUMULATIVE HUMAN IMPACT ASSESSMENT FOR ALGOA BAY

5.1 Introduction

5.1.1 Human uses

Humans continue to use the ocean for various purposes, including sustaining livelihoods, mineral resources, energy production, navigation, recreation, cultural practices and as a point of eliminating waste (Halpern et al., 2015). Knowledge of the locations and intensities of the human pressures on the marine environment resulting from human uses is vital for managing marine resources (Batista et al., 2014). In order to implement the management strategies efficiently, the relationships of human uses to the marine environment have to be accounted for (Batista et al., 2014).

Human uses have an impact on the marine environment through chemical, biological and physical changes (Ban & Alder, 2008). The impacts of humans on the marine environment have been attributed to the detrimental and unsustainable use of the ocean resources. Additional activities that may have significant impacts and should be considered in the impact assessments are land-based activities, dense human populations and tourism (HELCOM, 2010). Clarke Murray et al. (2015a) further emphasize that the effects of land-based activities on the marine environment have become an area of concern and should be considered in Cumulative Impact Assessment (CIA) since they are connected to the marine environment through freshwater runoff.

CIA is a common methodological approach used to assess the impacts of human uses on the marine environment. However, Clarke Murray et al. (2015b) argue that cumulative impact mapping has remained an academic analysis only and has not been incorporated and applied in environmental assessments. This Chapter builds onto the previous Chapter, calculating the cumulative impacts of the pressures mapped in Chapter 4.

5.1.2 Cumulative Impact Assessment (CIA) Model

The CIA method for quantifying human pressures can be a useful tool in MSP (HELCOM, 2010). The first quantification of the impact of human uses on the marine environment at a global scale was done by Halpern et al. (2008). Since then, the method has been modified to apply to regional and local scales (Selkoe et al., 2009; Ban et al., 2010; HELCOM, 2010; Korpinen et al., 2012; Parravicini et al., 2012; Andersen & Stock, 2013; Menegon et al., 2018) in order to inform regional analyses that will match the scales of management according to the regional setting (Kappel & Halpern, 2012).

CIA models provide valuable information on spatial patterns of human impacts as well as the marine ecosystem's carrying capacity. Therefore, this tool is powerful in identifying management measures in MSP, as it can point decision-makers in the direction of where reductions in human pressures should be a goal (Fernandes et al., 2017). CIA requires human stressor distribution and intensity maps, marine ecosystem maps and vulnerability stress impact scores (Selkoe et al., 2009; Kappel & Halpern, 2012;). Since CIA models often incorporate benthic and pelagic ecosystems, a pixel can have more than one ecosystem in it (Kappel & Halpern, 2012).

In their study, Clarke Murray et al. (2015b) argued that the limitation in mapping cumulative impacts is the absence of good, up-to-date and high-resolution datasets. As a result, analysis often includes uneven human activity data with different timescales and resolutions, even with the limitations highlighted. Clarke Murray et al. (2015b) state that cumulative effects mapping remains essential and useful for effective regulation and management of human uses as well as identifying areas for restoration and areas for protection.

5.1.3 Expert input scores into the Cumulative Impact Assessment Model

Kappel & Halpern (2012) developed a tool for expert elicitation to address the lack of empirical data in CIA. The tool was developed in such a way that the effects of multiple human stressors across various ecosystems on the same scale can be compared while accounting for the fact that an activity may result in different effects on different ecosystems in the study area (Kappel & Halpern, 2012; Andersen & Stock, 2013).

Expert assessment has been established as a method for obtaining estimates that may be difficult to observe directly (Uusitalo et al., 2016). The use of structured surveys allows experts to evaluate ecosystem vulnerability using the same set of structures and criteria. This has improved the repeatability of the assessment across other studies (Kappel & Halpern, 2012). Clarke Murray et al. (2015b) have pointed out that predicting the impacts of some human uses without experiments is difficult, resulting in different scores between experts. The limitation, however, of including the expert judgment in the assessment model is the subjectivity across experts as they may judge the impact on various ecosystems differently based on their experience and background (Korpinen et al., 2012).

5.1.4 The impacts of human pressures on the marine environment

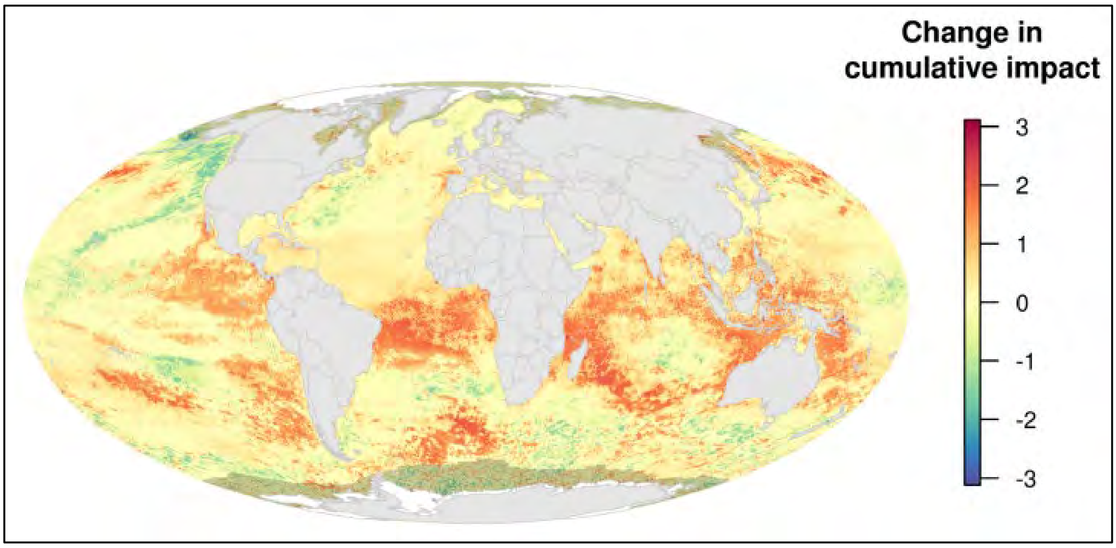


Figure 5. 1: Cumulative human impact on the global oceans (Halpern et al., 2015).

The patterns of cumulative human impact from a study by Halpern et al. (2015) show cumulative intensity of cumulative impacts around the equator, which were driven by increases in climate change stressors. However, regions in the northern hemisphere have seen an increasing interest in projects that seek to quantify the impacts of human uses on the marine environment are: the Baltic Sea (HELCOM, 2010; Korpinen et al., 2012); the Northern Sea (Andersen & Stock, 2013; Menegon et al., 2018) and the Ligurian Sea- North-West Mediterranean (Parravicini et al., 2012).

Understanding the Cumulative Human Impact (CHI) on the marine environment is essential given that multiple anthropogenic pressures threaten it. Several human uses that occur within the marine environment are growing and intensifying. As human populations are rapidly growing, the uses and impacts of marine activities are increasing (Clarke Murray et al., 2015b). According to Kappel & Halpern (2012), over 40% of the world's oceans are heavily impacted by pressures resulting from human uses. These human uses and activities are expected to increase over time, leading to multiple impacts on different marine ecosystems and species (Fernandes et al., 2017). Human uses exert different pressures on the marine environment resulting in different levels of impact on this environment.

The concern regarding the impacts of human uses on the marine environment has become a key area of research. It has led to the development of cumulative impact mapping, which contributes to management approaches such as MSP (Clarke Murray et al., 2015b).

Mapping the cumulative effects of human uses is heavily reliant on useful spatial data of human uses to show where the pressures that result from the human uses occur; this approach is known as “Cumulative Impact Assessment” (CIA) (Clarke Murray et al., 2015b). The availability of useful spatial data on the extent of human uses affecting the marine environment has improved our understanding of the CIA (Clarke Murray et al., 2015b).

The need to gain an understanding of the cumulative impacts of human uses on the marine environment has become increasingly important (Clarke Murray et al., 2015a). The assessment of the cumulative impacts allows for understanding the multiple impacts of the threats and how they affect the marine environment. The management of marine ecosystems is useful in increasing socio-economic benefits while reducing the degradation of the ecosystems (Selkoe et al., 2009).

The research objectives addressed in this chapter are stated as follows:

- To adapt a pressure-ecosystem matrix that reflects the relative, assumed impact of each pressure on each marine ecosystem.
- To create a spatially explicit cumulative impact layer for Algoa Bay.

5.2 Methodology

The method followed in this Chapter was derived from the 2018 NBA (Sink et al., 2019). Existing GIS data were integrated with data from experts and a pressure ecosystem matrix was produced, followed by a cumulative impact map for conservation planning purposes to feed into a marine spatial plan for the bay. Knowledge of the spatial locations of human uses and their impacts on the marine environment is vital for marine management (Ban et al., 2010). This current study is restricted to the bay’s marine ecosystems and does not include coastal ecosystems, which are the subject of an additional, high-resolution study.

5.2.1 Data Collection

Data used in this chapter were collected from the 2011 and 2018 NBA report, which consisted of normalised impact scores that were provided by experts, as well as the 2018 NBA marine ecosystems map (Sink et al., 2019) and the planning unit (PU) layer mapped in Chapter 4, which consisted of pressure intensities for 16 pressures and the resulting cumulative pressure layer. Figure 5.2 summarises the data collection methods that were used to address the research question: What is the impact of human activities on the marine ecosystems in Algoa Bay?

5.2.2 Data Analysis

Data analysis involves spatial analysis as well as statistical analysis of data in Microsoft Excel and ArcGIS.

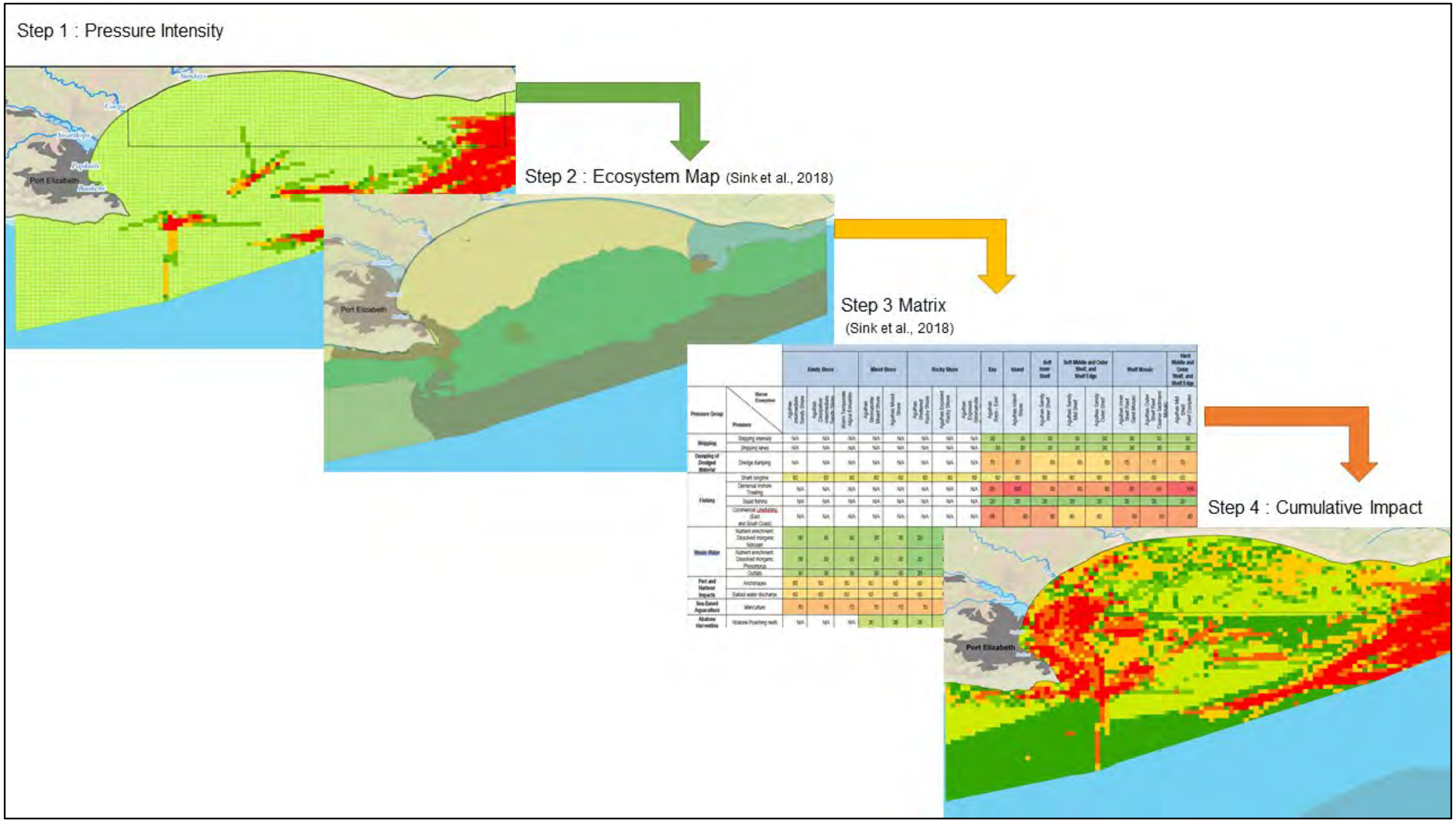


Figure 5. 2: Schematic presentation of the steps followed in data analysis.

5.2.2.1 Pressure-ecosystem matrix

In Microsoft Excel, the pressure-ecosystem matrix was drawn from information from the 2011 and 2018 NBA reports (Sink et al., 2012; 2019) and GIS data (sources summarised in Appendix 1). The 16 pressures identified in Chapter 4 were listed as rows and further grouped into pressure groups. The marine ecosystems from the 2018 NBA (Sink et al., 2019) were reported as columns and grouped into broad ecosystem categories. The matrix was then populated with the normalised (0-100) impact values from the 2018 NBA report and where data were missing, i.e. shark longline, the 2011 impact values from the 2011 NBA were used (and also normalised from 0-100). Research monitoring and recreational activities were excluded from the matrix because they were not included in the NBA pressure-ecosystem matrix.

5.2.2.2 Cumulative Impact Assessment

The matrix was converted into a format readable by ArcGIS by inverting the table (to display pressures as columns and ecosystems as rows) and by replacing spaces with an underscore "_". Data from the matrix were joined to the PU attribute layer (using a join function in ArcGIS) so that each PU had a value for its ecosystem (each PU was allocated to only one ecosystem type for ease of analysis), a value for the intensity of each pressure that occurs in the PU, and a value for the impact that each of the pressures has on that ecosystem.

Cumulative impact scores $\mathbf{I_{c\,j}}$ were calculated for each PU using the framework proposed by Halpern et al. (2007) and used by the NBA (Sink et al., 2011, 2018). This analysis assumes that each PU has only one marine ecosystem. As a result, $\mathbf{I_{c\,j}}$ was calculated for each marine ecosystem found within one planning unit. The cumulative impact for a marine ecosystem at a site was calculated as:

$$\mathbf{I_{c\,j}} = \sum_{(\mathbf{i=1})}^{\mathbf{n}} \boldsymbol{\beta}_{\mathbf{i}} \times \mathbf{W_{i\,j}}$$

Where $\boldsymbol{\beta}_{\mathbf{i}}$ is the normalised pressure value (scaled between 0 and 100) of the intensity of a pressure at location *i* and $\mathbf{W_{i\,j}}$ is the impact value for a pressure *i* on the marine ecosystem j. The 2018 NBA (Sink et al., 2019) calculated the impact values $\mathbf{W_{i\,j}}$ by an equal weighted average of the functional impact and recovery scores. Figure 5.3 summarises the steps followed in ArcGIS for the development of a cumulative impact layer.

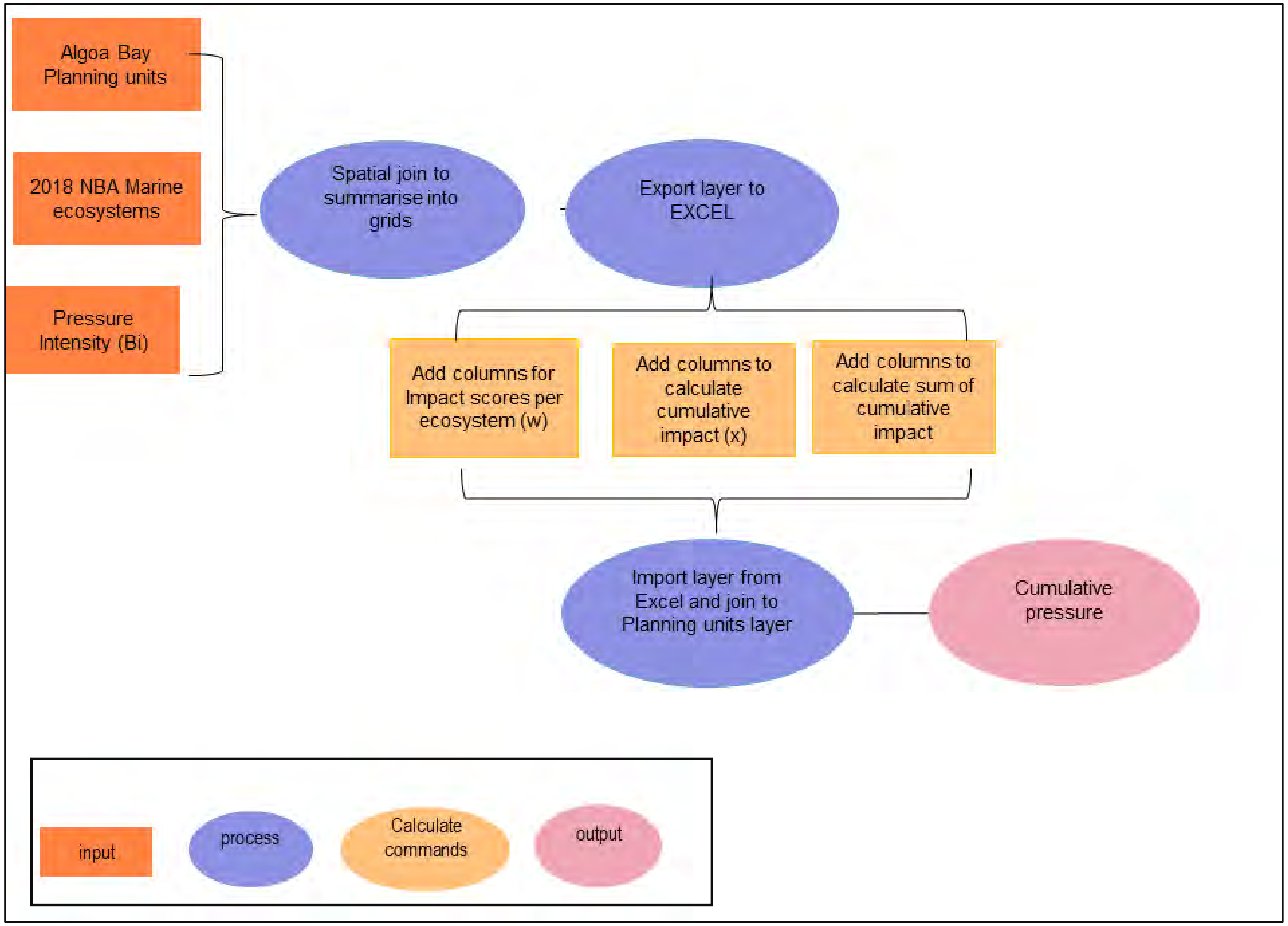


Figure 5. 3: Cartographic model of the process used in ArcGIS for the development of a cumulative impact layer for Algoa Bay.

5.3 Results

5.3.1 Pressure-Ecosystem Matrix

Table 5.1 shows the pressure-ecosystem matrix and provides the impact values for different ecosystems per pressure. Three broad pressure groups were defined as follows: shipping, fishing and wastewater.

5.3.1.1 Broad Pressure Group: Shipping

Pressures in the shipping group showed low impact values across the marine environment. In contrast, ports and harbour impacts indicated intermediate impact values and dredge dumping showed higher intermediate values when compared with port and harbour impacts.

5.3.1.2 Broad Pressure Group: Fishing

In the fishing pressure group, squid fishing and abalone poaching on reefs showed very low impact values when compared with the rest of the pressures within the group. Commercial line fishing and mariculture showed intermediate values across all the ecosystems. Demersal inshore trawling had extremely high impact values for all pressures identified in the matrix, with values of 100 assigned to the Agulhas Island Shore and Agulhas Mid Shelf Reef Complex.

5.3.1.3 Broad Pressure Group: Wastewater

All pressures in the wastewater group showed low to intermediate impact values. The spatial patterns of the impact values indicate a decreasing pattern out of the bay towards the offshore ecosystems.

Table 5. 1: Pressure- Ecosystem matrix for Algoa Bay.

The matrix reflects the impact values *for different ecosystems per pressure. The impact* values *were provided by expert judgement in the 2011 and 2018 NBA (Sink et al., 2012; Sink et al., 2019) are 0-100, with 100 reflecting a high value. The red shades reflect the pressures with the greatest impact per pressure, whereas orange reflects intermediate impacts and green represents pressures with the lowest impact. The marine ecosystems map is attached in Figure 3.3.*

			Broad Ecosystem															
			Sandy Shore			Mixed Shore		Rocky Shore			Bay	Island	Soft Inner Shelf	Soft Middle and Outer Shelf and Shelf Edge		Shelf Mosaic		Hard Middle and Outer Shelf and Shelf Edge
Broad Pressure Group	Pressure Group		Agulhas Intermediate Sandy Shore	Agulhas Dissipative -Intermediate Sandy Shore	Warm Temperate Algoa Estuaries	Agulhas Stromatolite Mixed Shore	Agulhas Mixed Shore	Agulhas Sheltered Rocky Shore	Agulhas Exposed Rocky Shore	Agulhas Exposed-Stromatolite Rocky Shore	Agulhas Bays - East	Agulhas Island Shore	Agulhas Sandy Inner Shelf	Agulhas Sandy Mid Shelf	Agulhas Sandy Outer Shelf	Agulhas Inner Shelf Reef Sand Mosaic	Agulhas Outer Shelf Reef Coarse Sediment Mosaic	Agulhas Mid Shelf Reef Complex
Shipping	Shipping	Shipping intensity	N / A	N / A	N / A	N / A	N / A	N / A	N / A	N / A	30	30	30	30	30	30	30	30
		Shipping lanes	N / A	N / A	N / A	N / A	N / A	N / A	N / A	N / A	30	30	30	30	30	30	30	30
	Port and Harbour Impacts	Anchorages	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
		Ballast water discharge	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
	Dumping of Dredged Material	Dredge dumping	N / A	N / A	N / A	N / A	N / A	N / A	N / A	N / A	70	70	60	60	60	70	70	70
Fishing	Fishing	Shark longline	50	50	50	50	50	50	50	50	50	60	60	60	60	60	60	60
		Demersal Inshore Trawling	N / A	N / A	N / A	N / A	N / A	N / A	N / A	N / A	90	100	80	80	80	90	90	100
		Squid fishing	N / A	N / A	N / A	N / A	N / A	N / A	N / A	N / A	20	20	20	20	20	20	20	20
		Commercial Line fishing (East and South Coast)	N / A	N / A	N / A	N / A	N / A	N / A	N / A	N / A	85	80	80	60	60	80	80	80
	Sea-Based Aquaculture	Mariculture	70	70	70	70	70	70	70	70	75	70	70	70	70	70	70	70
	Abalone Harvesting	Abalone Poaching	N / A	N / A	N / A	35	35	35	35	35	35	35	N / A	N / A	N / A	N / A	N / A	N / A
Wastewater	Wastewater	Nutrient enrichment: Dissolved Inorganic Nitrogen	30	30	30	30	30	20	20	20	60	30	50	40	40	50	50	50
		Nutrient enrichment: Dissolved Inorganic Phosphorus	30	30	30	30	30	20	20	20	60	30	50	40	40	50	50	50
		Outfalls	30	30	30	30	30	20	20	20	60	30	50	40	40	50	50	50

5.3.2 Spatial patterns of cumulative impact

The spatial patterns of the cumulative impact shown in Figure 5.4 show high impact values in the ecosystems closer to the harbours, where most pressures occur and in the Soft Middle and Outer Shelf and Shelf Edge broad ecosystems. Lower impacts can be seen in the Shelf Mosaic broad ecosystem groups. Patches of low to intermediate impacts can be seen dispersed around the rest of the marine ecosystems.

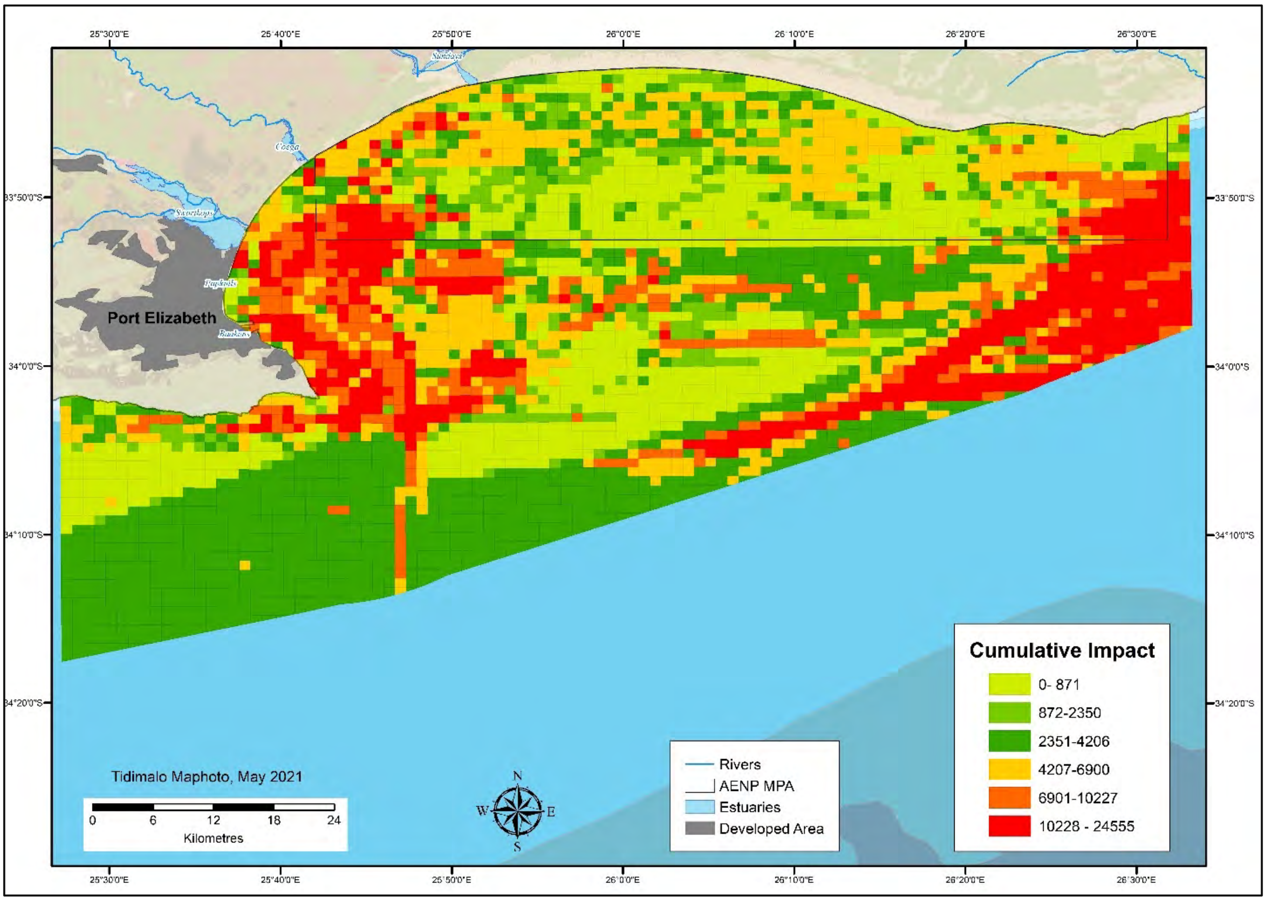


Figure 5. 4: Spatial patterns of cumulative Impact of human pressures in Algoa bay. Natural breaks were used as a classification method in ArcGIS to display data.

Figure 5.5 indicates the percentage distribution of cumulative impact values per marine ecosystem within the 4116 Pus (Planning Units). Very few ecosystems have high cumulative impact values and these include Agulhas Sandy Mid Shelf, Agulhas Mixed Shore and Agulhas Mid Shelf Reef Complex. Across the marine ecosystems, the Exposed Rocky Shore was the only marine ecosystem with cumulative impact values of Zero in all the planning units. When looking at most ecosystems (about 80%), they had low to medium impact values across the planning units.

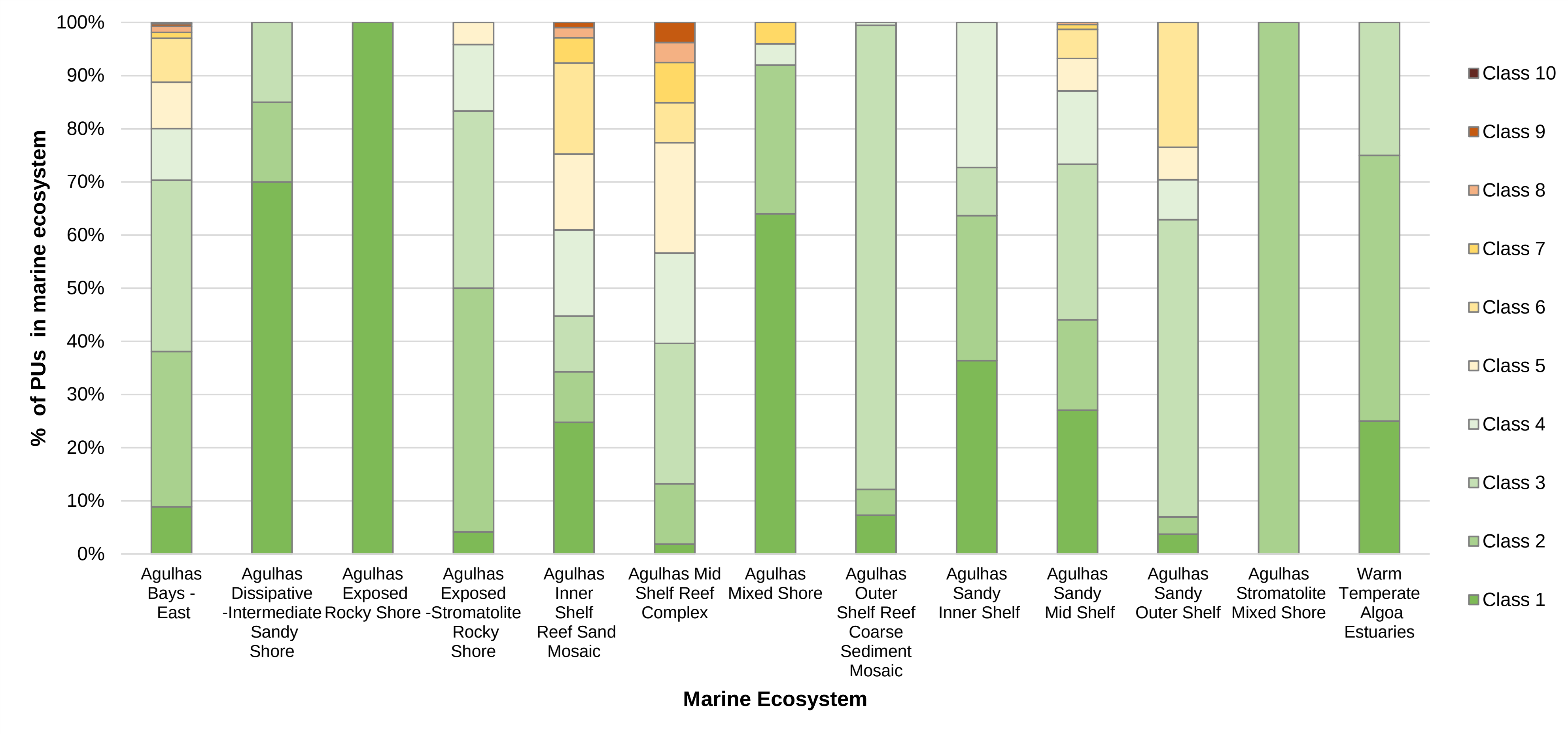


Figure 5. 5: Percentage distribution of impact values within the marine ecosystems.

*The impact values were grouped into ten classes: **Class 1** had planning units with a value of 0. **Class 2** had planning units with values between 1 to 2728. **Class 3** had planning units with values between 2729 to 5457. **Class 4** had planning units with values between 5458 to 8185. **Class 5** had planning units with values between 8186 to 10913. **Class 6** had planning units with values between 10914 to 13642. **Class 7** had planning units with values between 13643 to 16370. **Class 8** had planning units with values between 16371 to 19098. **Class 9** had planning units with values between 19099 to 21827. **Class 10** had planning units with values between 21828 to 24555. Low classes were represented by green shades (white), middle classes were represented by yellow shades, while high classes were reflected by dark shades (red).*

Figure 5.6 and Figure 5.7 illustrate the average cumulative impact value for the marine ecosystems in Algoa Bay. Higher average cumulative impacts can be seen in the nearshore marine ecosystems, the western side of the bay and offshore marine ecosystems. In contrast, small patches of low average cumulative impact values are concentrated on the eastern nearshore ecosystems. Intermediate average cumulative values are observed in the inshore marine environments. The Agulhas Mid Shelf Reef Complex, Agulhas Inner Shelf Reef Sand Mosaic and Agulhas Sandy Outer Shelf are the ecosystems with high average cumulative impact. When relating the spatial coverage to the average cumulative, the Agulhas Mid Shelf Reef Complex, which has the highest average, has the least spatial coverage. The spatial coverage of the other high averages is fairly high. The Agulhas Sandy Mid Shelf, with intermediate average impact, has the greatest spatial coverage.

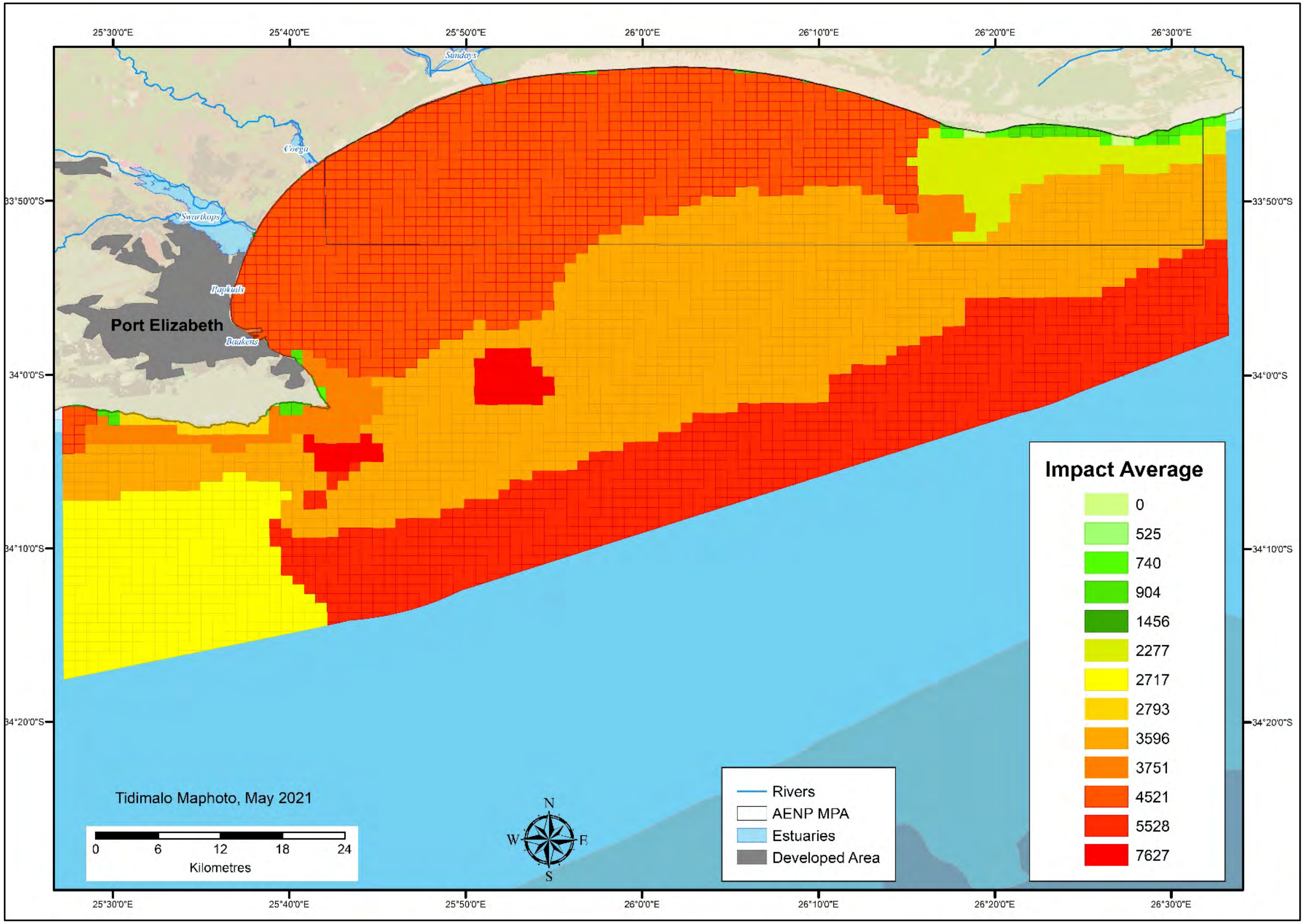


Figure 5. 6: Spatial patterns of average cumulative impact value per marine ecosystem.

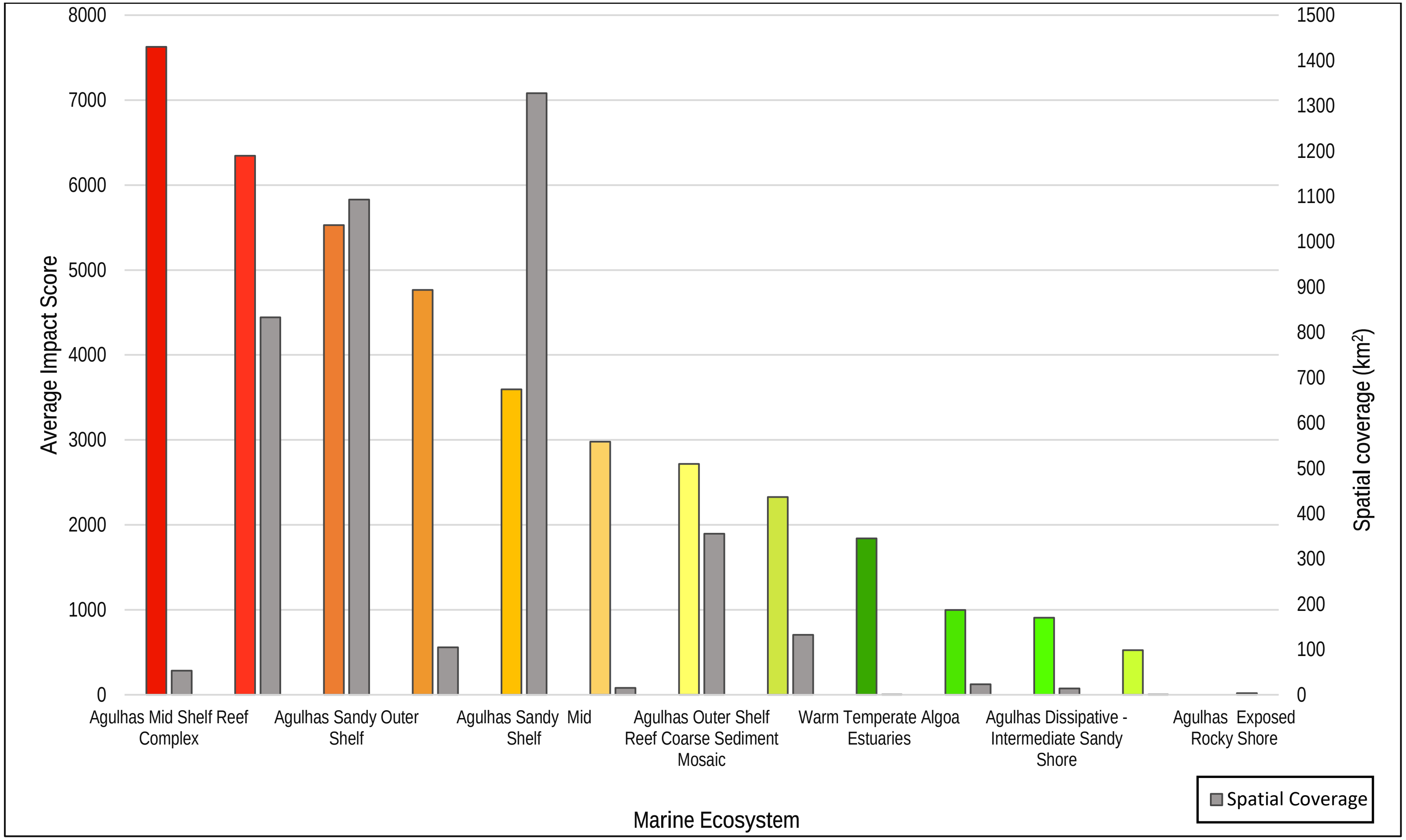


Figure 5. 7: Average cumulative impact and spatial coverage per marine ecosystem.

Spatial patterns of the pressures associated with shipping as well as ports and harbour impacts, as shown in Figure 5.8, show a concentration of high impact values in the Agulhas Bays-East ecosystem, with low impact values spreading away from the bay. However, shipping intensity reflected the greatest spatial extent of high impact values in the bay, spreading out to the offshore marine environment.

The spatial patterns of pressures associated with fishing indicate a dispersed pattern of impact values around the bay for squid fishing and line fishing, as shown in Figure 5.9. At the same time, the spatial patterns for demersal inshore trawling reflect the highest concentration of high impact values in the Soft Middle and Outer Shelf and Shelf Edge broad ecosystem. In contrast, low impact values are seen around the rest of the ecosystems. Shark longline fishing reveals a concentration of high impact values in the bay ecosystem and closer to the coastal areas.

Figure 5.10 indicates spatial patterns of additional fishing pressures, where impact values for mariculture reflect few high values in the bay ecosystem, closer to the harbour.

The pressures associated with wastewater and dumping of dredge material show few high to intermediate impact values in the bay ecosystem. The majority of the ecosystems have low impact values, as illustrated in Figure 5.11.

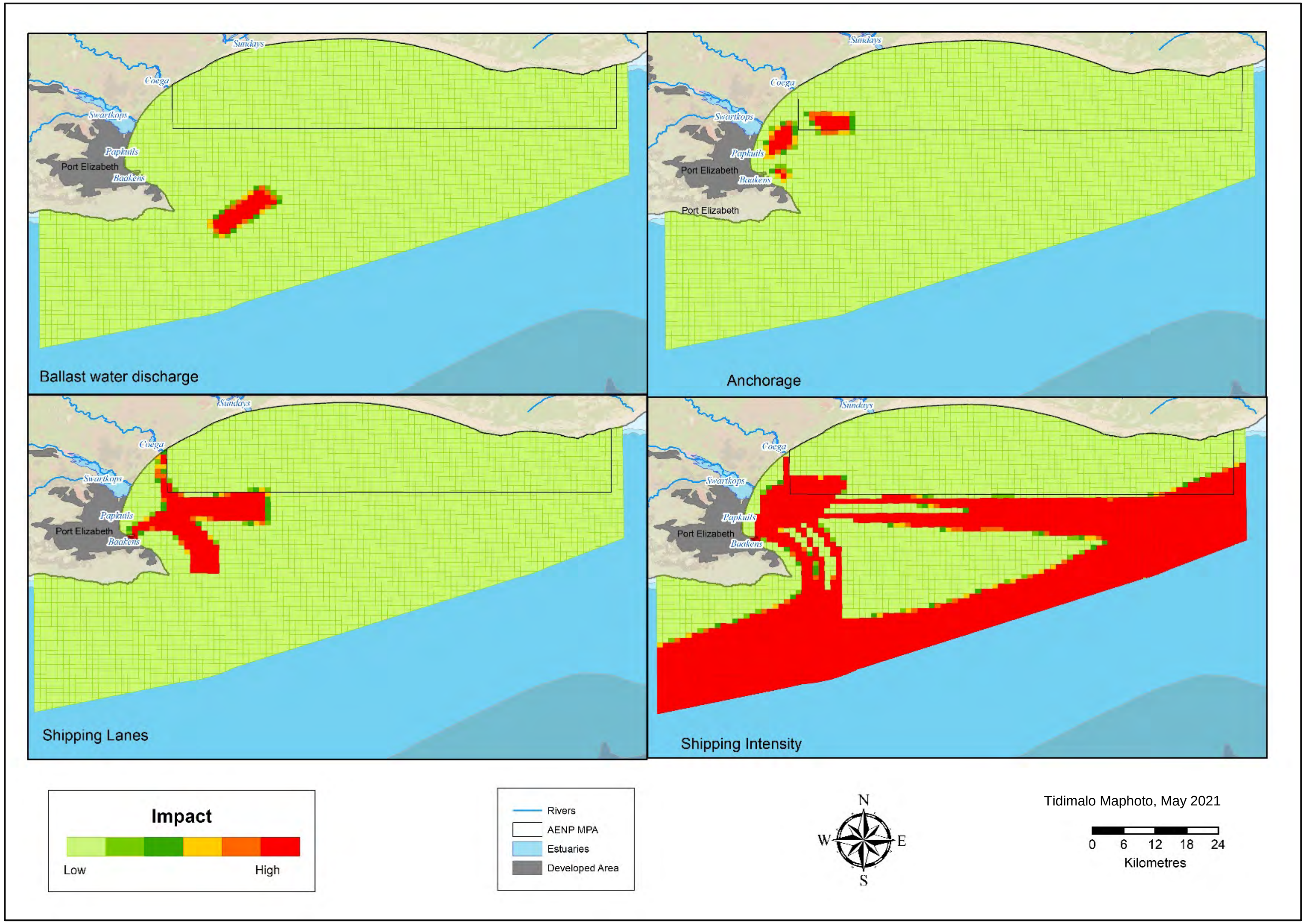


Figure 5. 8: Spatial distributions of impact values for a) Ballast water discharge, b) Anchorage, c) Shipping lanes and d) Shipping intensity. Natural breaks were used as a classification method in ArcGIS to display data.

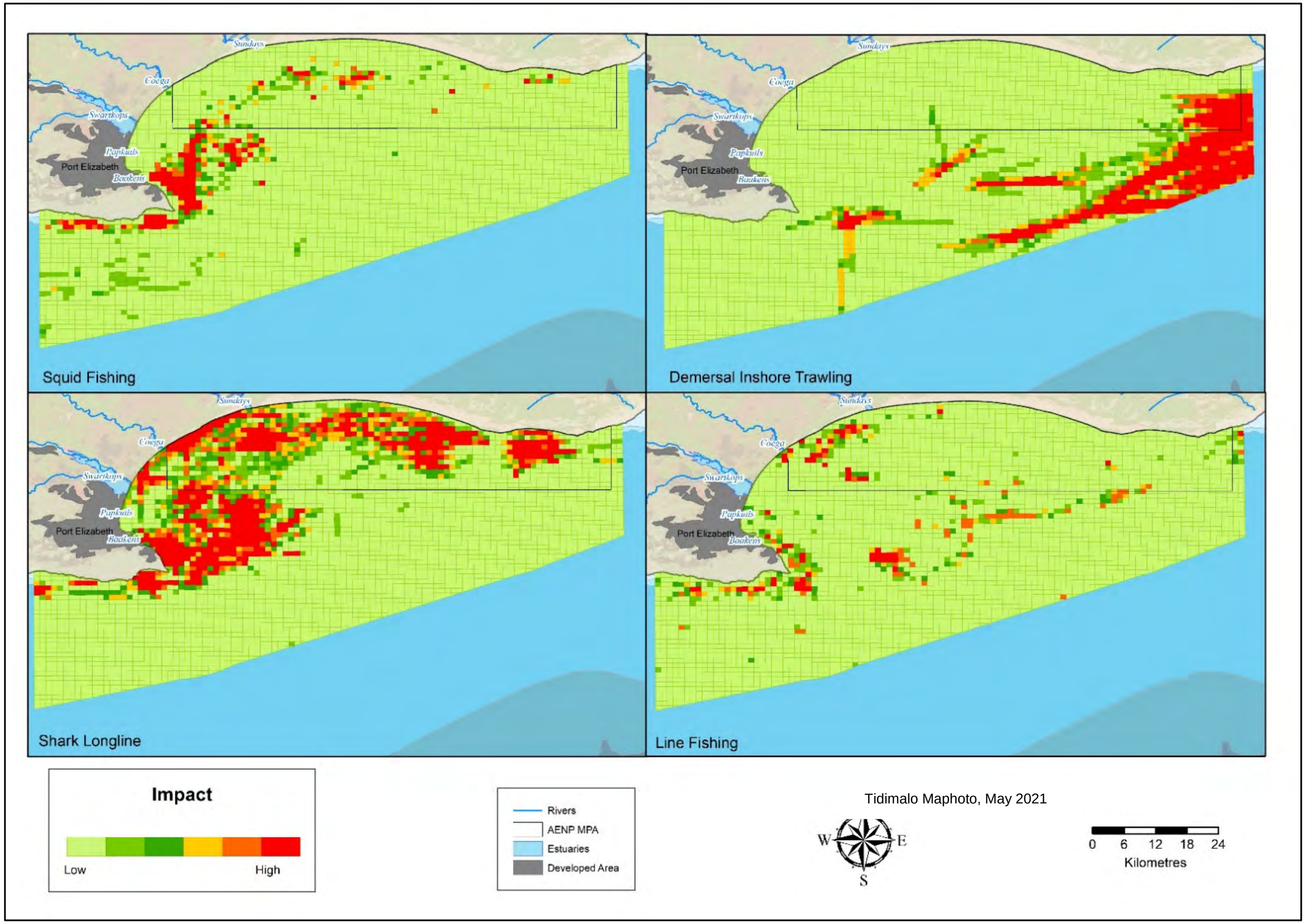


Figure 5. 9: Spatial distributions of impact values for a) Squid fishing, b) Demersal inshore trawling, c) Shark longline and d) Line fishing. Natural breaks were used as a classification method in ArcGIS to display data.

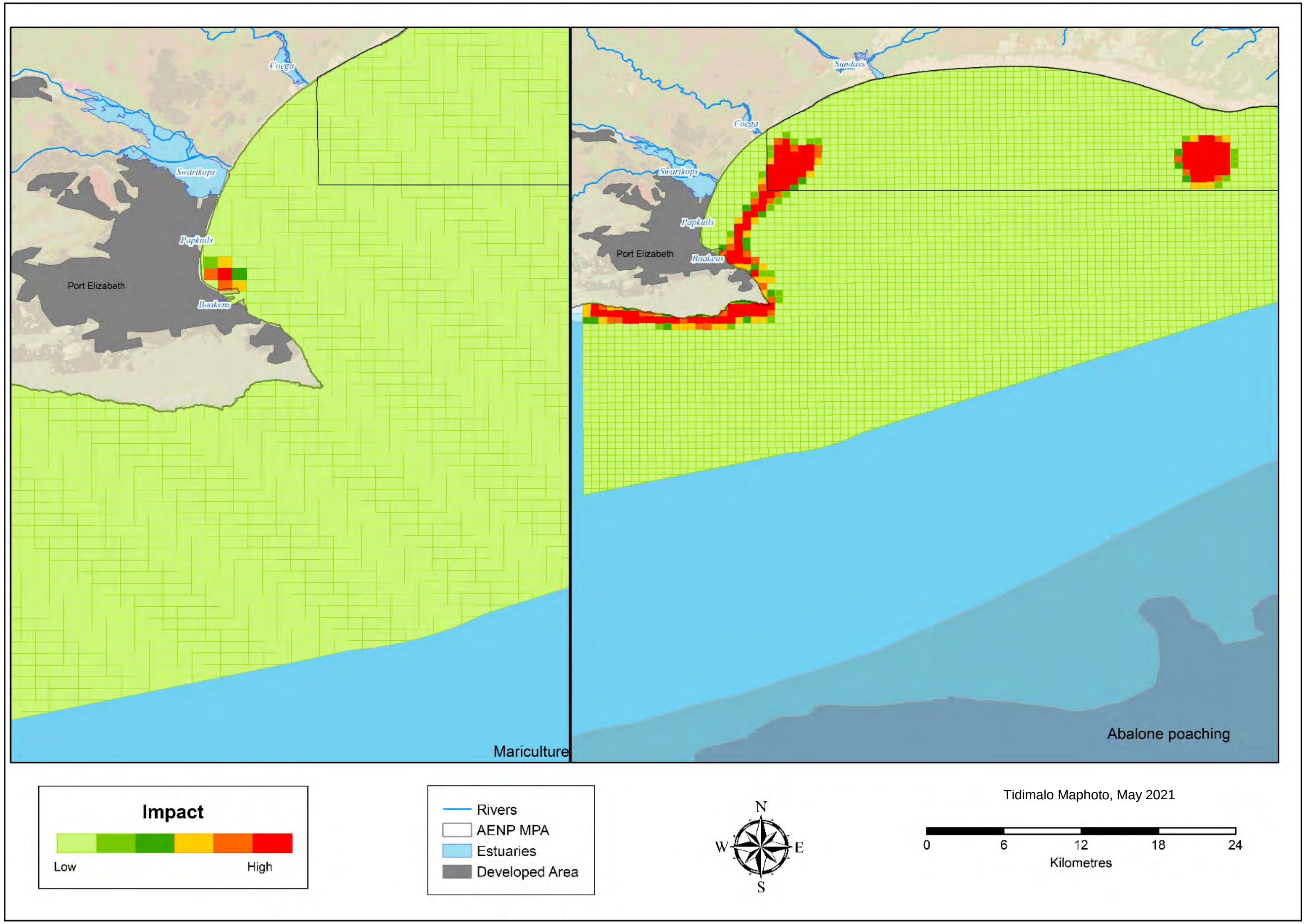


Figure 5. 10: Spatial distributions of impact values for a) Mariculture, b) Abalone poaching. Natural breaks were used as a classification method in ArcGIS to display data.

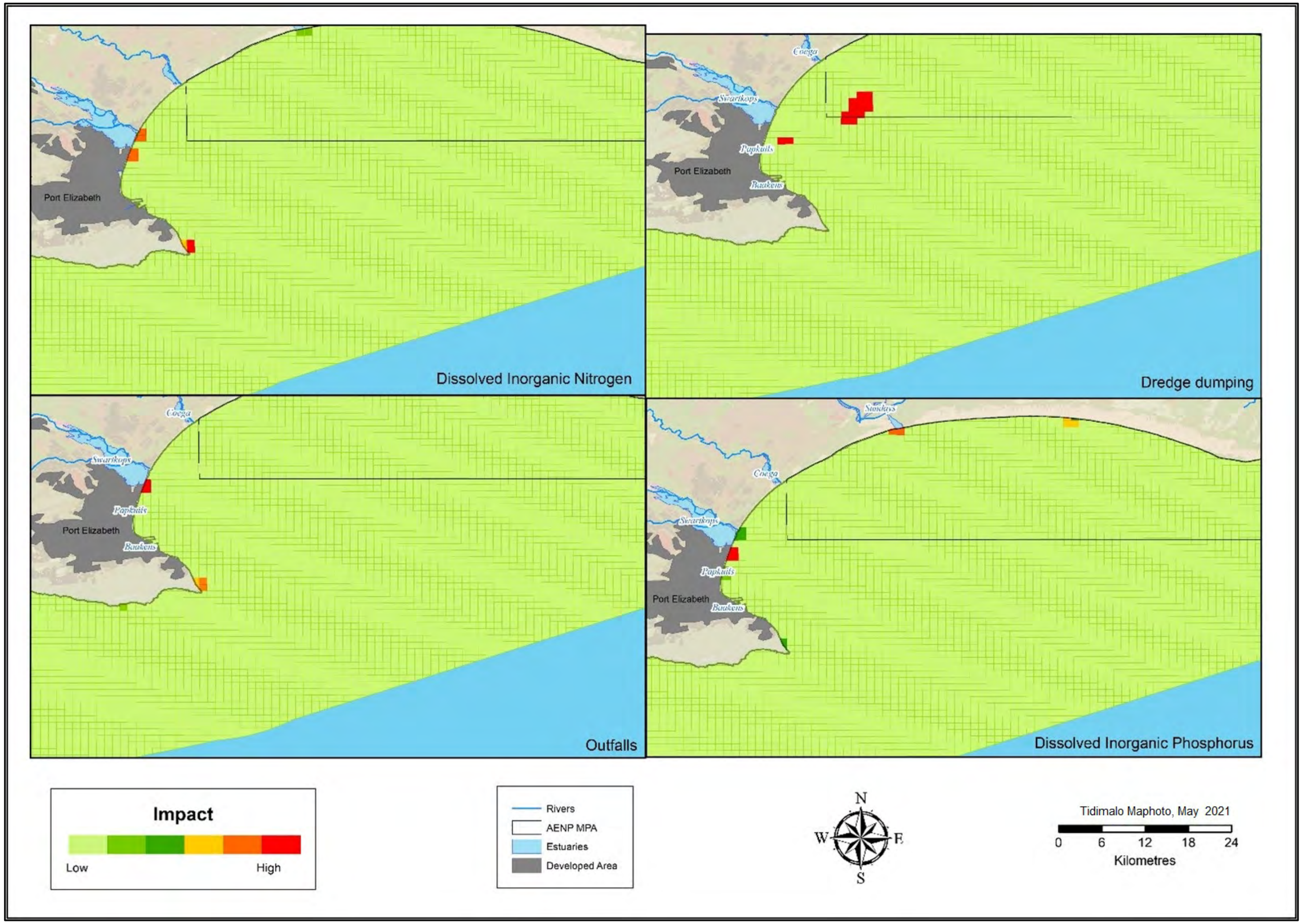


Figure 5. 11: Spatial distributions of impact values for a) Dissolved Inorganic Nitrogen, b) Dredge dumping, c) Outfalls and d) Dissolved Inorganic Phosphorus. Natural breaks were used as a classification method in ArcGIS to display data.

5.4 Discussion

The research objectives of this chapter were to adapt a pressure-ecosystem matrix that reflects the relative assumed impact of each pressure on the marine ecosystems and create a spatially explicit cumulative impact layer for Algoa Bay. The impact patterns of data-poor human uses can be identified by integrating expert knowledge and spatial datasets along with modelling techniques to assess the impacts of human uses on the marine environment. The results from the assessments inform coastal management and conversation (Halpern et al., 2008). Previous studies have noted harbours as the core centres of human impacts (Halpern et al., 2015). Halpern and Fujita (2013) emphasised that cumulative human impact is more complicated than a linear-additive model can explain. However, as with many other studies that lack more detailed information, the assessment of the cumulative impacts in the present study was based on the “linear-additive” assumption. The results of the addressed objectives provide spatially explicit maps of cumulative impact on marine ecosystems.

5.4.1 Pressure-ecosystem Matrix

Demersal inshore trawling has extremely high impact values for marine ecosystems, with an impact value of 100 assigned to the Agulhas Island Shore and Agulhas Mid Shelf Reef Complex. Shipping activities reflected low impact values on all the marine ecosystems in which it occurs, Wastewater pressures have low to intermediate impact values across all marine ecosystems.

5.4.2 Spatial patterns of Cumulative Impact

South African oceans experience a low to medium cumulative impact when compared with the rest of the world’s oceans (see Figure 5.1) (Halpern et al., 2015.

The spatial patterns of cumulative impact show that high impact values occur in the Agulhas Bays-East ecosystem closer to the harbours, where most pressures are present, and the Soft Middle and Outer Shelf and Shelf Edge broad ecosystem. According to Sink et al. (2019), the harbours are the critical drivers of cumulative impacts on the marine environment as they provide access points to the sea. Harbours are also associated with increased coastal development. Fishing pressures from demersal inshore trawling are triggering higher cumulative impacts owing to high impact values and high-pressure intensities. In the current study, the Warm Temperate marine ecosystems had fairly low cumulative impacts; Clarke Murray et al. (2015a), likewise, observed low impacts in areas outside the estuaries.

The distribution and vulnerability of marine ecosystems play an important role in producing the spatial variations in the cumulative impacts that are observed (Halpern et al., 2009). For instance, lower impacts can be seen in the Shelf Mosaic broad ecosystem groups. Patches of low to intermediate impacts can be seen dispersed around the rest of the marine ecosystems. Very few ecosystems (refer to Table 5.1) have high cumulative impact values, and these include Agulhas Sandy Mid Shelf, Agulhas Mixed Shore and Agulhas Mid Shelf Reef Complex. Across the marine ecosystems, the Agulhas Exposed Rocky Shore was the only marine ecosystem with cumulative impact scores of zero in all marine ecosystems. High cumulative impact patterns are driven by the presence of high impact values and high-pressure intensities. In instances where zero cumulative impact values were observed, i.e. Agulhas Exposed Rocky Shore, it is possible that the impact for the marine ecosystem was Zero, which cancelled out the pressure intensity when multiplied. Areas with high cumulative impacts would suggest an increased need for management in order to mitigate the impacts (Clarke Murray et al., 2015a).

The distribution patterns of cumulative impact can be influenced by using different algorithms such as average vs sum. Considering that most cumulative impact models are based on 'linear additive' assumptions (Halpern and Fujita 2013). Coll et al. (2012) emphasize that this might not be valid in marine ecosystems. However, Halpern et al. (2008) showed that the average algorithm derived a cumulative map similar to that produced by the additive algorithm.

5.4.3 Impacts associated with pressures

In the context of Algoa Bay, pressures with the least spatial coverage are mariculture (Figure 5.10 b), outfalls (Figure 5.11 c) and nutrient enrichment (Figure 5.11 a, b). The impacts of these pressures are associated with water quality issues, pollution as well as the introduction of alien species and pathogens (Sink et al., 2019), while impacts related to wastewater pollution to the marine environment include decreased species diversity and a declining population of species (Batista, 2014). Although these pressures have the least spatial extent, the impacts are most likely going to diffuse from the point source and into the bay.

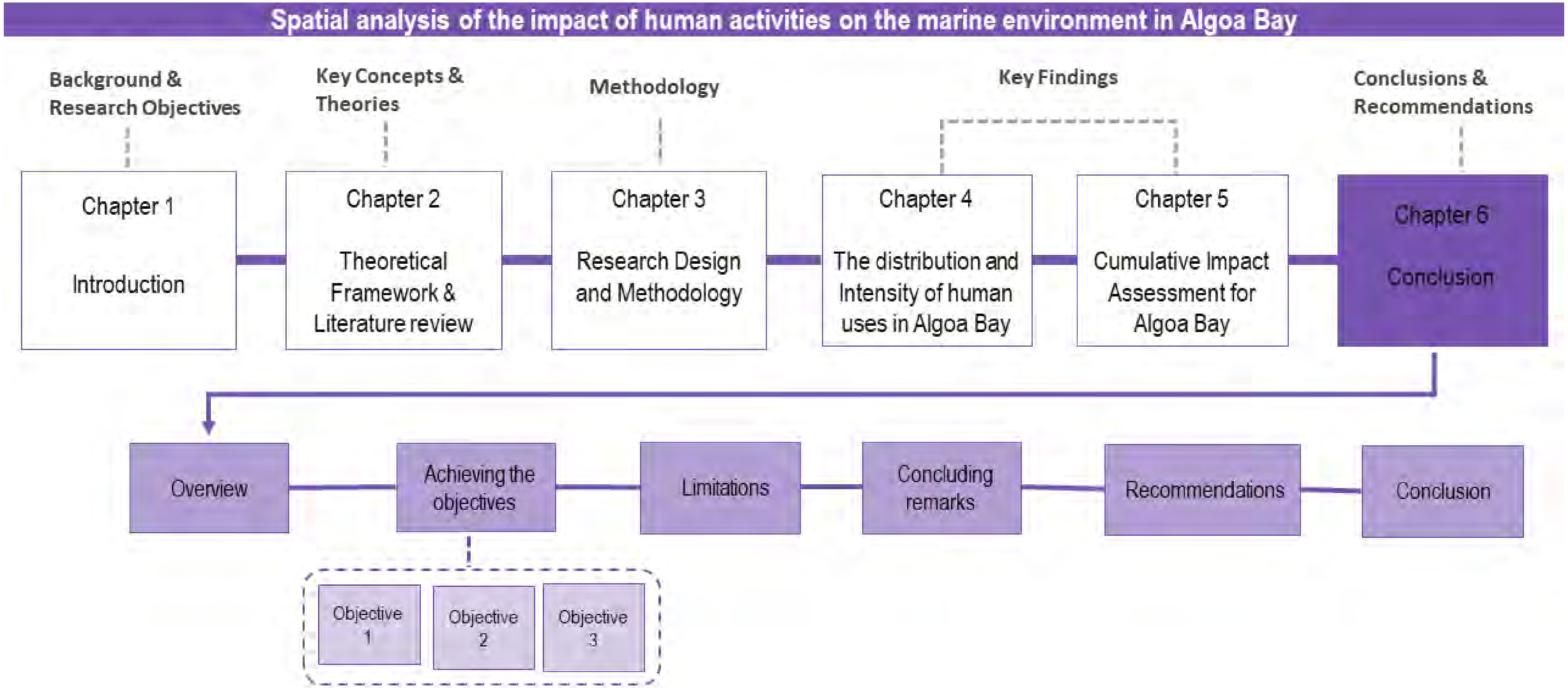
Pressures with the greatest spatial coverage are shipping intensity (Figure 5.8 c), demersal inshore trawling (Figure 5.9 c) and shark longline fishing (Figure 5.9 d). These pressures are associated with devastating impacts on the marine environment, which include the introduction of alien species due to shipping and direct impact on benthic communities and vulnerable marine ecosystems due to demersal inshore trawling (Sink et al., 2019). And the vulnerability of target species and from loss of top predators due to shark longline fishing (Sink et al., 2019).

5.5 Limitations and Conclusions

The methodology for calculating cumulative impact was a simple additive model, which does not account for synergistic effects between pressures that may exist. According to Halpern and Fujita (2013), the additive model assumes a linear response from marine ecosystems to the increasing impact and that all locations of the same marine ecosystem respond in the same way to a pressure. Using an average model could be used to supplement the results obtained from the additive model.

This study produced maps of spatial patterns of cumulative human impact in Algoa Bay. The pressure-ecosystem matrix reveals that Agulhas Island Shore and Agulhas Mid Shelf Reef Complex have high impact values for most pressures (indicating that they are more vulnerable to pressures). Since inshore trawling has the highest individual pressure intensity, as well as high impact value, this resulted in the spatial pattern of high cumulative impact scores in the offshore marine ecosystems where trawling is prevalent. The high cumulative impact values closer to the city centre and harbours are a result of a sum of many pressures occurring in one area.


6
Conclusion



Chapter Six Overview

6. CONCLUSION

Humans continue to use the ocean for many purposes, and a growing population means these uses will escalate, and new uses (e.g. seabed mining) will be introduced. Knowledge of the locations, intensities and impacts of human uses is vital for managing marine resources (Batista et al., 2014).

6.1 Overview

This study aimed to investigate the spatial distribution of human uses and their impacts on the Algoa Bay marine environment. This study followed the DPSIR framework within the socio-ecological systems theoretical framework as the basis of the theoretical underpinnings. A summary of the key findings is given below. Chapter 4 answered research question (a): What are the human activities and their spatial distribution in Algoa Bay? Research question (a) was answered based on research objective 1. Chapter 5 answered research question (b): What is the impact of human activities on the marine ecosystems in Algoa Bay? Research question (b) was answered based on research objectives 2 and 3.

6.1.1 Research Objective 1

- *To identify and map the spatial extents of human pressures in Algoa Bay.*

Spatial distribution of human activities

This objective was achieved and indicated a wide distribution of human uses in Algoa Bay. Most activities are taking place closer to the coast as well as the inshore environment. Fishing has the greatest extent compared with the other groups considered. Fishing, pollution, nutrient enrichment, and shipping had the highest associated impacts on the marine environment compared with the rest of the activities identified by experts. Experts identified six themes that addressed the marine environment's responses to the pressures associated with human uses.

Cumulative pressures

Intermediate cumulative pressures showed the greatest spatial extent, while high cumulative impact showed the least spatial extent in Algoa Bay, this is attributed to multiple pressures occurring at the same area (closer to the city). The spatial patterns of cumulative pressure indicated high pressures along the coast. The results from the 2020 cumulative pressures showed a noticeable difference in patterns of high and low cumulative pressures when compared with the cumulative pressure mapped by Sink et al. (2019).

This difference in patterns can be attributed to the addition of data onto the cumulative pressure that was initially mapped by Sink et al. (2019). This work has added value to the existing work as it provides additional datasets that were not included in the 2018 and 2019 analysis by Sink et al., 2019 and Algoa Bay Project (2019).

6.1.2 Research Objective 2

- *To adapt a pressure-ecosystem feature matrix for Algoa Bay*

Pressure - Ecosystem Matrix

The adaptation of the pressure- ecosystem matrix was successful as it painted a picture of the links and interactions of pressures with the marine environment. The matrix reflected extremely high impact values for demersal inshore trawling, reflected extremely high impact values on all the marine ecosystem types in which it occurs. Wastewater pressures indicated low to intermediate impact values across the marine ecosystems, with spatial patterns of the impact values indicating a decreasing pattern out of the bay towards the offshore ecosystems. Shipping activities reflected low impact values on all the marine ecosystems in which it occurs

6.1.3 Research Objective 3

- *To create a spatially explicit Cumulative Impact layer for Algoa Bay*

Cumulative Impact Assessment

The cumulative impact map (Figure 5.4) considers the distribution of the range of pressures and distribution of marine ecosystems as well as the potential impact of a pressures on an ecosystem. The cumulative impact on the Algoa Bay Marine ecosystems, as plotted, indicates that the top three pressures in Algoa Bay are fishing, shipping, and pollution. The high impact area occurs on the bay's western side, close to the coast, where shipping activities take place. Algoa Bay has a very small area with “high cumulative impact”, based on the distribution patterns of the cumulative impact values.

6.2 Concluding Remarks

Different factors drive the observed peaks and troughs in patterns based on the spatial patterns of cumulative pressure (achieved in objective 1- Figure 4.13) and cumulative impact (achieved in objective 3- Figure 5.5). High cumulative pressures in PUs (Planning Units) are driven by high-pressure intensities across most pressures that are present in that PU, or by the presence of a very high-intensity pressure (for example, shipping and fishing intensities, see Figures 4.9 and 4.10). Conversely, low cumulative pressures PUs are driven by the presence of low-pressure intensities (for example, research monitoring and recreational activities shown in Figure 4.13). However, high cumulative impact patterns are driven by high pressure intensities coupled with high impact values for the pressure-ecosystem pairs present in any PU. This is significant as zoning recommendations can be made for different activities based on cumulative impact patterns to protect both vulnerable ecosystems and industry requirements.

6.3 Recommendations and future work

Given that this study was framed around MSP and management interventions, the activities with the highest impact on the marine environment should be given the highest management priority in mitigating the impacts. Ways in which the impacts could be mitigated include the implementation of strict restrictions (limited use of heavily impacted area) or controlled uses of the marine environment, for example, identifying areas that need to be allocated to particular industries when there is a conflict of use, given the relative importance of the industries to the society. Conservation efforts can also be focused on marine ecosystems that are heavily impacted by human uses.

Important steps to further this work include developing and updating pressure data that could not be mapped for this study (such as HABs, small pelagic, bunkering and possibly regional climate change). The participatory mapping methods could be improved by involving more commercial fishers with mapping knowledge. The fishers in this study indicated that they could not map things accurately. The questionnaire survey could be improved to allow the participation of all experts, as some of the participants indicated that the questionnaire was technical and opted to answer questions with an interviewer rather than assigning impact values.

For future CIA assessments, we need to measure the impacts of these pressures in situ to not assume the impacts of different pressures on different marine ecosystems. A more detailed marine ecosystem map is also needed, as the current one is too broad to be helpful for MSP and fine-scale zoning in the bay. Pressure data along the coast is needed to match the fine-scale marine ecosystem data that we currently have.

This study built onto the Algoa Bay project by providing updated maps of human uses and producing a cumulative impact map. The analysis should be updated each time new data become available. The new data layers that were added in this study's analysis were: ballast water discharge, abalone poaching, Dissolved Inorganic Nitrogen (DIN), Dissolved Inorganic Phosphorus (DIP), outfalls, recreational activities, research monitoring, anchorages and mariculture.

6.4 Conclusion

Human well-being relies on a biodiverse and healthy ocean. Unfortunately, the ocean's health and biodiversity have been degraded owing to centuries of intensifying human uses. Some remedial measures have been adopted worldwide, such as an ecosystem approach to fisheries and implementing marine protected areas (MPAs). Although ecosystem approach to fisheries has been adopted on paper, implementation and adaptation of these strategies as a way to inform management is still relatively rare, which make the gaps even greater.

Tools such as GIS have been useful in empowering decision-makers with knowledge on the location of human uses and where the cumulative impacts of the activities occur. There is, however, a lack of data for many activities, especially in the least developed countries. This study addresses some knowledge gaps associated with data availability using techniques such as incorporating local and expert knowledge with scientific data. This study has provided geographical insight into the distribution of human activities and their cumulative impacts on the ecosystems in Algoa Bay.

The findings from this research build on the Algoa Bay Project's (2019) efforts to develop a marine spatial plan for the bay by including improved and additional human use data from additional stakeholders.

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8. APPENDICES

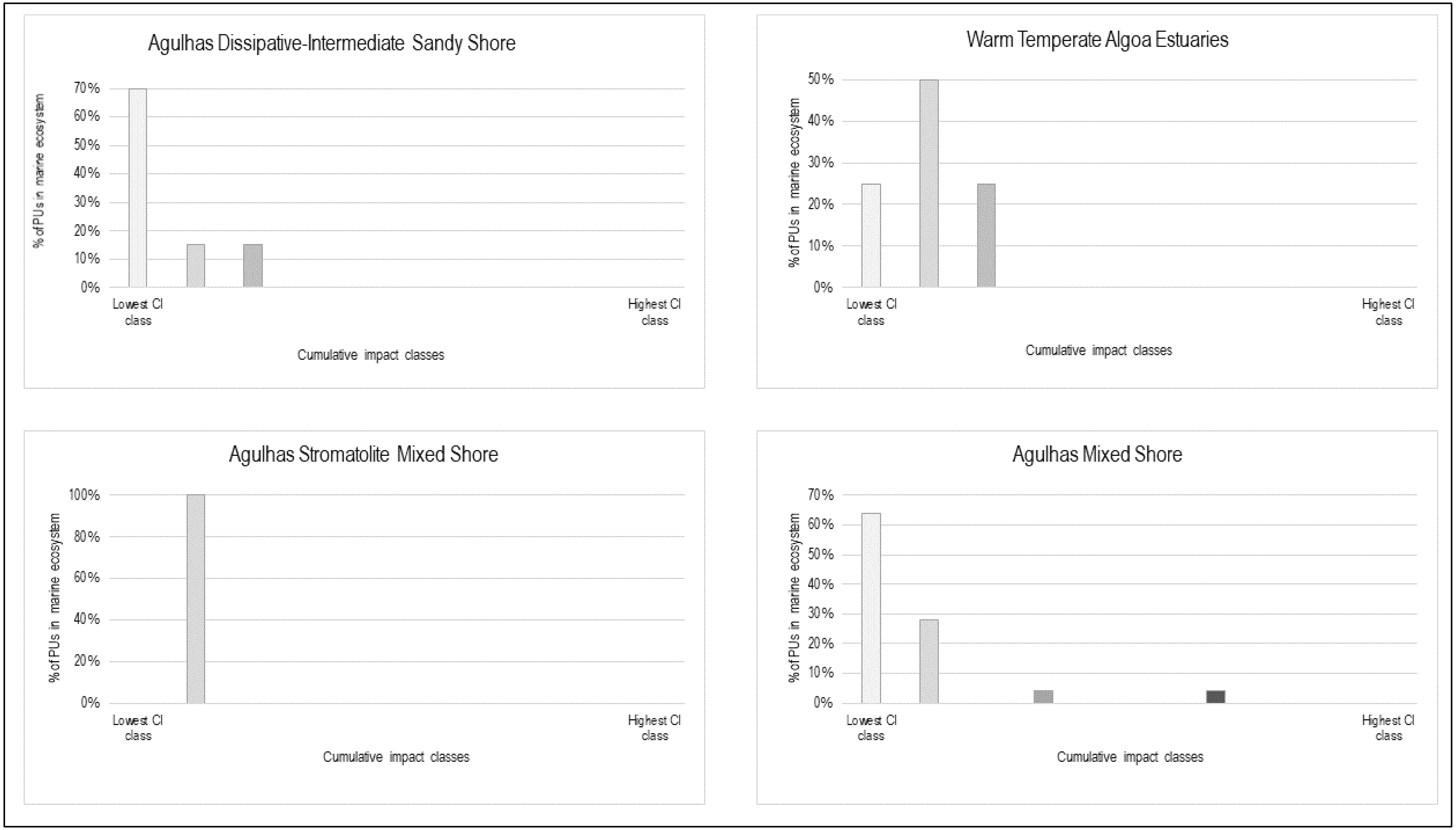
Appendix 1: Metadata table of human activities used for spatial analysis (See Table 4.1).

Data Layer	Source of Data/ Scientific organization	Format	Scale / Resolution
Anchor	Digitised from SAN 1024 Hydrographic chart	Shapefile: Polygon	Algoa Bay
Aquaculture	Digitised from SAN 1024 Hydrographic chart	Shapefile: Polygon	Algoa Bay
Recreational Activities	Hannah Truter- Algoa Bay Project	Shapefile: Points	1:50 000
Outfalls	Department of Environmental Affairs	Microsoft Excel spreadsheet: x-y coordinates	1:50 000
Nutrient enrichment (DIN and DIP)	Digitised from Lemley et al., 2019	Shapefile: Points	Algoa Bay
Research Monitoring	Hannah Truter- Algoa Bay Project	Shapefile: Points	Algoa Bay

Appendix 2: Nodes compared by the number of coding references in NVivo

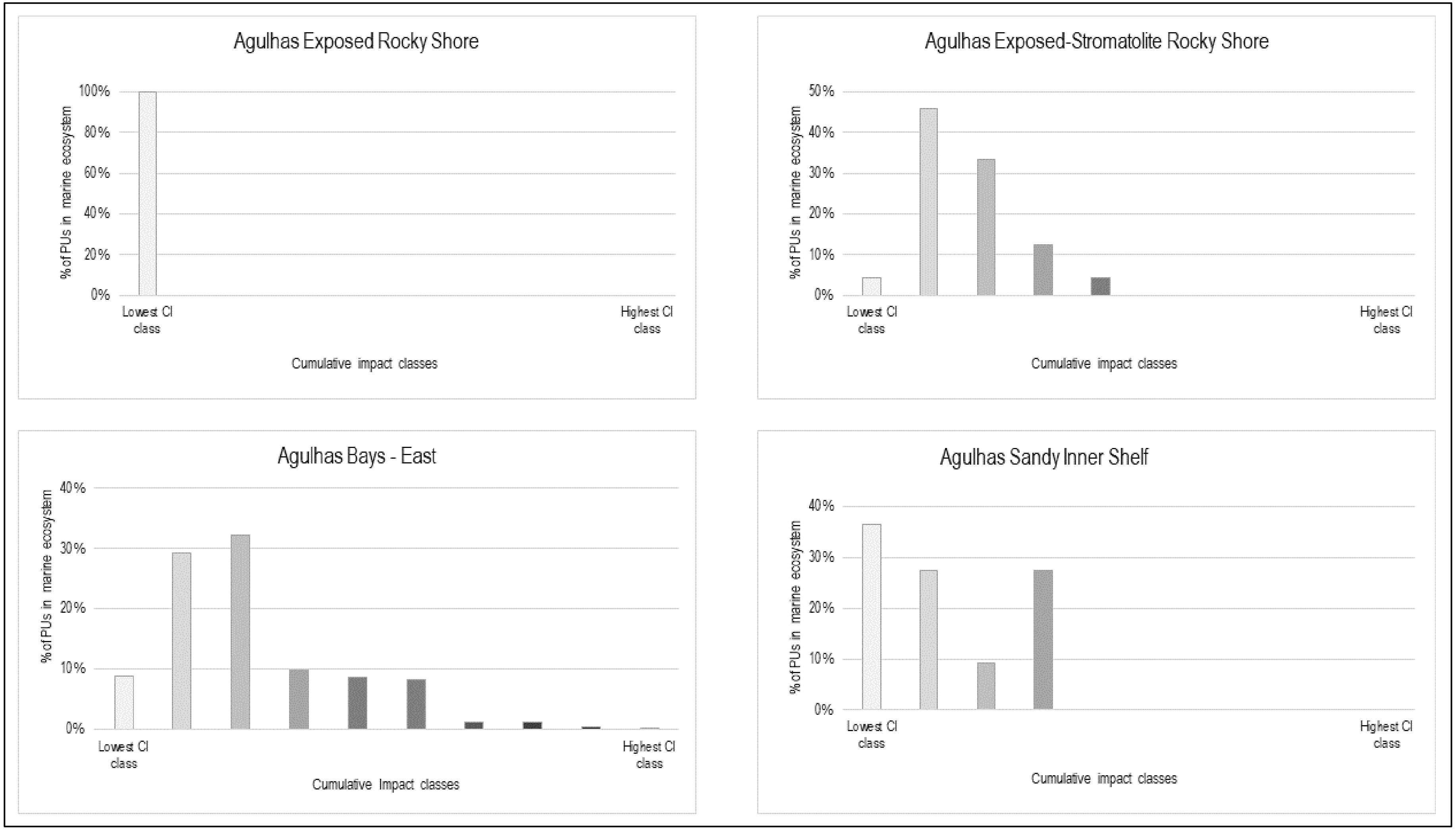
Appendix 3:Distribution of impact values within planning units in marine ecosystems.

a) Agulhas Dissipative-Intermediate Sandy Shore, b) Warm Temperate Algoa Estuaries, c) Agulhas Stromatolite Mixed Shore and d) Agulhas Mixed Shore



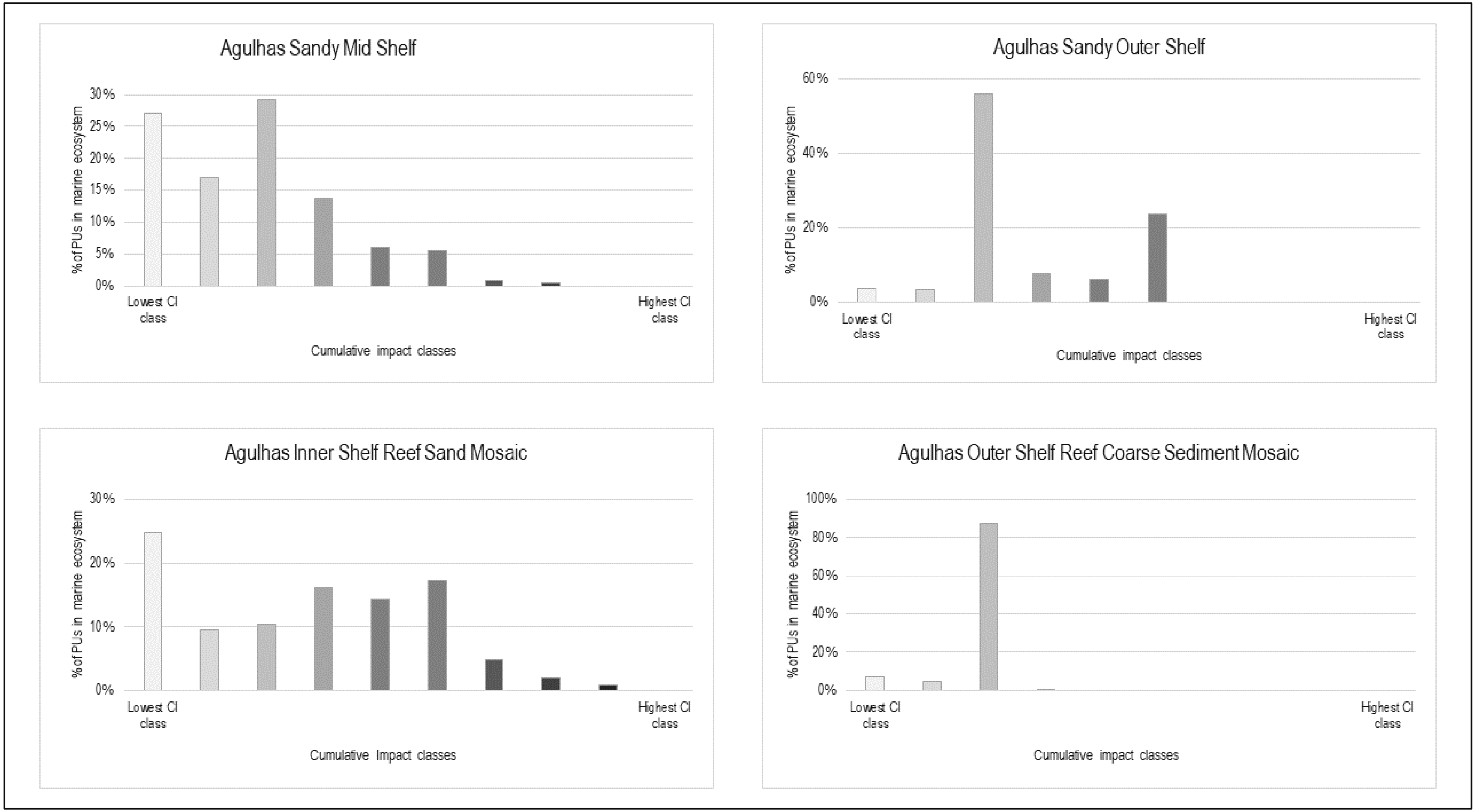
Appendix 4: Distribution of impact values within planning units in marine ecosystems.

a) Agulhas Exposed Rocky Shore, b) Agulhas Exposed-Stromatolite Rocky Shore, c) Agulhas Bays-East, and d) Agulhas Sandy Inner Shelf.



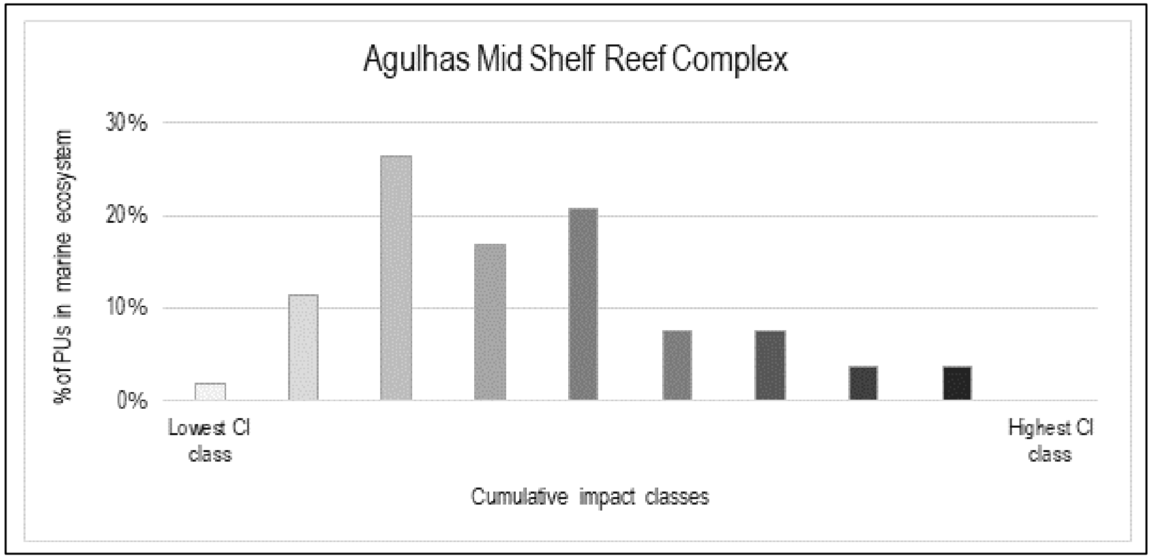
Appendix 5: Distribution of impact values within planning units in marine ecosystems.

a) Agulhas Sandy Mid Shelf, b) Agulhas Sandy Outer Shelf, c) Agulhas Inner Shelf Reef Sand Mosaic, and d) Agulhas Outer Shelf Reef Coarse Sediment Mosaic.



Appendix 6: Distribution of impact values within planning units in marine ecosystems.

a) Agulhas Mid Shelf Reef Complex



Appendix 7: Questionnaire Survey

Tidimalo Maphoto - MSc Geography _ Rhodes University

Algoa Bay Marine Ecosystem Pressures Survey

This survey is designed to call for contributions of 'local knowledge' to an exercise in mapping Algoa Bay marine ecosystem pressures. We ask you to reflect your extensive knowledge of this ecosystem through **filling a table after the instructions** and **reporting the information on a map**. Your answers (Part A: Questions 1 to 5 and Part B: Expert Mapping) will be used as input to a 'model' that measures human impact on the marine environment in Algoa Bay.

The following conditions will be met by the researcher:

- Data collected will be used for research purposes only.
- Responses will be kept confidential, and your name or affiliation will not be identified in my thesis.
- The finding of the research will be communicated back to interested participants.

Declaration by participant: ☐

I declare that I understand the conditions stated by the researcher. I understand that taking part in this study is voluntary, and I am free to withdraw at any point.

Personal information:

Name:	
Affiliation:	

Part A: Survey Questions:

1. What is your background in terms of the marine environment? Please describe your interest and involvement

   ----

   ----

2. How long have you dealt with the marine environment?

   ----

3. Please fill in the table below to answer question 3. ***Row 1 indicates an example to guide you in answering.***

   a) What do you see as the main issues to the marine ecosystem associated with human activities in the Bay? Please list the issues in **Table 1**.

   b) Are the issues identified past or current issues? Alongside your list – indicate a 'P' for past or a 'C' for current

1

With regard to the issues you have listed – fill in the table according to the questions below *(please highlight your answers in the table as show on row 1):*

c) **What is the broader Impact?** (The result of that issue acting on the ecosystem.)

d) **Extent of impact on the ecosystem** – the level at which the impact happens.

e) **Intensity** – can you give a relative measure of the issue?

f) **Frequency** – the relative frequency of the issue within the Bay.

g) **Spatial Dimension** – the geographical distribution of the issue within the Bay.

h) **Scale** – the average spatial scale at which the issue impacts the marine environment.

Table 1: Please fill in the table below based on the issues identified in question 3.

	3a & b	**3c**	**3d**	**3e**	**3f**	**3g**	**3h**
No	**Issue**	**Impact**	**Extent of impact**	**Intensity**	**Frequency**	**Spatial Dimension**	**Scale**
1	Ship anchor route - C	Physical damage to reef Petro-Chemicals Pollution	Unknown	Unknown	Unknown	Unknown	Unknown
			Species	Low	Rare	Spread through the bay	<1 km^2
			Single trophic level	Low-Medium	Occasional		1-10 km^2
			Community Level	Medium	Annual/Regular	Confined to position	10-100 km^2
			Habitat structure	Medium-High	Persistent		100-1000 km^2
				High			>1000 km^2
2			Unknown	Unknown	Unknown	Unknown	Unknown
			Species	Low	Rare	Spread through the bay	<1 km^2
			Single trophic level	Low-Medium	Occasional		1-10 km^2
			Community Level	Medium	Annual/Regular	Confined to position	10-100 km^2
			Habitat structure	Medium-High	Persistent		100-1000 km^2
				High			>1000 km^2
3			Unknown	Unknown	Unknown	Unknown	Unknown
			Species	Low	Rare	Spread through the bay	<1 km^2
			Single trophic level	Low-Medium	Occasional		1-10 km^2
			Community Level	Medium	Annual/Regular	Confined to position	10-100 km^2
			Habitat structure	Medium-High	Persistent		100-1000 km^2
				High			>1000 km^2
4			Unknown	Unknown	Unknown	Unknown	Unknown
			Species	Low	Rare	Spread through the bay	<1 km^2
			Single trophic level	Low-Medium	Occasional		1-10 km^2
			Community Level	Medium	Annual/Regular	Confined to position	10-100 km^2
			Habitat structure	Medium-High	Persistent		100-1000 km^2
				High			>1000 km^2

3

7. How does the marine environment respond to the disturbance of the issues?

Additional comments / notes:

Part B: Expert Mapping

There are 2 options for putting your expert knowledge recorded in the table you filled in - on a map. One is to fill it in on the attached map of Algoa Bay, the other option is to fill it in through Google Earth.

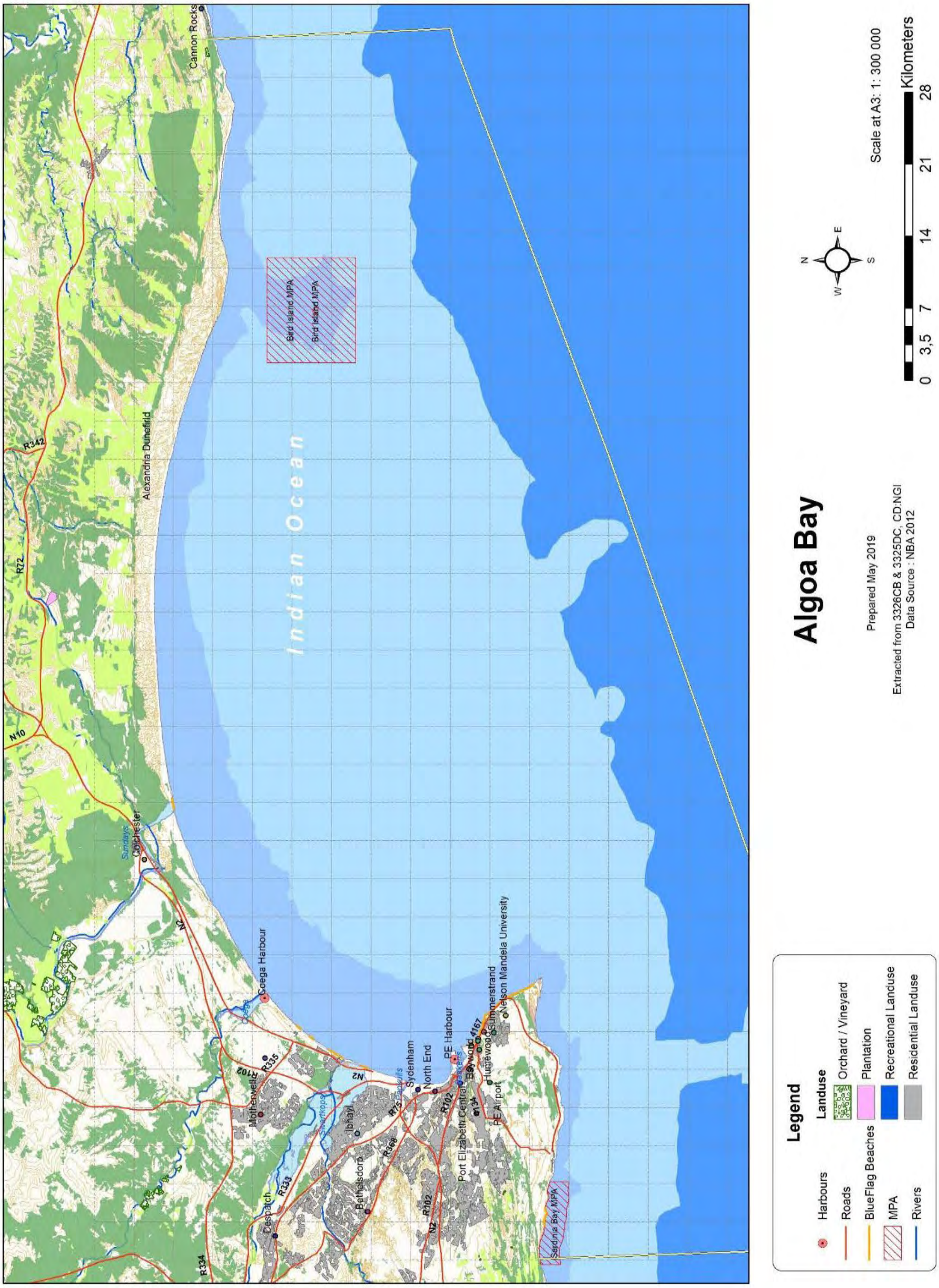
Filling in the map (Attached image)

1. Draw a polygon or a marker point that indicates the approximate location of the issue you identified.
2. Write the number of the issue (according to the numbers you used in Table 1) inside the polygon or next to the marker point.

Instructions for marking *Marine issues* in Google Earth

1. In your email double click on the *Marine issues* KMZ folder to open Google Earth (the file shows the study area and will be listed under *Temporary Places* when Google Earth opens).
2. Right click on the *Marine issues* folder and from the drop-down menu choose *Add*...and select either a *Polygon* or a *Placemark*.
3. In the dialogue box that opens, name the *Polygon/Placemark* according to your list in Table 1. Drag the *Placemark/Polygon* to the correct location. Once you have finished, check the *OK button*. Repeat the process to add more *Polygons* or *Placemarks.*
4. Once you are done, if you right click on the *Marine issues* folder – you can choose the option to Email... this will prompt you to open you email – from there you can send the new Placemarks/Polygons in kml/kmz format to maphototidimalo@gmail.com .
5. You can also attach your filled in questionnaire.

4


Algoa Bay
Prepared May 2019
Extracted from 3326CB & 3325DC, CD:NGI
Data Source : NBA 2012
Scale at A3: 1: 300 000
0 3,5 7 14 21 28
Kilometers
Legend
Harbours
Roads
BlueFlag Beaches
MPA
Rivers
Landuse
Orchard / Vineyard
Plantation
Recreational Landuse
Residential Landuse
Indian Ocean
Bird Island MPA
Sardinia Bay MPA
Cannon Rocks
Alexandria Dunefield
Colchester
Coega Harbour
PE Harbour
Port Elizabeth Central
Nelson Mandela University
Summerstrand
PE Airport
North End
Sydenham
Motherwell
Bethelsdorp
Ibhayi
Despatch
N2
N10
R72
R342
R334
R333
R335
R102

5

Table 2: List of Issues and pressure groups that have been identified for Algoa Bay

Code	Marine Issues
1	Anchor routes
2	Shipping
3	Shipping -ballast water
4	Dredge spoil
5	Alien Species
6	Commercial fishing
7	Recreational fishing
8	Over fishing
9	Trawling
10	Poaching
11	Sewage and other (Pollution)
12	Coastal development
13	Recreational activities
14	Blue Flag Beaches
15	Research (scientific input)
16	Oil and Gas Exploration
(Your own terms/issues) **17**	
18	
19	
20	

Appendix 8: Interview Questions

Tidimalo Maphoto - MSc Geography _ Rhodes University

Algoa Bay Marine Ecosystem Pressures

This survey is designed to call for contributions of 'local knowledge' to an exercise in mapping Algoa Bay marine ecosystem pressures. We ask you to reflect your extensive knowledge of this ecosystem through answering the questions and reporting the information on a map.

The following conditions will be met by the researcher:

- Data collected will be used for research purposes only.
- Responses will be kept confidential, and your name or affiliation will not be identified in my thesis.
- The finding of the research will be communicated back to interested participants.

Declaration by participant: ☐

I declare that I understand the conditions stated by the researcher. I understand that taking part in this study is voluntary, and I am free to withdraw at any point.

Personal information:

Name:	
Affiliation :	

Part A: Interview Questions:

1. What is your background?
2. How long have you been living in Algoa bay?
3. What are the economic drivers in the bay?
4. What environmental issues are you aware of?
5. Which human activities pose a threat to the marine environment?
6. How do you see the future as a resident of Algoa Bay, given the issues you described?

1

Appendix 9: Focus Group Questions

Tidimalo Maphoto-MSc Geography _Rhodes University

Algoa Bay Marine Ecosystem Pressures

This survey is designed to call for contributions of 'local knowledge' to an exercise in mapping Algoa Bay marine ecosystem pressures. We ask you to reflect your extensive knowledge of this ecosystem through answering the questions and reporting the information on a map.

The following conditions will be met by the researcher:

- Data collected will be used for research purposes only.
- Responses will be kept confidential, and your name or affiliation will not be identified in my thesis.
- The finding of the research will be communicated back to interested participants.

Declaration by participant: ☐

I declare that I understand the conditions stated by the researcher. I understand that taking part in this study is voluntary, and I am free to withdraw at any point.

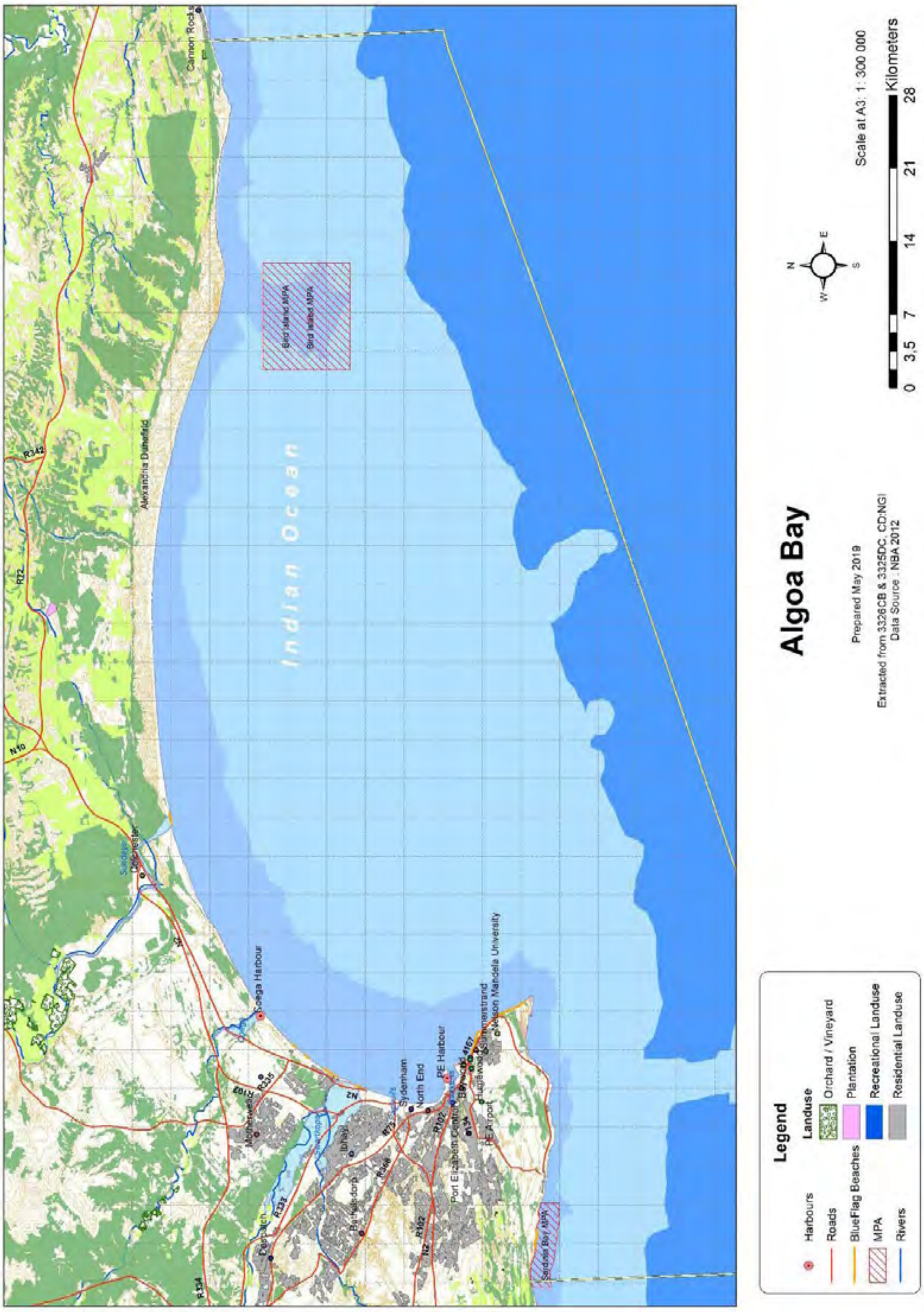
Personal information:

Name:	
Affiliation :	

Interview Questions:

1. How long have you worked as a fisherman?
2. Can you please describe your experiences of working as a fisherman at Algoa Bay?
3. What, in your opinion, is the biggest challenge for fishermen at Algoa Bay (human activities, climate change, regulations, conflicts)
4. Which human activities pose a threat to the marine environment?
5. Do any of the human activities interfere with your work? If yes, which ones?
6. How do you see the future as a fisherman at Algoa Bay, given the issues you described?
7. How do you see the future of the sea?

1


Algoa Bay
Prepared May 2019
Extracted from 3326CB & 3325DC, CD:NGI
Data Source : NBA 2012
Scale at A3: 1: 300 000
0 3,5 7 14 21 28
Kilometers
N
E
S
W
Indian Ocean
Bird Island MPA
Alexandria Dunefield
Cannon Rocks
Coega Harbour
PE Harbour
Nelson Mandela University
Port Elizabeth
Sydenham
North End
Motherwell
Despatch
Bethelsdorp
Colchester
Sardinia Bay MPA
PE Airport
R342
R72
N10
N2
R335
R334
Legend
Harbours
Roads
BlueFlag Beaches
MPA
Rivers
Landuse
Orchard / Vineyard
Plantation
Recreational Landuse
Residential Landuse

2

Appendix 10: Interview Consent Form

Research Information and Consent Form

Title of Research Study:

Spatial analysis of the impact of human activities on the Marine Environment in Algoa Bay, South Africa

Researcher:

Tidimalo Maphoto, MSc Geography, Rhodes University

Aim/Purpose of the Research:

To identify and investigate the spatial distribution of human activities and their impacts on the Algoa Bay Marine system

What will be asked of the Interviewee:

Questions asked include information from the participants on the human activities that take place in the Bay and how they impact the environment and/or their work. Participants will be asked to indicate on the map where these activities take place.

Risks and Discomforts:

There are no anticipated negative consequences for interviewees involved in this study. Even with administrative consent the interviewee will be free to refuse to participate or withdraw from participation at any time without any negative consequences to either the interviewee or the institution with which they are affiliated.

Voluntary Participation and withdrawal:

The interviewee and organization are aware that their participation is voluntary, and they may cancel the interview or stop at any point if they choose to terminate their participation.

Confidentiality/Anonymity:

Interviewees can request that their anonymity be protected. In this case, the interviewee's name will not be recorded, nor any identifying personal information.

Questions about the interview or research:

Questions about the interview or research project may be directed to Researcher's name and email address or by telephone at Researcher's telephone number. Alternatively, one may contact the research supervisor(s), Insert supervisor's name and email address. Upon completion of the project a copy of the research study can be provided in English to all participating organizations or interviewees.

Legal Rights and Signatures of Interviewee:

I ______________________________ (interviewee's name), give consent to be interviewed by Researcher's name, for their research study. I fully understand the nature of this interview. My consent is indicated by my signature below:

Interviewee Signature: __________________________

Name of Organization (if applicable): ____

Date: ______________________________________

Researcher Signature: ____

Date: ____

Appendix 11: Ethical clearance letter

RHODES UNIVERSITY
Where leaders learn

Science Faculty Ethics Sub-committee
Biological Science Building, Grahamstown, 6139, South Africa
PO Box 94, Grahamstown, 6140, South Africa
t: +27 (0) 46 603 8443
f: +27 (0) 46 603 7576
e: j.dames@ru.ac.za

www.ru.ac.za

20 September 2018

Dear Gillian McGregor and Tidimalo Mphoto

Tracking Number SCI2018/044
Date Submitted 29 August 2018
Proposal title **Spatial analysis of the impact of human Activities on the marine environment in Algoa Bay, South Africa.**

This letter serves to notify you of the outcome of your ethics application submitted to the Science Faculty Ethics Sub-committee.

	Outcome	**Comments**
Approved with conditions	X	*Please provide an indication of who the experts and stakeholders will be and how will they be recruited. This may be addressed in an email.*
Provisional approval with stipulations		
Refer to RUESC-HE/RUESC-AE		
Does not require ethics approval:		
Referred back to applicant		
Rejected		

Please ensure that the Science Faculty Ethics Committee is notified should any substantive changes be made, for whatever reason, during the research process. An annual progress report is required in order to renew approval for the following year. The purpose of this report is to indicate whether or not the research was conducted successfully, if any aspects could not be completed, or if any problems arose that the 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.

Prof Joanna Dames (Chair)