State of the Coast KwaZulu-Natal

A review of the state of the coast of KwaZulu-Natal

KWAZULU-NATAL PROVINCE
ECONOMIC DEVELOPMENT, TOURISM AND ENVIRONMENTAL AFFAIRS
REPUBLIC OF SOUTH AFRICA

GROWING KWAZULU-NATAL TOGETHER

State of the Coast KwaZulu-Natal

A review of the state of the coast of KwaZulu-Natal

March 2022

Editors: Bronwyn Goble and Rudy van der Elst

KWAZULU-NATAL PROVINCE
ECONOMIC DEVELOPMENT, TOURISM AND ENVIRONMENTAL AFFAIRS
REPUBLIC OF SOUTH AFRICA

SAAMBR INCORPORATING OCEANOGRAPHIC RESEARCH INSTITUTE uShaka SEA WORLD
Helping people to care for our ocean

State of the Coast KwaZulu-Natal
A review of the state of the coast of KwaZulu-Natal

First published in 2022.

Suggested citation of this publication
Goble, B.J. and van der Elst, R.P. (eds.) **2022**. *State of the Coast KwaZulu-Natal - A review of the state of the coast of KwaZulu-Natal*, KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs, Pietermaritzburg, 244 pp.

KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs
Sub-directorate: Coastal and Biodiversity Management
Private Bag X9152
Pietermaritzburg, 3200
South Africa
Telephone: (+27-33) 264 2500
Website: www.kznedtea.gov.za

Acknowledgements:
This is a joint publication between the Department of Economic Development, Tourism and Environmental Affairs (EDTEA) and the Oceanographic Research Institute (ORI).

This publication is compiled through collaboration with many experts, organisations and individuals that are acknowledged and sincerely thanked for their contributions, without which this publication would not be possible.

Contributing Authors

Chapter 1: Introduction and Background
Introduction and Background: Dr Bronwyn Goble (ORI)

Chapter 2: Overarching Drivers
2.1 The Blue Economy: Rudy van der Elst and Dr Bronwyn Goble (ORI)
2.2 Human Settlements: Dr Bronwyn Goble, Marilyn Bodasing and Rudy van der Elst (ORI)
2.3 Pollution: Steven Weerts and Susan Taljaard (CSIR)

Chapter 3: Climate Variability
3.1 Climate Change: Dr Andrew Mather (eThekwini Municipality)
3.2 Extreme Events: Dr Andrew Mather (eThekwini Municipality)
3.3 Oceanographic Events: Dr Laura Braby (SAEON, Egagasini Node)

Chapter 4: Coastal Environment
4.1 Sandy Shores: Dr Linda Harris (Coastal and Marine Research & Department of Zoology, NMU)
4.2 Swamp Forests: Dr Taryn Riddin and Prof. Janine Adams (Institute for Coastal and Marine Research, NMU)
4.3 Rocky Shores: Dr Kaylee Smit (UCT & SANBI)
4.4 Coastal Lakes: Fiona MacKay (ORI) and Steven Weerts (CSIR)
4.5 Wetlands: Dr Heidi van Deventer (CSIR & WITS)
Peatlands insert: Dr Piet-Louis Grundling (DFFE & UFS), Dr Althea Grundling (ARC & UNISA), Dr Heidi van Deventer (CSIR & WITS) and Jason le Roux (WETREST)
4.6 Coastal Vegetation: Dr Debbie Jewitt (Ezemvelo KZN Wildlife)

Chapter 5: Estuarine Environment
5.1 Estuaries: Fiona MacKay (ORI) and Steven Weerts (CSIR)
5.2 Mangroves: Prof. Janine Adams (Institute for Coastal and Marine Research, NMU)
5.3 Submerged Macrophytes: Prof. Janine Adams (Institute for Coastal and Marine Research, NMU)

Chapter 6: Marine Environment
6.1 Coral Reefs: Prof. Michael Schleyer and Dr Sean Porter (ORI)
6.2 Rocky Reefs: Prof. Michael Schleyer and Dr Sean Porter (ORI)
6.3 Soft Sediments: Fiona MacKay (ORI)
6.4 Pelagic Environment: Prof. Sean Fennessy (ORI)

Chapter 7: Human Environment
7.1 Coastal Access: Marinel Willemse (formerly ORI)
7.2 Small-scale Fisheries: Dr Bruce Mann (ORI) and Dr Stephen Lamberth (DFFE)
7.3 Recreational Fishing: Dr Bruce Mann and Erika Steyn (ORI)
7.4 Boat-based Activities: Dr Bruce Mann (ORI)

Chapter 8: Economic Environment

8.1 Ports and Shipping: Dr Bronwyn Goble (ORI)
8.2 Tourism: Dr Bronwyn Goble and Rudy van der Elst (ORI)
8.3 Aquaculture: Neil Stallard (Previous Director: Zini Fish Farms) and Dr Larry Oellermann (SAAMBR)
8.4 Agriculture: Dr Bronwyn Goble and Marilyn Bodasing (ORI)
8.5 Manufacturing and Industry: Dr Bronwyn Goble (ORI)
8.6 Commercial Fishing: Prof. Sean Fennessy (ORI)
8.7 Coastal Dune Mining: Dr Bronwyn Goble (ORI) and Dr Larry Oellermann (SAAMBR)
8.8 Sand Mining: Fiona MacKay and Bianca McKelvey (ORI)
8.9 Offshore Mining: Prof. Sean Fennessy (ORI)
8.10 Oil and Gas Exploration: Prof Sean Fennessy (ORI)

Chapter 9: Governance Environment

9.1 Coastal Management: Dr Bronwyn Goble and Rudy van der Elst (ORI)
9.2 Marine Protected Areas: Dr Bruce Mann (ORI) and Tamsyn Livingstone (Ezemvelo KZN Wildlife)

Chapter 10: Conclusions

Conclusions: Dr Bronwyn Goble (ORI)

Project Managers
Dr Bronwyn Goble and Marilyn Bodasing (ORI)

Proof reading
Marilyn Bodasing (ORI) and Kirsty Pope-Ellis

Design and Layout
Dr Bronwyn Goble (ORI)

VISION

A vibrant, healthy and safe coast with sustainable access to resources for all.

Through co-operative governance and best practice, the intrinsic value of the coast is protected, restored and enhanced for future generations, while promoting equitable access and sustainable use of coastal resources for all stakeholders and user groups.

CONTENTS

EXECUTIVE SUMMARY

The coastal zone of KwaZulu-Natal (KZN) is one of this Province's greatest assets and arguably one of South Africa's richest environmental treasures. This 580 km strip represents a major contributor to the economy of KZN, a refuge for its people, a drawcard for tourists and a bulwark against climate change. This State of the Coast Report (SOCR) is a statutory requirement and provides detailed knowledge as to the current state of our coastal environment and resources. It outlines which pressures ecosystems are exposed to and better informs future management decisions.

The people of KZN can be proud of the high (>22%) percentage of our coastline that is protected, mostly in the Isimangaliso World Heritage reserve. Similarly, the goods and services provided by the coastal zone are still diverse and available. However, cracks in the system have appeared and while there is excellent legislation and scientific capacity in place, it is the implementation of policy that needs strengthening.

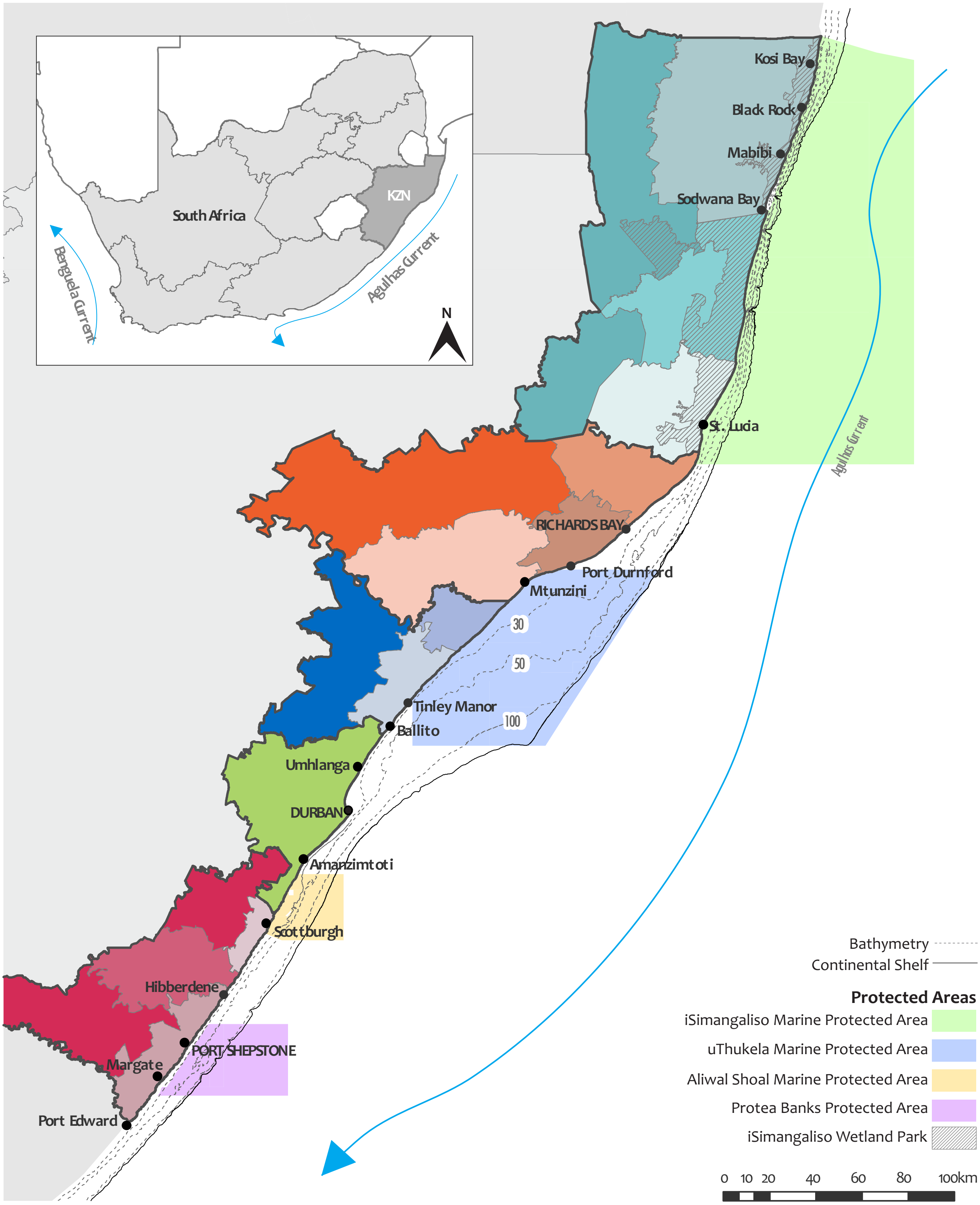
This report was compiled at a time when coastal KZN was under duress: the Covid 19 pandemic, major lockdowns, riots and associated pollution, infrastructure was severely damaged and basic services were interrupted for many months that followed. These events highlighted the fragility of the KZN coastal zone.

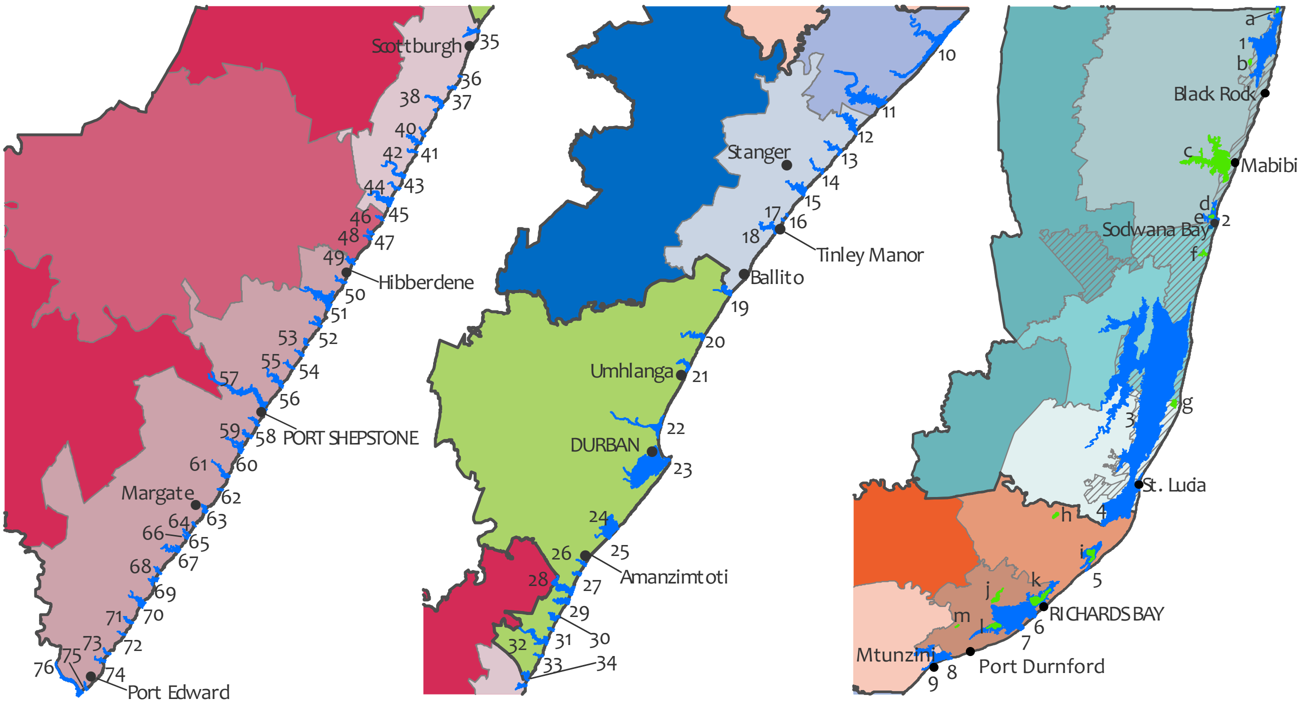
The KZN SOCR provides an overview of the six main ecosystems, the drivers of change, the pressures on them, the current state, potential impacts and identifies key response actions for each. The report highlights the six main ecosystem types: the coastal, estuarine, marine, human, economic and governance environments (Chapters 4 to 9), while chapters 2 (overarching drivers) and 3 (climate variability) provide a broader overview as to global drivers of change and cross-cutting issues of concern.

A summary of each sub-system is provided in a set of fascicles which can be independently updated to track progress in coastal management. Overall, the state of the KZN coast is concerning with 23 of the 35 sub-systems identified as being in a moderate state and 11 in a poor state. The overall trend shows a dismal trajectory with 18 sub-systems in a declining trend, 12 considered stable and only one: Marine Protected Areas showing improvement. The main crosscutting environmental threats identified by this report include pollution (especially sewage treatment), climate change, coastal sand mining, oil and gas exploration and changes in human settlements. In addition, possible emerging issues to be considered going forward include water quality concerns, new diseases, largely through aquaculture, ongoing and increased mining in the estuarine EFZs and oil and gas exploration.

Chapter 10 of this report summaries the specific actions for each sub-system (Table 10.1) and provides more general actions that can be taken to improve the overall state of the KZN coastal environment. These include actions relating to governance, awareness and education, planning and long-term monitoring.

MAP OF KZN COAST





District Municipalities

- Umkhanyakude
- King Cetshwayo
- iLembe
- eThekwini
- Ugu

Local Municipalities

- Umhlabuyalingana
- The Big 5 False Bay
- Mtubatuba
- Mfolozi
- uMhlathuze
- uMlalazi
- Mandeni
- KwaDukuza
- Umdoni
- Umzumbe
- Ray Nkonyeni

Estuaries

1	Kosi	31	iNgane	61	oHlangeni
2	uMgobezeleni	32	uMkhomazi	62	uVunguza
3	St Lucia	33	uMahlongwane	63	iKongeni
4	iMfolosi / uMsunduze	34	uMahlongwa	64	uVuzana
5	iNhlabane	35	uPhambanyoni	65	iBilanhlonhlo
6	Richards Bay	36	Rocky Bay	66	iMvutshini
7	uMhlathuze	37	uMzimayi	67	iMbizana
8	uMlalazi	38	uMuziwezinto	68	iKhaba
9	iSiyaya	39	iNkomba	69	uMhlangomkhulu (North)
10	aMatigulu / Nyoni	40	uMkhumbane	70	iMpenjani
11	uThukela	41	iSezela	71	iKhandalendlovu
12	iZinkwazi	42	uMdesingane	72	uMuntongazi
13	iNonoti	43	iFafa	73	iMbhoyibhoyi
14	uMdlotane	44	uMvuzi	74	iSandlu
15	uMvoti	45	uMthwalume	75	iSolwane
16	uSetheni	46	uMnamfu	76	uMthavuna
17	Bob's Stream	47	uMakhosi		
18	uMhlali	48	uMfazezala		
19	uThongathi	49	uMhlungwa		
20	uMdloti	50	uMhlabashana		
21	uMhlanga	51	uMzumbe		
22	uMngeni	52	iNjambili		
23	Durban Bay	53	iKoshwana		
24	iSiphingo	54	iDombe		
25	iZimbokodo	55	uMhlangomkhulu (North)		
26	aManzimtoti	56	uMthente		
27	aManzanamtoti	57	uMzimkhulu		
28	iLovu	58	uMbango		
29	uMsimbazi	59	iBhobhoyi		
30	uMgababa	60	iZotsha		

Coastal Lakes

a	Zilonde
b	Shengeza
c	Sibaya
d	Shazibe
e	iMgobezeleni
f	Bhangazi (North)
g	Bhangazi (South)
h	Eteza
i	iNhlabane
j	Nsezi
k	Mzingazi
l	Qubhu
m	Mangeza

ACRONYMS & ABBREVIATIONS

ADZ: Aquaculture Development Zone

AIS: Alien Invasive Species

ARC: Agricultural Research Council

ASCA: Agulhas System Climate Array

BLSMS: Boat Launch Site Monitoring System

CBAs – Critical Biodiversity Areas

CBD: Convention for Biological Diversity

CITES: Convention on International Trade in Endangered Species

CMEMS: Copernicus Marine Service

CMLs: Coastal Management Lines

CMP – Coastal Management Programme

COTS: Crown-of-thorns starfish, *Acanthaster planci*

CPP: Coastal Public Property

CPUE: Catch Per Unit Effort

CPZ: Coastal Protection Zone

CSIR: Council for Scientific and Industrial Research

DAFF: Department of Agriculture, Forestry and Fisheries*

DDT: Dichlorodiphenyltrichlorethane

DEA: Department of Environmental Affairs*

DEAT: Department of Environmental Affairs and Tourism*

DFFE: Department of Forestry, Fisheries and the Environment

DMR: Department of Mineral Resources*

DMRE: Department of Mineral Resources and Energy

DWS: Department of Water and Sanitation

ECRL: East Coast Rock Lobster

EDTEA: Department of Economic Development, Tourism and Environmental Affairs

EEZ: Exclusive Economic Zone

EFZ: Estuarine Functional Zone

EHI: Estuarine Health Index

EIA: Environmental Impact Assessment

EKE: Eddy Kinetic Energy

EKZNW / Ezemvelo: Ezemvelo KwaZulu-Natal Wildlife

EMP: Estuarine Management Plan

EPAs: Estuarine Protected Areas

EWR: Ecological Water Requirements

FADs: Fish Aggregation Devices

FAO: United Nations Food and Agriculture Organisation

FCOs: Fishery Control Officers

GDP: Gross Domestic Product

GPA: Global Programme of Action

HWM: High-water mark

I&APs: Interested and Affected Parties

ICM: Integrated Coastal Management

ICCMSBW: International Convention for the Control and Management of Ships' Ballast Water

IDC: Industrial Development Corporation

IDP: Integrated Development Plans

IDZ: Industrial Development Zones

IEH: Industrial Economic Hubs

IOCB: Indian Ocean Coastal Belt

IPBES: International Platform on Biodiversity and Ecosystem Services

IPCC: Intergovernmental Panel on Climate Change

IUCN: International Union for Conservation of Nature

KZN: KwaZulu-Natal

MARPOL: International Convention for the Prevention of Pollution from Ships

MEC: Member of the Executive Council (part of provincial government, under the provincial premier)

MKE: Mean Kinetic Energy

MLRA: Marine Living Resources Act (18 of 1998 and amendment Act 5 of 2014)

MMP: Mouth Management Plan

MPA: Marine Protected Areas

MPRDA: Mineral and Petroleum Resources Development Act (28 of 2002)

MSY - maximum sustainable yield

NBA – National Biodiversity Assessment

NDP – National Development Plan

NEMA: National Environmental Management Act (107 of 1998)

NEsMP: National Estuarine Monitoring Programme

NFEPA: National Freshwater Ecosystems Priority Areas

NGO: Non-governmental Organisation

NGP - New Growth Path

NMU: Nelson Mandela University

NSBA – National Spatial Biodiversity Assessment

NSRI: National Sea Rescue Institute

OCP: Organochlorine pesticide

ORI: Oceanographic Research Institute

OSCP: Oil Spill Contingency Plan

PAH: Polycyclic Aromatic Hydrocarbons

PASA: Petroleum Agency of South Africa

PCB: Polychlorinated Biphenyls

PCC – Provincial Coastal Committee

RBM: Richards Bay Minerals

SADC: Southern African Development Community

SAEON: South African Environmental Observation Network

SAM - Sustainable Aquaculture Management

SAMAC: Macadamias, South Africa

SAMSA: South African Maritime Safety Association

SANBI: South African National Biodiversity Institute

SAPPI: South African Pulp and Paper Industries Limited

SASA: South Africa Sugar Association

SDF: Spatial Development Framework

SDGs - Sustainable Development Goals

SEA: Strategic Environmental Assessment

SLP: Social and Labour Plans

spp.: Species

SSF: Small-Scale Fishery

SST: Sea Surface Temperature

SWIOFC: South-West Indian Ocean Fisheries Commission

SWSA: Strategic Water Source Areas of South Africa

TAE: Total Allowable Effort

TIKZN: Trade and Investment KwaZulu-Natal

TRAFFIC: The Wildlife Trade Monitoring Network

UFS: University of Free State

UNCTAD: United Nations Conference on Trade and Industry

UNFCC: United Nations Framework Convention on Climate Change

UNISA: University of South Africa

WESSA: Wildlife and Environmental Society of South Africa

WETREST: Centre for Wetland Research and Training

WITS: University of the Witwatersrand

WRC: Water Research Commission

WSSD: World Summit for Sustainable Development

***Previous departmental names**

1 INTRODUCTION & BACKGROUND

Zinkwazi Beach, KZN north coast
Photo: Kierran Allen

CHAPTER 1: INTRODUCTION & BACKGROUND

INTRODUCTION & BACKGROUND

Dr Bronwyn Goble (ORI)

INTRODUCTION

Worldwide, coasts are regarded as an important environment for human settlement, recreational activities and access to numerous resources. It is estimated that the average population density in coastal areas is approximately 80 persons per square kilometer, twice that of the world's average population density (Creel 2003). Predictions indicate that coastal populations will continue to grow, driven by natural population increase, as well as in-migration to coastal areas. A growing population puts the coastal environment under pressure from urban encroachment, pollution, water extraction and over-exploitation of resources. KwaZulu-Natal's (KZN's) coastal zone is no exception, being sought after for tourism, recreation, residential and industrial development. As such, it is important to understand the drivers of change and manage potential impacts on the KZN coastal environment.

The KZN Province, situated on the east coast of South Africa, is known as the garden province due to its green spaces and abundant plant and animal life. It is home to a cosmopolitan population with a wide mix of cultures. The KZN coast extends some 580 kms from the Mozambique border in the north, to the uMtavuna River bordering the Eastern Cape Province in the south; to the east it is bordered by the warm Indian Ocean. It is intersected by 76 of South Africa's 290 estuaries and is home to the St Lucia system, the largest and one of the most important systems in South Africa.

The coast is regarded as a national asset and legacy for future generations. This makes management measures of the utmost importance for the promotion of its current and future sustainable use (DEA 2014). To facilitate this management, the Integrated Coastal Management Act (ICMA), (24 of 2008 and Amendment 36 of 2014) outlines roles and functions for all spheres of government and places the onus on provincial authorities to report on the state of the coastal environment every four years, through the development of a State of the Coast Report (SOCR). The SOCR aims to provide decision-makers with current data and information about the state of the KZN coast. It should identify emerging problems and guide management actions such as conservation, development planning and legislation going forward, in support of sustainable targets for development.

STATE OF THE COAST REPORTING

The SOCR is therefore a statutory requirement intended to acquire practical knowledge on the current state of the coastal environment, the condition, trends, and pressures ecosystems are exposed to, with the aim of informing future management decisions. It should identify emerging problems and guide management actions such as conservation, development planning and legislation going forward. A key output of this initial SOCR is to identify data gaps and monitoring needs.

REPORTING FRAMEWORK

The relationships between human activities and the environment are quite complex. The DPSIR (Drivers- Pressures- State- Impact- Response) Framework (Figure 1.1, Table 1.1) represents a multidimensional and integrated theoretical framework for describing environmental challenges and their relationships with socioeconomic issues to create a strategy of management action. According to the DPSIR framework there is a chain of associations starting with 'Drivers' from human activities to 'Pressures' from emissions and waste, to physical, chemical and biological 'States' which 'Impact' on ecosystems and human health and leads to political action as 'Responses' (Kristensen 2004).

Figure 1.1. Drivers-Pressures-State-Impact-Response Framework

The DPSIR model provides indicators of environmental change and simplifies the contribution of the different scientific disciplines involved in biodiversity research. This conceptual framework provides a background that focuses on the interaction between various sectors in biosciences and the social sciences. Biosciences mainly deals with identifying and measuring pressures, state and changes in the state of biodiversity, while social sciences contribute to the understanding of driving forces of socio-economic impacts and of responses.

LIMITATIONS OF THE SOCR

The SOCR provides an overview of the current state considering historic trends. It is largely conducted as a desktop analysis using existing information regarding a range of coastal themes. However, critical indicators where data is lacking, may not be reported on, but can be identified as gaps. This process will ensure that areas that require monitoring for future reporting can be highlighted, and appropriate monitoring programmes put in place.

DEFINING THE COASTAL ZONE

The definition of the coastal zone differs between countries but is broadly described as that portion of the terrestrial environment influenced by being near the sea and that part of the marine environment influenced by being near land (Preston-Whyte and Tyson 1988). This can include rivers, estuaries, wetlands, coastal lakes, dunes, coastal forests, cities, farms coral reefs, and sediment or rocky substrates.

Table 1.1. DPSIR Framework

Component	Definition
Drivers	Drivers are the underlying forces which affect the environment. They generally reflect primary and secondary needs, such as the need for shelter, food and water. **Typical drivers include:** population (number, age structure, education levels, political stability), transport (persons, goods, road, water, air, off-road), energy use (energy factors per type of activity, fuel types, technology), power plants (types of plants, age structure, fuel types), industry (types of plants, age structure, resource types), refineries/mining (types of plant/mines, age structure), agriculture (number of animals, types of crops, stables, fertilisers), landfills (type, age), sewage systems (types), non-industrial sectors and land use (Kristensen 2004).
Pressures	Pressures result from human activities which are designed to meet human needs and are often consumptive or productive processes (DAEA&RD 2010). These include activities such as transportation or food production. **Pressures include**: use of resources, direct and indirect emissions (per driving force for numerous compounds) to air, water and soil, production of waste, production of noise, radiation, vibrations and hazards (risks).
State	State refers to the condition of the environment because of the 'pressure' applied in meeting the need (DAEA&RD 2010). **Changes in 'State' affect:** air quality (national, regional, local, urban, etc.), water quality (rivers, lakes, seas, coastal zones, groundwater), soil quality (national, local, natural areas, agricultural areas), ecosystems (biodiversity, vegetation, soil organisms, water organisms) and humans (health).
Impact	**Impacts refer to the consequences of chang**e in the state of the environment; changes may have environmental or economic 'impacts' on functioning of ecosystems and their life supporting abilities (Kristensen 2004). Impacts may be real or theoretical, and the likelihood of accordance varied
Response	**Responses refer to the actions taken** to mitigate or prevent negative environmental impacts. Reponses may include policies and legislation to regulate the pressures, management strategies to reduce environmental damage, rehabilitation plans for degraded environments or increased expenditure on environmental research (DAEA&RD 2010).

However, this definition is too general and absolute boundaries of the area are difficult to determine. In South Africa, the ICM Act defines the coastal zone as illustrated in Figure 1.2. Notification of these boundaries must be gazetted by the appropriate national or provincial authority or managed using by-laws in local municipalities. In terms of the ICM Act the coastal zone includes:

- Coastal Public Property (CPP)
- Coastal Protection Zone (CPZ)
- Coastal Access Land
- Coastal Waters
- Coastal Protected Areas
- Special Management Areas
- Coastal Management Lines (CMLs)

COASTAL PUBLIC PROPERTY (CPP)

This is land held by the State on behalf of the citizens of South Africa. It cannot be transferred, sold, attached or acquired and the State must ensure that CPP is used, managed, and conserved in the interests of all citizens and not a few individuals (Celliers *et al.* 2009). It includes:

- Coastal waters (including territorial waters, continental shelf, and estuaries).
- Land submerged by coastal waters.
- Islands in coastal waters (e.g., when a harbour is created).
- The seashore (between the Low-Water Mark (LWM) and the High-Water Mark (HWM)).
- Admiralty Reserve owned by the State (including government reserve, beach reserve and coastal forest reserve).
- Any other State land designated CPP by the Minister.
- Any natural resources including within the Exclusive Economic Zone (EEZ) and harbour.
- CPP does not include assets of infrastructure such as harbours.

The Minister is the responsible person for gazetting CPP in the Government Gazette.

COASTAL PROTECTION ZONE (CPZ)

The HWM is defined as the highest line reached by coastal waters but does not include any line reached by abnormal weather conditions. It is important as it is used as a marker for several other coastal definitions.

The CPZ refers to a strip of land that is:

- 100 m inland of the HWM: In urban areas

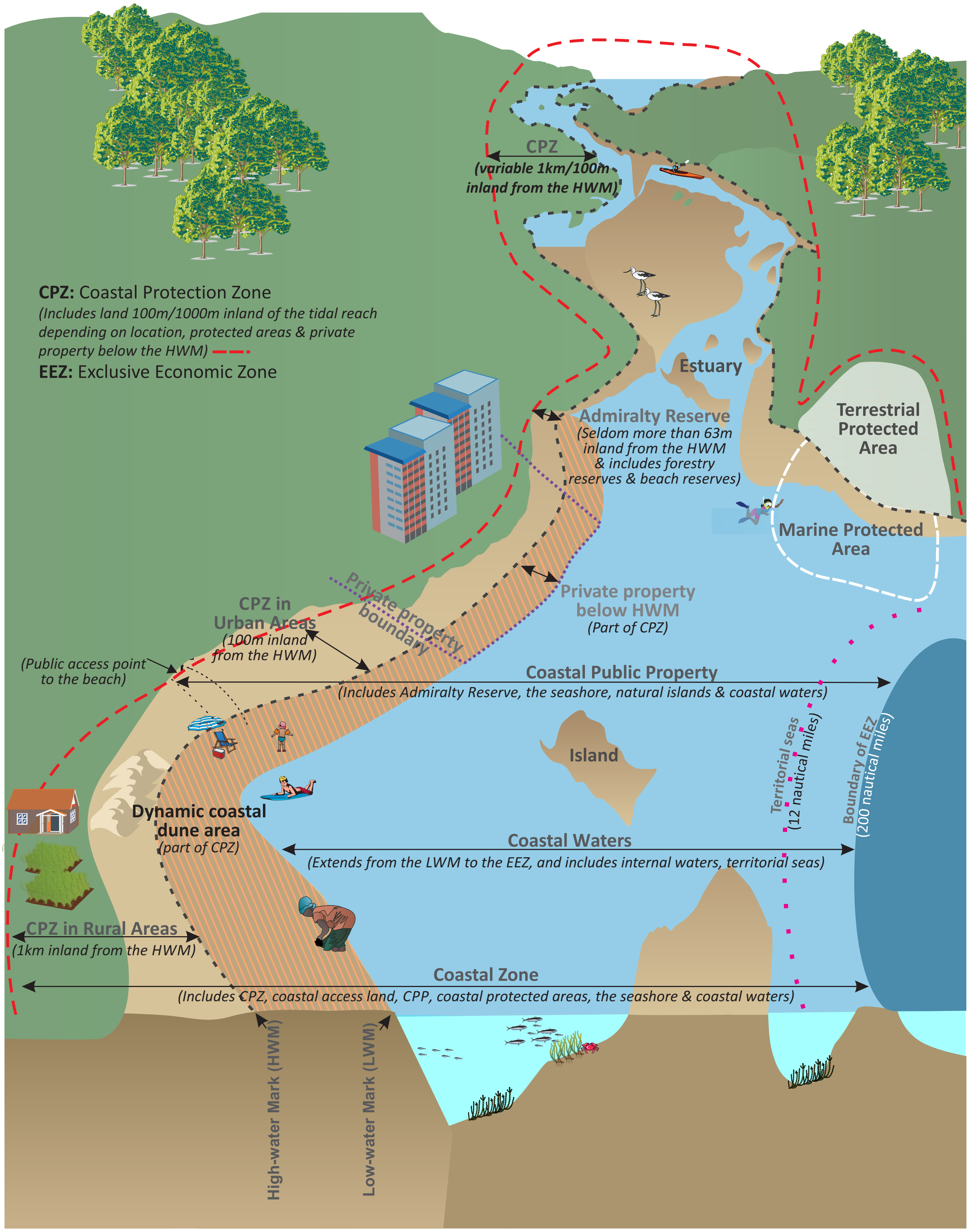


Figure 1.2. Summary of the Coastal Zone (From: KZN EDTEA 2019)

(zoned residential, commercial, or public open space).
- 1000 m inland of the HWM: In rural (undeveloped, agricultural land, undetermined) areas.
- A Sensitive coastal area (e.g., Pennington and Umtamvuna Sensitive Coastal areas) (DEA and Royal Haskoning DHV 2017).
- A part of the littoral active zone not included in CPP.
- A wetland, lake, or lagoon within 1000 m of the HWM.
- Part of the seashore that is not CPP but is below the HWM.
- Admiralty Reserve that is not CPP.
- Land that would be inundated by a 1:50 year flood or storm event.

The CPZ is declared by the MEC and gazetted in the Provincial Gazette. It is meant to protect the ecology, character, economic, social, and aesthetic value of CPP (DEA and Royal Haskoning DHV 2017).

COASTAL ACCESS LAND

This is land meant to ensure that people have access to CPP. In South Africa, the provision of coastal access is a legal requirement in terms of the ICM Act. The Act stipulates that municipalities are responsible for setting aside areas of land through which members of the public will be able to access the coast. Municipalities manage these areas using by-laws, and need to maintain the land, promote access, provide appropriate amenities, prevent environmental degradation, and report progress to the MEC. Coastal Access needs to be indicated as access land on municipal zoning schemes, Integrated Development Plans (IDPs) and Spatial Development Frameworks (SDFs). The KZN Department of Economic Development, Tourism and Environmental Affairs (EDTEA) has produced a geospatial tool to support decision-making through improved understanding of coastal access localities and quality (EDTEA 2019).

COASTAL WATERS

This includes marine waters that are part of South Africa's internal and territorial waters and estuaries.

COASTAL PROTECTED AREAS

The National Environmental Management Protected Areas Act (57 of 2003) provides for the conservation of areas which represent biological diversity, natural landscapes and seascapes and which are included in the national, provincial or local protected areas register. This includes special nature reserves, national parks, marine protected areas (MPAs) nature reserves and protected environments. These areas are managed according to national norms and standards (Celliers *et al.* 2009).

SPECIAL MANAGEMENT AREAS

These are declared by the Minister, based on the environmental, socioeconomic or cultural importance and after consultation with the interested and affected parties (I&APs) and must be gazetted. The Minister may prohibit certain activities from taking place and appoint a manager to manage this area.

COASTAL MANAGEMENT LINES (CMLS)

(Previously Setback lines)

This term was changed from setback lines to Coastal Management Lines (CMLs) in the amended version of the ICM Act to avoid confusion and distinguish it from the EIA development setback lines.

CMLs are meant to protect:
- Coastal public property, e.g., beach amenities.
- Coastal private property, e.g., residences and business property.
- Public safety in case of extreme weather events.
- The coastal protection zone.
- The aesthetics of the coastal zone.

CMLs can be created for various reasons and there may be more than one line. This is a provincial responsibility, but the MEC can only declare such a line in consultation with municipalities.

READING THIS REPORT

This report covers a range of ecosystems and human activities important to understanding the state of the KZN coast. It is important to remember that the coastal zone is an integrated environment and no one section can be read in isolation. Table 1.2 provides an overview of the sections that have the greatest cross-referencing, highlighting which sections to read with your section of interest. Within each section, the icons relating to sections that affect or cross-reference with your section of interest are again highlighted.

Table 1.2. Cross-referencing of sections in this State of the KZN Coast Report

Sphere	Topic		Cross-reference with the following sections:
Overarching Drivers	2.1 Blue Economy	The Blue Economy	Human Settlements, Coastal Access, Ports & Shipping, Tourism, Aquaculture, Agriculture, Manufacturing & Industry, Commercial fishing, Coastal Dune Mining, Offshore Mining, Oil & Gas Exploration, Coastal Management
	2.2 Human Settlements	Human Settlements	Pollution, Climate Change, Extreme Events, Coastal Access, Small-scale Fisheries, Recreational Fishing, Boat-based Activities, Tourism, Agriculture, Manufacturing & Industry, Sand Mining, Coastal Management
	2.3 Pollution	Pollution	Human Settlements, Coastal lakes, Estuaries, Soft Sediments, Ports & Shipping, Aquaculture, Agriculture, Manufacturing & Industry, Sand Mining, Oil & Gas Exploration, Coastal Management
Climate Variability	3.1 Climate Change	Climate Change	Oceanographic Events, Sandy Shores, Estuaries, Tourism, Coastal Management, Marine Protected Areas
	3.2 Extreme Events	Extreme Events	Oceanographic Events, Sandy Shores, Estuaries, Tourism, Coastal Management, Marine Protected Areas
	3.3 Oceanographic Events	Oceanographic Events	Climate Change, Extreme Events, Pelagic Environment, Small-scale fisheries, Recreational fishing, Commercial fishing
	4.1 Sandy Shores	Sandy Shores	Estuaries, Coastal Vegetation, Rocky Reefs

Sphere	Topic		Cross-reference with the following sections:
Coastal Environment	4.2 Swamp Forests	Swamp Forests	Human Settlements, Pollution, Climate Change, Estuaries, Coastal Management
	4.3 Rocky Shores	Rocky Shores	Climate Change, Sandy Shores, Coral Reefs, Rocky Reefs, Small-scale Fisheries, Coastal Management
	4.4 Coastal Lakes	Coastal Lakes	Pollution, Swamp Forests, Wetlands, Submerged macrophytes
	4.5 Wetlands	Wetlands	Sandy Shores, Swamp Forests, Coastal Lakes, Estuaries
	4.6 Coastal Vegetation	Coastal Vegetation	Human Settlements, Pollution, Climate Change, Agriculture, Coastal Dune Mining, Coastal Management
Estuarine Environment	5.1 Estuaries	Estuaries	Pollution, Swamp Forests, Wetlands, Mangroves, Submerged macrophytes, Recreational Fishing, Ports & Shipping, Sand Mining, Coastal Management, Marine Protected Areas
	5.2 Mangroves	Mangroves	Swamp Forests, Estuaries, Submerged macrophytes
	5.3 Submerged Macrophytes	Submerged macrophytes	Human Settlements, Estuaries, Mangroves, Coastal Management
Marine Environment	6.1 Coral Reefs	Coral Reefs	Pollution, Rocky Shores, Rocky Reefs, Coastal Management, Marine Protected Areas
	6.2 Rocky Reefs	Rocky Reefs	Pollution, Rocky Shores, Coral Reefs, Coastal Management
	6.3 Soft Sediments	Soft Sediments	Pollution, Oceanographic Events, Sandy Shores, Estuaries, Commercial fishing, Sand Mining
	6.4 Pelagic Environment	Pelagic Environment	Pollution, Climate Change, Oceanographic Events, Small-scale Fisheries, Recreational Fishing, Boat-based Activities, Ports & Shipping
Human Environment	7.1 Coastal Access	Coastal Access	Human Settlements, Small-scale Fisheries, Commercial fishing, Coastal Management
	7.2 Small-scale Fisheries	Small-scale Fisheries	Recreational Fishing, Commercial fishing, Coastal Management, Marine Protected Areas

Sphere	Topic		Cross-reference with the following sections:
Human Environment	7.3 Recreational Fishing	Recreational Fishing	Climate Change; Small-scale Fisheries; Commercial fishing; Coastal Management; Marine Protected Areas
	7.4 Boat-based Activities	Boat-based Activities	Recreational Fishing; Commercial fishing; Coastal Management; Marine Protected Areas
Economic Environment	8.1 Ports & Shipping	Ports & Shipping	The Blue Economy; Pollution; Climate Change; Commercial fishing; Coastal Dune Mining
	8.2 Tourism	Tourism	The Blue Economy; Human Settlements; Pollution; Climate Change; Coastal Access; Coastal Management; Marine Protected Areas
	8.3 Aquaculture	Aquaculture	The Blue Economy; Human Settlements; Pollution; Climate Change
	8.4 Agriculture	Agriculture	Human Settlements; Pollution; Estuaries
	8.5 Manufacturing & Industry	Manufacturing & Industry	The Blue Economy; Human Settlements; Pollution; Coastal Vegetation; Estuaries; Coastal Management
	8.6 Commercial Fishing	Commercial fishing	The Blue Economy; Climate Change; Pelagic Environment; Small-scale Fisheries; Recreational Fishing; Manufacturing & Industry
	8.7 Coastal Dune Mining	Coastal Dune Mining	The Blue Economy; Sandy Shores; Sand Mining; Coastal Management
	8.8 Sand Mining	Sand Mining	Climate Change; Sandy Shores; Estuaries; Soft Sediments; Coastal Dune Mining
	8.9 Offshore Mining	Offshore Mining	The Blue Economy; Soft Sediments; Coastal Dune Mining; Marine Protected Areas
	8.10 Oil & Gas Exploration	Oil & Gas Exploration	The Blue Economy; Soft Sediments; Offshore Mining; Marine Protected Areas
Governance Environment	9.1 Coastal Management	Coastal Management	The Blue Economy; Human Settlements; Pollution; Climate Change; Coastal Access; Small-scale Fisheries; Recreational Fishing; Coastal Dune Mining; Sand Mining; Marine Protected Areas
	9.2 Marine Protected Areas	Marine Protected Areas	Small-scale Fisheries; Recreational Fishing; Commercial fishing; Coastal Management

2 OVERARCHING DRIVERS

The Port of Durban
Photo: Kierran Allen

CHAPTER 2: OVERARCHING DRIVERS

2.1 The Blue Economy
2.2 Human Settlements
2.3 Pollution

2.1 THE BLUE ECONOMY

Rudy van der Elst and Dr Bronwyn Goble (ORI)

INTRODUCTION

Following the 2008 economic crisis, which resulted in widespread recession, many countries considered the marine environment a potential panacea for a global economic revival. Collectively, this new frontier was named the 'Blue Economy' and it identified a range of new and existing sectors that could be expanded to deliver a better return. Despite the enthusiasm for the Blue Economy, there is no consensus on its definition, or its overall scope. Some of the major international stakeholders' definitions are quite varied, although all focus on the aquatic environment and stewardship.

The range of definitions of the 'Blue Economy' provides a good basis on which to forge an approach for KZN and South Africa. A strong feature of these foregoing descriptors is the dichotomy of approach, the exploitation of ocean resources (economic growth) on the one hand, matched by the concomitant wise use and sustainability of the ocean ecosystems (ecological economics) on the other. This is a visionary approach and will require a trade-off between Gross Domestic Product (GDP) and environmental quality, (such as the 17 Sustainable Development Goals) resulting in long-term stability.

Without warning, the world was gripped by the COVID-19 pandemic which necessitated a massive shut down of societies around the world. Some

International Blue Economy definitions:

"All economic activities related to oceans, seas and coasts; sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystem. **(World Bank, 2017)**

"...an emerging concept which encourages better stewardship of our ocean or 'blue resources'." **(Commonwealth of Nations, 2021)**

"...blue economy includes economic benefits that may not be marketed, such as carbon storage, coastal protection, cultural values and biodiversity." **(Bertazzo, 2018)**

"...sustainable blue economy as one that provides not just economic, but social benefits for present and future generations.

A blue economy recognizes marine ecosystems as its natural capital and protects and maintains them accordingly. It also aspires for social and economic stability through the use of clean technology and renewable energy. " **(WWF, 2020).**

"...the blue economy challenges us to realize that the sustainable management of ocean resources will require collaboration across borders and sectors through a variety of partnerships, and on a scale that has not been previously achieved. This is a tall order, particularly for Small Island Developing States (SIDS) and Least Developed Countries (LDCs) who face significant limitations." **(United Nations, 2021).**

sectors were especially impacted, such as tourism and associated transport. The drop in South Africa's national GDP has been set at 51%, dwarfing any prospect of a flourishing Blue Economy. Yet, the enormous socioeconomic challenges that COVID-19 presents highlights the potential extra value of forging a new Blue Economy.

DRIVERS

In consideration of the Blue Economy, the main driver for current and proposed future activities is economic, linked to growing the country's GDP, employment creation and improvement of livelihoods. Specifically blue economic resources are important for the improvement of food supply for much of the country's population. Significantly, under the South Africa National Development Plan, *Operation Phakisa* was launched to facilitate employment and economic stimulation; this embodies aspects of the Blue Economy.

The marine and coastal areas of KZN are rich in biodiversity which can and do sustain such 'blue' economic activities. For example, fisheries and biotechnology are directly dependent on the prevailing state of biodiversity. Biodiversity also provides potential indirect benefits, through activities such as scuba diving, coastal tourism, and sense of place. Additionally, there are non-living resources, including minerals which hold blue economic value, and features which are directly available to society, such as ecosystem services, maritime transport and climate protection, which add significant value.

Importantly, the effects of a global market have given rise to a near limitless demand for marine transport, driving the industry to grow and develop its blue economic potential. The scale of this is spectacular, with thousands of vessels active at any time, transporting liquids, gases and solids. South Africa, especially KZN, features strongly in this plethora of shipping by providing port facilities, with Durban and Richards Bay being two of the most active ports on the continent (Section 8.1).

PRESSURES

The development of the blue economy will result in increased pressure on resources such as the provision of energy and fresh water. This is excoriated by a growing population in need of these resources, which may require the consideration and development of alternative technologies for energy and fresh water. Coupled with this is the potential increase in waste discharged into the marine environment. A total estimate of 555 000 m^3 of waste is discharged through seven outfalls in KZN coastal waters daily (Section 2.3). While the process is subject to permit conditions to ensure the discharge is within the assimilative capacity, there are several challenges that lead to extreme pressure on the receiving environment, including poorly maintained and aging infrastructure.

In addition, marine debris presents a growing problem. While much of it originates from land-based sources, the high percentage of plastics causes concern. Recent findings on the long-term impact of microplastics have revealed it's biological, as well as high economic cost.

STATE

There are several activities currently taking place that contribute to the blue economy of KZN, these are detailed in this report. Important aspects of their blue economic benefits are highlighted in this Chapter.

Aerial view of the economic hub of Durban Harbour
Photo: Kierran Allen

TOURISM
Tourism has a wide economic footprint, with a diversity of sectors involved in servicing the supply chain for the tourism industry. Tourism occurs across a range of sectors, including recreation and leisure, fishing, diving, cultural, whale watching, cage diving, sports tourism, passenger cruising and eco-tourism. While tourism often provides the only source of essential revenue to a high-dependence region, funds can dry up overnight, placing the province at serious socioeconomic risk. Crime, shark attacks and the viral pandemic all pose such threats. These should be identified and risk-assessed to avoid major economic and social problems.

AQUACULTURE
Globally, aquaculture continues to grow, driven by an insatiable demand for seafood, so that in 2018 the total production for the first time exceeded the total world's wild caught catch (FAO 2020). The diversity of species implicated, the number of countries and the value chains continue to contribute to the economies and food security in many parts of the world. However, only 2% of the global aquaculture production (FAO 2020) was derived from Africa, of which a mere 0.4% (5 418 mt) was produced in South Africa (Section 8.3). As demand for marine ornamental fishes grow and wild caught specimens are restricted to permit conditions, there has been an increased effort to culture some of the rarer species. While this proved successful in terms of breeding, these projects failed because of the limitations of transport to international clients (Bok 1998).

FISHERIES
Commercial fisheries activities are underpinned by food-security, the economics of which are variable and sensitive to currency fluctuations. Although fisheries resources in KZN are modest compared to the cooler Cape waters, they remain an important feature of the KZN environment. The different types of commercial

fishing operations reported from KZN include large, harbour-based trawlers; small beach seine-net operations; small boat-based hook and line fishing; and hand picking of oysters in the intertidal/shallow subtidal zone (Section 8.6). Closely linked are the small-scale fisheries, which allows for the harvesting of marine resources for their own use (Section 7.2).

The majority harvest their catches from the shore where intertidal invertebrates represent the most accessible source of food. Linefishing and traditional fish kraals, as in Kosi lakes, make up the total annual catch of around 150 tons per year.

Lastly, the KZN fisheries resources support a veritable mecca for recreational fishing, driven largely by the rich species diversity and frequent seasonal peaks in abundance (Section 7.3).

MINING

Large sections of the KZN north coast comprise heavy mineral-bearing sands; mining these contributes significantly to the GDP of KZN and South Africa (Section 8.7). While there have been several changes in the mining sector, it remains the second largest employer in South Africa (after agriculture).

Mining exerts added environmental pressures and there needs to be a balance between the revenue generated and the potential environmental impact, including the socioeconomic effect on communities (Section 8.7).

In most cases, the status of the resources has not been established, except for the heavy metals vested in the dune systems. Each mineral resource must be assessed, and the economic value realistically rated against its environmental impact – so that short term benefits do not result in long-term environmental impacts.

SAND MINING

Development activities bring with it the need for building material which results in increased sand (river) mining. Rivers deposit quantities of sand in their estuarine areas, providing an important feeder system to inshore sand budgets and associated ecosystems. However, sands are harvested by legally permitted and illegal operators, at a cost to the integrity of coastal and estuarine environments. A total of 76 estuaries are implicated, giving a total estimated yield of 750 000 m^3. The depletion of sand along the coast has been costed at R1 million per km for loss of protection, erosion and biological control, while in popular beach tourism zones, the loss can reach more than R110 million per km (Goble 2014; Section 8.8).

OIL AND GAS

Parts of the seabed off the Thukela Bank has been identified as holding potential oil and gas reserves and are rich in heavy metals. A further source of valuable minerals is found in deep oceans, which requires specialised skills and equipment for extraction. The future demand for petroleum products is uncertain, considering the low market price and competition with green energy products.

NON-CONSUMPTIVE RECREATIONAL ACTIVITES

The unique coastal and marine life of KZN drives exploration and interest. Approximately 14 850 non-consumptive launches have been recorded from KZN launch sites with activities such as scuba diving, pleasure trips, shark diving and whale/dolphin watching being highlights (Section 7.4). These activities generate substantial 'blue' revenue, much of it dispersed at the local level. Sea turtles, dolphins, whales and large sharks all attract tourists in large numbers, creating a host of opportunities for tourism, including night-time turtle tours, diving with tiger sharks and whale watching cruises.

BIOTECHNOLOGY

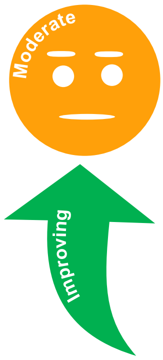
South Africa is one of the most biologically diverse countries in the world, and this also applies to KZN. Many marine invertebrate organisms, their associated microbial communities as well as marine algae contain unique compounds that have potentially valuable properties for use in pharmaceuticals and cosmetics, such as industrial enzymes, food flavours, fragrances, emulsifiers, oleoresins, extracts and essential oils. The process of discovery, development and patenting is lengthy and expensive, but the potential benefits of a new drug can be enormous. Historically there was no control over the bioprospecting for natural products, which saw the 'loss' of several potentially valuable products. The 2002 Biodiversity Act sets out several permit conditions which controls prospecting for natural products and specifies the sharing of proceeds. By mid-2018, 85 permits had been issued in South Africa, more than 18 of these derived from marine natural products (from sponges and tube worms) which have already been patented for their anti-cancer activity.

Bioprospecting requires long-term commitment, but the potential benefits, both to human health and the economy, are huge.

IMPACT

Developing the blue economy comes with a range of potential impacts on the marine and coastal environments; thus 'tapping' into the blue economy needs to consider the cost-benefit and sustainability of any such development.

RESPONSE



Priorities of *Operation Phakisa: the 2014 ocean's economy programme*, include maritime transport and marine manufacturing; offshore oil and gas exploration; aquaculture; marine protection services and ocean governance; coastal and marine tourism and small harbour development. Initiatives that have been implemented since its inception include the establishment of the South African International Maritime Institute, a research, innovation and knowledge management hub (in Port Elizabeth), refurbishment and upgrades at various ports, work on an offshore oil and gas supply base in Saldanha and two new offshore supply vessels. There are possibilities in terms of increasing the Blue Economy benefits in KZN, but these require vigilance to avoid environmental damage.

Annual Sardine Run - Sardine net brought in at Durban
Photo: ORI

In South Africa, considerations need to be given to cleaner alternative technologies for energy. While numerous land-based systems have been developed, the marine environment is increasingly seen as a potential source of sustainable clean energy. Several such systems are operational around the world, including tidal flow, wind generation and wave energy. No such systems are found in KZN, especially as there is only a 2 m tidal range and no shallow offshore banks. However, preliminary studies have indicated that it may still be viable in the future.

Equally important is the consideration of strained fresh water supplies, which are likely to be exacerbated with climate change. The experience of water shortages in Cape Town has accentuated this pressure, especially as it impacts on other blue economy generators such as tourism. The potential to desalinate sea water for use on land can be a viable option, albeit expensive.

Several international studies have attempted to put a value on the benefits generated by the marine and coastal environment for humanity. In doing so, eight different ecosystems were identified as having distinct properties that benefit society. Many of the goods and services are non-market related, so that calculating their economic contribution to society is difficult, but clearly important. Based on large scale regional estimates it was projected that in 2007, the value of the goods and services provided by the KZN marine and coastal environment was R100 billion (van der Elst and Goble 2014).

The measure of success of implementing the Blue Economy cannot only be a percentage change in GDP but needs to be assessed in terms of other environmental and social factors. For example, offshore mining may well increase the GDP, but if pollution levels increase, then the mining should be modified or terminated. In effect, it recognises that GDP growth is never limitless but is dependent on the limits of the natural resource base.

Data Requirements

The blue economy is made up of a wide range of sectors that draw from the marine and coastal environments to contribute to GDP and employment generation. Thus, information pertaining to each of these sectors builds an overview and understanding as to the blue economy. Importantly, *Operation Phakisa* promotes the blue economy as a growth area, thus monitoring data pertaining to effected ecosystems is critical. This allows for better management and sustainability of the 'new frontier –

2.2 HUMAN SETTLEMENTS

Dr Bronwyn Goble, Marilyn Bodasing and Rudy van der Elst (ORI)

INTRODUCTION

Along the South African coast, early coastal human settlements can be traced back some 160 000 years through archaeological sites (Marean 2010). In KZN, for example, shell middens are found at coastal sites at the Bluff (Schoute-Vanneck 1958), Ingane River (Schoute-Vanneck and Walsh 1959) and Umhlanga (Beater and Maud 1963). KZN archaeological sites indicate Middle Stone Age, Late Stone Age and Iron Age occupation (Le Roux 2014); with many of these sites inside coastal caves, used for shelter and access to natural resources (Marean 2010, Horwitz *et al*. 1991).

Over many centuries, alluvial floodplains and the availability of water influenced the selection of coastal sites for early agriculture, while the advent of boats, ships, commerce, trade and tourism further influenced settlement along the coast.

Internationally, coastal migration and development have resulted in an average population density of 112 people/km² at the coast compared to an average overall density of 44 people/km² (Small and Nicholls 2003).

Given the high desirability of residing at the coast, it follows that equitable planning is important to prevent uncontrolled proliferation of human settlements which impact on natural resources, environmental quality and sustainability (DEA&DP 2018). South Africa's Constitution (1996) safeguards one's rights to a healthy and protected environment (Section 24), adequate housing (Section 26), food and water (Section 27). The latter two fall within the Government's human settlement portfolio, while sustainable human settlements relate to environmental protection and the right to a healthy environment (Stats SA 2016b).

DRIVERS

Population growth and in-migration are both major factors that continue to drive the growth of urban human settlements. These in turn shape the landscape of the built environment (DEA 2012) and are an important component of social and economic systems. The IUCN (2007) succinctly summarises the situation: "Because of the economic benefits that accrue from access to the coast, ocean navigation, coastal fisheries, tourism and recreation, human settlements are often more concentrated in the coastal zone than elsewhere".

Increased migration to urban centres to escape income inequality and poverty in rural areas results in an increased rate of urbanisation;

hence an increased need for basic services such as housing, water, electricity, sewerage, and waste removal, all of which put pressure on the receiving environment. A significant and growing proportion of human settlements can be found in urban centres; with eight of the world's ten biggest cities being coastal (UN Atlas of the Oceans 2016). Populations within the urban areas of developing counties are growing at a rate of 2.4% annually, double that of the global population growth rate (DEA 2012).

In South Africa, close to 62% of the population is urbanised (2019), up from 53% in 1996 (Stats SA 2016a, 2020). As with the rest of the developing world, this rapid urban growth has placed significant pressure on natural coastal systems (DEA 2016). Coastal urban areas generally offer better access to infrastructure, natural resources such as water and land, and lifestyle elements such as beaches (EDTEA 2017). In KZN, coastal urban or metropolitan areas are characterised by extensive peri-urban developments as relics of apartheid. Increasingly, these areas are expanding through informal settlements, mostly highly populated and located in areas that are inappropriate for human settlement, such as unstable soils, wetlands, and flood risk areas (DEA 2012). Inadequate services to these areas, especially water and sanitation, have a direct impact on the environmental quality of the coast.

PRESSURES

As population density and economic activity in the coastal zone increases, pressures on coastal ecosystems rise. Among the most important pressures are habitat conversion, land cover change, increased pollutant loads, and the introduction of invasive species. These pressures can lead to a loss of biodiversity, new diseases, harmful algal blooms, siltation, reduced water quality, and a threat to human health through toxins in fish and shellfish and pathogens such as cholera and hepatitis A residing in polluted water (United Nations 2018).

The Millennium Ecosystem Assessment stated that coastal ecosystems are among the most productive in the world, but the most threatened by human settlement (Agardy and Alder 2005). It is estimated that about one third of coastal mangrove forests and one fifth of coral reefs have already been lost (UNEP 2006) while many fish populations have declined (ORI 2013, 2015). In addition, estuaries and wetlands are under increased pressure from domestic and industrial waste (McGranahan *et al.* 2007, Tibbets 2002).

The influx of tourists into small coastal towns during the holidays creates seasonal recreational hubs which boost the local economy. However, this results in seasonal pressures on the receiving environment and service delivery. Overall, these centres are challenging to plan for and manage demand. It becomes increasingly more difficult for the coastal ecosystems to adapt to the accumulating collective demands and damage from coastal communities and markets (Agardy and Alder 2005).

STATE

SETTLEMENT

In KZN, as with much of South Africa, settlement patterns have been profoundly shaped by former apartheid policies and planning (DAEA&RD 2010). Apartheid resulted in the mass resettlement of black South Africans into 'homeland' areas, some of which were in the KZN coastal zone, but few right on the coast (Figure 2.1) (DAEA&RD 2010). Since 1994, the constraints on settlement were removed, so that the demography of coastal people has progressively changed, largely through migration and urbanisation of homeland areas.

HOUSING

Under apartheid, planned townships were constructed on the fringes of towns and cities. The services were often basic, yet frequently superior to those found in the informal residential areas that have subsequently grown within and around them. Ndegwa *et al.* (2004) suggest that migrants from poor areas tend to occupy these peripheral poorer residential areas, commonly called shacks in informal settlements.

There are several different settlement types in KZN, ranging from largely populated urban areas to sparsely populated rural areas (DAEA&RD 2010). It is estimated that approximately 559 302 (14,3%) households reside in RDP/government-subsidised dwellings (Stats SA 2016a). According to Statistics South Africa's Mid-Year Population Survey (Stats SA 2020), 81,9% of South African households lived in formal dwellings, 12,7% in informal dwellings (13,7% in KZN), and 5,1% in traditional dwellings in 2019. Access to services has increased since 2002 but the in-migration into coastal towns and cities has resulted in a constant backlog, putting more strain on existing infrastructure.

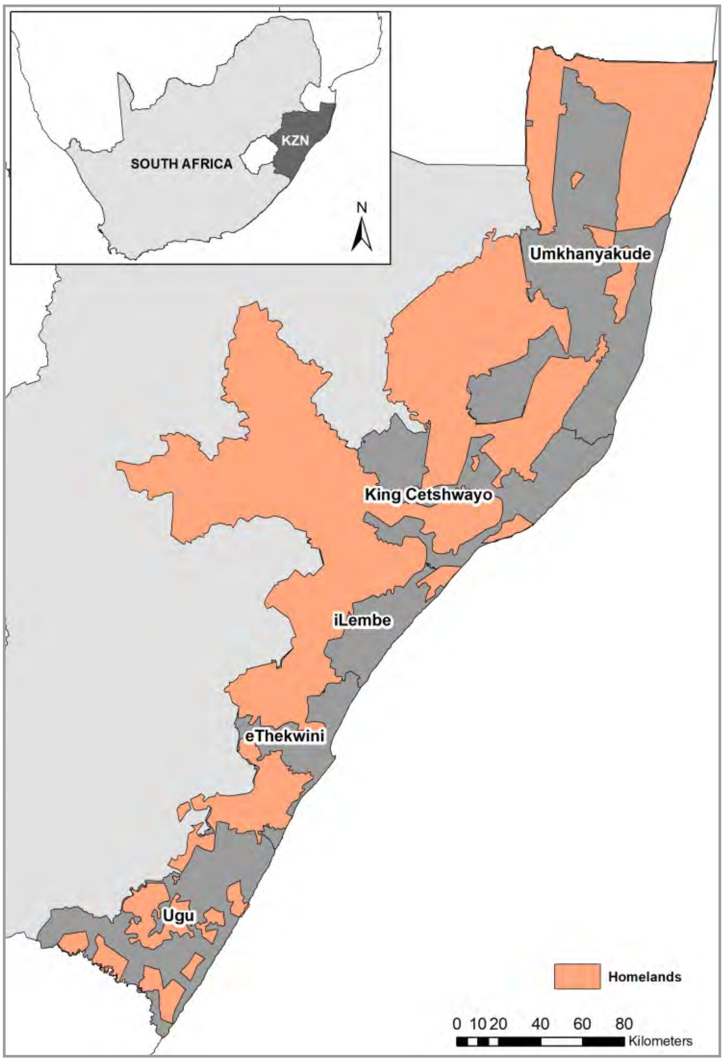


Figure 2.1: Homeland areas in KZN

POPULATION

KwaZulu-Natal is the second most densely populated province, with an average population density of 117.2 people/km^2. Significantly, many coastal areas have densities far higher than the provincial average; eThekwini, uMhlathuze, KwaDukuza, uMdoni, Ray Nkonyeni and Mandeni municipal areas are among the top twenty-five most densely populated municipalities in South Africa.

The eThekwini Metropolitan Municipality makes up a third of the KZN population (3.7 million people); it is only the third largest growing population, compared to other districts in the province. Notably, the coastal municipality of KwaDukuza has experienced the highest growth rate of 4.1% (Figure 2.2). Other coastal areas that have seen a high increase in coastal population include Mtubatuba (3.2%), uMhlathuze (2.8%) and Ray Nkonyeni (2.7%). Population growth in urban areas is usually largely driven by in-migration, with people seeking employment opportunities, education and access to health care (DEA 2012).

Ethekwini, followed by uMgungundlovu, and then Ugu have received the highest level of migrants (Stats SA 2006). KZN also received the second highest number of immigrant workers from neighbouring countries (18.4%) (Stats SA 2006).

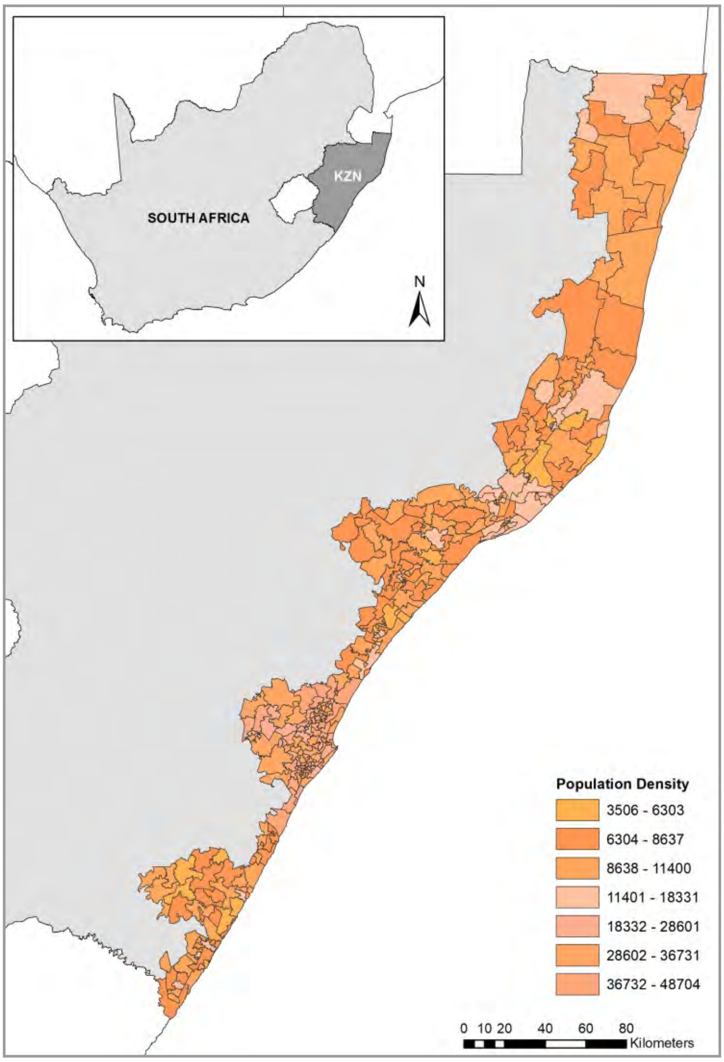


Figure 2.2: Population Density for KZN Coastal Districts

For urban planners, a high population density area results in a more compact plan and lower resource inputs. However, as populations grow, so too does the need for land and associated resources. This can lead to a loss of productive agricultural land and biodiverse areas through clearing for housing. Additionally, pressure is placed on natural resources to meet demands for water, food and waste assimilation.

The eThekwini municipality, with Tongaat Hulett, developed integrated housing such as the Cornubia development, which balance subsidised housing with 50 000 mixed-income, mixed-density houses (planned up to 2026) and industry (Tongaat Hulett Developments, 2018). Restricting further urban sprawl and investing in development for mixed-use residential and commercial use will bring people closer to economic opportunities and services. Increasing population density without increased waste removal, water, transport and energy services, as well as facilities such as suitable public spaces, will have adverse effects on the quality of life, human health and the environment (Tongaat Hulett 2018). Opportunities in this development exist for waste services, water and sanitation services to be rolled out more efficiently. In addition, there are opportunities to minimise waste generation through raising awareness about means to reduce wasteful consumption, re-use resources and recycle (EDTEA 2017).

IMPACT

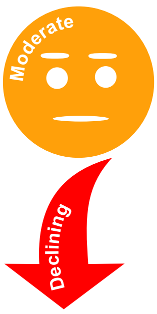
The quality and function of human settlements relates largely to the delivery of services, such as water, sanitation, electricity, schools, healthcare, recreational facilities, and public open space in formally planned areas (DAEA&RD 2010, EDTEA 2017). The size and type of the settlement and the provision of these services impacts the surrounding natural environment. KZN has high levels of poverty, especially in informal settlements, with reduced access to sanitation and waste management services, resulting in untreated waste and litter entering rivers and streams and ultimately into coastal environments (Du Plessis and Landman 2002).

This combination of mixed human settlement with industry needs to be carefully planned and monitored to avoid industrial accidents and the associated hazards, as occurred in the recent fire in July 2021. Toxins from a chemical fire and washout from attempts to douse the fire affected local people, closed beaches and killed

Sprawling informal settlements grow around industry south of Durban
Photo: ORI

numerous fish, birds, amphibians and other coastal animals, and the environment will take many years to recover (Guy 2021).

RESPONSE



While the quality of life has improved considerably since 1994, with most people now having access to shelter, water, sanitation and electricity, concerns remain regarding the sustainability of the settlements that have been created (Du Plessis and Landman 2002). Impacts and long-term effects of poor spatial planning are well documented, and there are several legislative frameworks in place to govern land management and ensure better long-term planning. Many of these are aimed at addressing historic land management practices and redressing past errors and include *the Development Facilitation Act (1994), the Local Government Transition Act (1993), Spatial Planning and Land Use Management Act (2013)* and *the KZN Development and Planning Act (1998).*

While legislation is focused on the provision of housing, water and sanitation, there needs to be careful management of the process to ensure impacts on the natural environment are minimised. This is primarily addressed through *the NEMA (Act 107 of 1998)*, which requires environmental authorisation for new developments and changes in land use. Additional regulations for development and planning within the coastal zone are outlined by the ICM Act (Section 9.1).

Uncontrolled coastal settlement is likely to damage sensitive and important ecosystems and disrupt ecosystem services. It is imperative for urban planners to consider mitigation, migration, and modification. Planners should consider the potential impact of sea-level rise and intense weather events, such as storm surges, on infrastructure development and investment in coastal areas. The risks to human settlements could be reduced by encouraging a move away from the most risk-prone coastal locations (McGranahan *et al*. 2007).

Municipalities should prepare for disaster by addressing environmental health issues such as improved water, sanitation, waste disposal and drainage systems. Land issues need to be resolved where people settle on land susceptible to flooding, or to seaward hazards such as sea-level rise and tropical storms. An ecosystem-based adaptation approach ensures that long-term planning for coastal areas incorporates the relevant climate information (DEA 2016) and that a risk-averse approach to planning is taken to cope with the expected migration of communities into the high-risk coastal areas.

Regulation of development, including buffer zones and coastal management lines ensure forward planning for coastal settlements (Mukheibir and Ziervogel 2006). Well-planned and serviced settlement has the potential to mitigate the environmental impacts that are generated by informal settlements, because the services can be delivered more economically. Going forward, the most important environmental threat to settlements in South Africa is water scarcity, which planners and managers will have to address.

Data Requirements
Human settlements and population are critical components of the natural coastal environment. Statistics SA undertakes a census which provides much of the information needed and presented in this section.

2.3 POLLUTION

Steven Weerts and Susan Taljaard (CSIR)

INTRODUCTION

Pollution is a crosscutting pressure impacting coastal habitats and resources across the world and the KZN coast is no exception. Coastal environments are intrinsically connected by flows of water and sediment. This connectivity underpins ecosystem function and the goods and services we derive from our coast, but also facilitates the introduction of pollutants in various forms from land- or marine-based sources, and their distribution through the media of water, sediments and tissues of biota.

DRIVERS

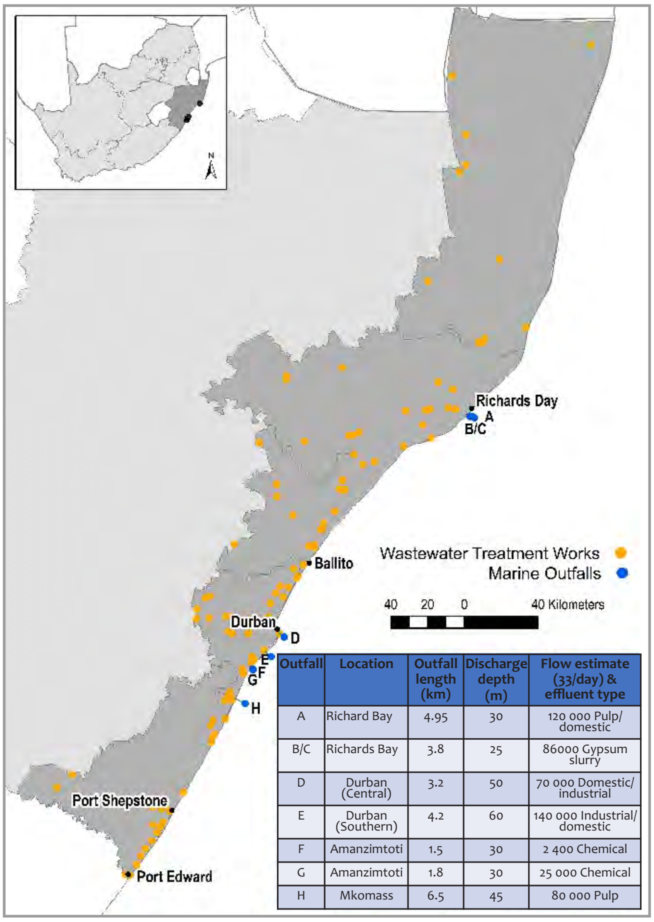
The primary driver of coastal pollution in KZN is development, fuelled by population growth and urban migration (Section 2.2). Pollution takes several forms, but water pollution is the main issue. Impacted systems include coastal lakes, rivers, estuaries, beaches, nearshore and offshore marine waters.

URBANISATION AND TOURISM

Coastal populations have grown disproportionately compared to inland areas, with most of this growth in urban centres. In KZN these include the eThekwini Metropolitan Municipality and the District Municipalities of uMhlathuze, KwaDukuza and Ray Nkonyeni (Section 2.2). Stormwater runoff along with overflows and leakage from municipal wastewater systems is a source of water pollution. Large areas of informal settlement with poor access to waste services invariably results in contaminated runoff into surface waters (coastal freshwaters and estuaries). Human waste, faecal bacteria and viruses are carried by stormwater into coastal waters, along with nutrients, soaps, oils, organic matter and pharmaceuticals. Solid waste (litter) is the most conspicuous component of stormwater runoff and is omnipresent in waters and on beaches, abundantly so after rainfall events. It comprises a wide variety of materials of different buoyancies; cigarette butts, glass bottles, tin cans, cardboard and nappies are common, but the most significant contributor is plastic which persists in the aquatic environment, and as it breaks down into smaller pieces, can be spread over large areas.

INDUSTRY

Industrial development has occurred primarily near the ports of Durban and Richards Bay. Wastewater from industry is typically handled via municipal sewerage infrastructure, after being treated at source to meet a required standard. This wastewater can contain a wide range of potential contaminants, from high suspended solids to heavy metals and synthetic chemicals. There are four areas on the KZN coast where



Outfall	Location	Outfall length (km)	Discharge depth (m)	Flow estimate (33/day) & effluent type
A	Richard Bay	4.95	30	120 000 Pulp/ domestic
B/C	Richards Bay	3.8	25	86000 Gypsum slurry
D	Durban (Central)	3.2	50	70 000 Domestic/ industrial
E	Durban (Southern)	4.2	60	140 000 Industrial/ domestic
F	Amanzimtoti	1.5	30	2 400 Chemical
G	Amanzimtoti	1.8	30	25 000 Chemical
H	Mkomass	6.5	45	80 000 Pulp

Figure 2.3: Wastewater treatment works and marine outfalls along the KZN coast.

industrial wastewater is discharged directly to sea (Figure 2.3). Two marine outfalls at Durban, and two at Richards Bay discharge industrial and domestic wastewater. On the south coast two outfalls at Amanzimtoti and one at Mkomaas discharge industrial effluent to sea (Figure 2.3).

MINING

In KZN, mining on the coast has historically been limited to heavy minerals (Section 8.7) This activity and its associated residue dams and processing plants have clear impacts on coastal environments in terms of habitat destruction and water use. Sand mining occurs on a smaller individual scale, but cumulatively over a larger area (Section 8.8). It is poorly regulated and controlled and pollution impacts are likely more severe. These include increased suspended solids and contaminants such as metals.

AGRICULTURE AND AQUACULTURE

Sugarcane farming and forestry are prominent land uses in catchments along the KZN coast (Section 8.4). These activities rely on the application of a wide variety of pesticides, including toxic synthesized organic chemicals which are carried in "return flows" by surface runoff into coastal waters. While progress has been made in the development of pesticides that degrade relatively quickly in the environment, many are persistent and have the propensity to bioaccumulate and biomagnify in food chains. Fertilisers widely applied in agriculture are also carried in return flows to coastal waters where they contribute to nutrient pollution.

Aquaculture is not widely practised in KZN (Section 8.3). However, pollution impacts include water and sediment quality deterioration by various contaminants, including pharmaceuticals. Biological pollution can occur in the form of pathogens that proliferate in captive stocks being lost to surrounding natural waters affecting wild biota. Alien invasive species introductions occur as escapees of either non-indigenous farmed stock or associated biota that are inadvertently introduced (e.g., snails on aquarium plants).

PORTS AND SHIPPING

The ports of Durban and Richards Bay contribute to pollution through various activities. However, water quality in these ports is primarily impacted by surrounding city catchments. There are clear hotspots in sediment contamination in both ports that can be ascribed to bulk cargo handling, ship repair activities and drainage from urban catchments. Underwater hull cleaning is a growing pressure that will add to contamination of waters and sediments in both ports. Contaminants include antifouling agents that are used in paints applied to ships, and toxicity impacts in port sediments occur. Waste from ships in port is discharged to port reception facilities which, in most categories are regarded as satisfactory in both ports (APWC 2020). Dredging is carried out at both ports with dredged material being disposed at registered open water sites. This has the potential to release plumes of fine sediment as well as contaminants to port and offshore waters, and to pollute the seabed in the vicinity of the dumpsites.

The origin of most waste on beaches is from land-based sources (Ryan 2020). However, there is good evidence that waste, including plastic, is dumped by ships at sea (Ryan *et al.* 2021). Bilgewater discharge, often contaminated with oil is difficult to track and regulate. Shipping accidents can also be significant sources of pollution; oil spills are typical examples.

ENERGY

The energy sector is not a major contributor to KZN coastal pollution, but with growing interest in oil and gas (Section 8.10) this may change. An imminent issue is that of powerships proposed at the Port of Richards Bay. These have the potential to contaminate water as well as introduce light and noise pollution.

PRESSURES

Pollution pressures on the KZN coast arise from an array of sectors which contribute to a diverse range of pollutants (Table 2.1). Rapid urbanisation has put considerable pressure on authorities to provide waste and sanitation services. Although non-sewered, on-site sanitation technologies are being trialed in Durban informal settlements (Sutherland *et al.* 2021), centralised sewerage systems remain the primary focus. These comprise a network of pipes that deliver water-borne sewage to wastewater treatment works, where it is treated to a permitted standard and discharged as effluent to surface waters (Figure 2.3).

Marine outfalls deliver a range of potential contaminants into the marine environment that

Table 2.1: Key pressures and associated pollutants

KEY PRESSURE SECTORS AND ASSOCIATED ACTIVITIES	POLLUTANTS															
	Thermal pollution	Brine (high salinity)	Discolouration	Solid waste (litter)	pH	Biodegradable organic matter	Suspended/ settable solids	Inorganic nutrients	Micro-biological contaminants	Toxic inorganic pollutants	Metals	Petro-chemicals	Agro-chemicals	Pharmaceuticals	Persistent organic pollutants	Harmful organisms
URBANISATION & TOURISM																
Stormwater runoff				●	●	●	●	●	●	●	●	●	●	●		
Municipal wastewater					●	●	●	●	●	●	●			●		
Solid waste					●						●			●		
INDUSTRY & MINING																
Chemical			●		●	●	●			●	●				●	
Paper & pulp	●		●	●		●	●			●						
Coastal mining							●			●						
AGRICULTURE, FORESTRY & AQUACULTURE																
Agricultural return flows							●	●	●				●			
Aquaculture				●		●	●	●								●
PORTS & SHIPPING																
Port activities				●	●	●	●	●	●		●	●				
Ship repair & hull cleaning			●				●				●				●	●
Ballast water discharge																●
Dredge spoil disposal							●				●	●			●	
Ship waste at sea				●		●						●				
Oil spills							●					●				

are specific to the industries being served. They also have the potential to impact some of the basic physico-chemical properties of seawater. Salinity is an obvious example (waste is typically carried in freshwater), but some of the industrial effluents are discharged at temperatures well above and at pH levels well below ambient seawater. In some cases, domestic and industrial effluent is diluted with clean seawater prior to discharge, but fundamentally these outfalls rely on the high assimilative capacity of the KZN offshore environment to dilute and disperse contaminants to levels which pose little or no risk to human health and the natural environment as quickly as possible, impacting only an area designated as a mixing zone.

STATE

Coastal waters of KZN are showing clear signs of pollution. In urban areas, rivers and estuaries are significantly impacted by municipal wastewater. This is manifest in elevated nutrient loads and bacteriological contamination, which extends to adjacent surf zones and beach waters. Bacteriological contamination is evident in all 16 estuaries in eThekwini (Forbes and Demetriades 2008). This is not limited to the central coast, faecal bacteria have historically been reported from systems along the whole KZN coast (Begg 1984). Recent years have seen an increase in both the frequency, duration and levels of contamination. Sewerage infrastructure failures result in repeated and prolonged raw sewage overflows into many systems, including the iKongeni Estuary (Margate), Durban Bay and uMngeni Estuary with consequent closure of swimming beaches.

Data on cases of water-borne diseases in beach users are not available but increases in gastrointestinal and respiratory illness, and skin, eye, ear, nose, throat infections are commonly

Laguna Beach Durban
Photo: Omar Parak

reported, especially after rainfall events. At least two cases of flesh-eating bacteria infections have been reported in the last 15 years. Such water quality issues significantly impact the tourism value of the coast (Nahman and Rigby 2008).

In addition, stormwater runoff and municipal wastewater inflows have led to elevated nutrients and organic matter loads in many KZN estuaries. There are clear signs that many of our estuaries are suffering consequences of nutrient overload. This is evident in periodic phytoplankton and macroalgae blooms. Over the last five years, serious overflows of untreated sewage and/or fish kills have been recorded in over 20 KZN estuaries. Many systems between the iSiphingo and the uThukela (including Durban Bay) have suffered repeated fish kills. Further south, beaches at Margate and Uvongo have frequently needed to be closed to protect bathers from sewage outflows.

Solid waste (litter) is another major category of pollution. In KZN, beaches most affected are between Durban and Richards Bay. Most of this litter is plastic. An estimated 60-90% of plastic from land-based sources ends up on beaches, where most is buried (Ryan 2020), but some invariably remains afloat in coastal waters. Systematic coastal water quality monitoring is not performed, but annual monitoring of waters and the seabed in the vicinity of marine outfalls is conducted, and in most cases, includes surveys of areas at some distance away to serve as reference sites. This monitoring indicates that there are pollution impacts but these are limited to close proximity (generally < 1 km) of the outfall diffuser areas. Outfalls discharging in shallow water, close to shore or discharging dense rather than buoyant effluent have been problematic. For example, the industrial outfall at Mkomaas has been extended twice since it was first commissioned in 1967, in part to deal with nearshore water quality issues (foaming). Diffuser blocking and deposition of non-soluble gypsum on the seafloor at Richards Bay has necessitated the installation of a third industrial line (Retief and Fijen 2008). In general, however, these outfalls are well managed and working to their required engineering specifications, with expected, but limited environmental impact.

In South Africa, most marine outfalls were designed by applying the "receiving water quality objective and fitness for use" approach (DEA 2014). This requires that the treatment and disposal of wastewater must consider the receiving environment. Following this approach, if operations are within design limits, marine outfalls are not expected to have a major impact beyond a pre-defined mixing zone. In contrast, discharge of wastewater to rivers, estuaries and surf zones has historically been licenced based on a "uniform effluent standard" approach. Volumes and chemical compositions of these discharges have not been based on the assimilative capacity of the receiving environment, but rather on uniform legal standards. In KZN, malfunctioning or overloaded treatment facilities no doubt contribute to adverse impacts in estuaries especially, but wastewater discharges, even if their compositions comply with current standards (legal limits), have simply become too large for these systems waters to assimilate.

Disposal of dredge material to sea for port operations is licenced under the ICM Act and appears to be conducted at levels that are sustainable and do not result in lasting or widespread pollution. While regular monitoring of offshore dredge disposal sites is not performed, periodic monitoring before, during and after large-scale capital works indicates impacts are limited to close proximity of the disposal sites and recovery is rapid once dredge disposal ceases.

In addition to the persistent inflow of pollutants, the frequency of large-scale pollution events that have recently occurred is a concern. This is well illustrated by the massive agrochemical spill from the United Phosphorus Ltd (UPL) warehouse into the uMhlanga River during the July 2021 riots, which will have long lasting pollution impacts. Others include the fire at Sun Oil Refineries resulting in hundreds of thousands of litres of firewater and edible vegetable oil spilling into Durban Bay (March 2015), a fire at a Transnet warehouse resulting in firewater and tons of wax entering the Durban Bay (March 2017), a shipping accident which spilled 49 tonnes of plastic pellets into Durban Bay (October 2017) (Schumann *et al.* 2019), a massive spill of oil into the Umbilo River and Durban Bay from a Transnet pipeline (October 2020), two major sewage overflow events into the Port of Durban (May 2019, November 2021), and a more recent one into the uMngeni Estuary (January 2022). A multitude of smaller fire events have also occurred, several in the Durban south area, including those at the SAPREF refinery, as well as fires in the Durban central business district (the most recent, the burning of the China Emporium).

IMPACT

Eutrophication of KZN estuaries significantly reduces the biodiversity and nursery value of these systems, with fisheries and tourism impacts. Pollutants impacting estuaries also flow into the sea, affecting beaches and nearshore waters by bacteriological contamination and solid waste. The most pressing impacts of pollution by sewage are those associated with human health. Solid waste on beaches has obvious implications for recreational beach value and tourism.

Ingestion of microplastics by various biotic assemblages has been demonstrated, e.g., estuarine fishes (Naidoo *et al.* 2020), crabs and rocky shore invertebrates (Iwalaye *et al.* 2020). Actual impacts of this have not been studied locally, but from international literature range from physical damage in digestive tracts affecting feeding, development, growth and reproduction, uptake in tissues and organs, and toxicological impacts from leached plastic additives or pollutants adsorbed from seawater, causing carcinogenesis and endocrine disruption (Wright *et al.* 2013). Entanglement, chocking and digestive tract impacts of larger plastics have been documented locally in sharks (Cliff *et al.* 2020) and turtles (Mann-Lang *et al.* 2020).

By and large, offshore marine water quality off KZN remains good, despite the presence of marine outfalls discharging domestic and industrial wastewater directly into these waters. This is mainly attributable to the dynamic nature and high assimilative capacity of these waters. Rivers and estuaries are far more susceptible to accumulation of persistent pollutants. Metals, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) are widespread in port and estuarine waters in eThekwini (Newman *et al.* 2015). Fish and mussels in Durban Bay, uMngeni and iSiphingo estuaries have been found to accumulate metals, PAHs and PCBs in their tissues at concentrations high enough to pose a potential risk to human health *(acknowledging limitations in data - notably on consumption rates of local recreational and subsistence fishers)* (Newman *et al.* 2015). While limited research of pharmaceutical contaminants has been conducted, they are known to occur in waters in the lower uMngeni catchment, either because of incomplete removal, or inflows of untreated wastewater (Agunbiade and Moodley 2014; Segura *et al.* 2015).

RESPONSE

While it is convenient to regard waste assimilation as one of the ecosystem services that coastal waters provide, it must be recognised that there are limits to what the sea can absorb. In the last 30 years pollution has emerged from being a relatively minor pressure on the KZN coast to a grave concern. Estuaries are under extreme threat, which is a serious warning. Direct consequences for human health, livelihoods and economies are now clearly emerging. South Africa's legislation pertaining to coastal and marine pollution is guided by several international conventions. Implementation is supported by a range of norms and standards. As with many other pressures on coastal and marine resources, management is constrained not by a lack of legislation, but rather by poor enforcement and compliance (Taljaard *et al.* 2019; Table 2.2).

Pollution of estuaries and beaches by municipal wastewater and stormwater runoff is the most significant pollution issue demanding management response:

- Resources must be allocated to the development and maintenance of sewerage infrastructure, and systems put in place to monitor wastewater treatment works. The latter can be achieved by re-instituting the *Green Drop programme.*

- Regular, systematic monitoring of receiving waters should be performed, for example, as used to be the case for eThekwini Municipality State of Rivers Reporting. This provides information on the condition of waters, allowing the identification of pollution hotspots, problem stormwater inflows and failing sewerage infrastructure. Estuaries are the most polluted of all coastal habitats in KZN and they should be included in long term monitoring programmes. These programmes can be expensive, but if well designed they can be rationalised and implementable to provide valuable information to manage pollution pressure.
- The national lack of analytical laboratory capacity to measure known and emerging pollutants needs to be addressed by investment in marine laboratory capability.
- Litter boom projects and beach clean ups, often community led, play a significant role in reducing solid waste pollution but *preventing* waste entering coastal waters is the ultimate solution. Society must adopt a paradigm shift in its generation / disposal of solid waste. The Sihlazimvelo programme (led by eThekwini) provides a template to stimulate this shift. It is a community-based stream management programme, creating jobs and working to reduce flooding through removing blockages in streams from solid waste.
- In the case of plastics, government policy intervention is needed either in terms of bans, pricing mechanisms or recycling initiatives.
- Persistent and emerging pollutants in coastal waters and their human health impacts need to be investigated better. Information on fish consumption rates in local communities is required to contextualise this risk for KZN.
- Recycling technologies should be developed and trialed for commercial feasibility.

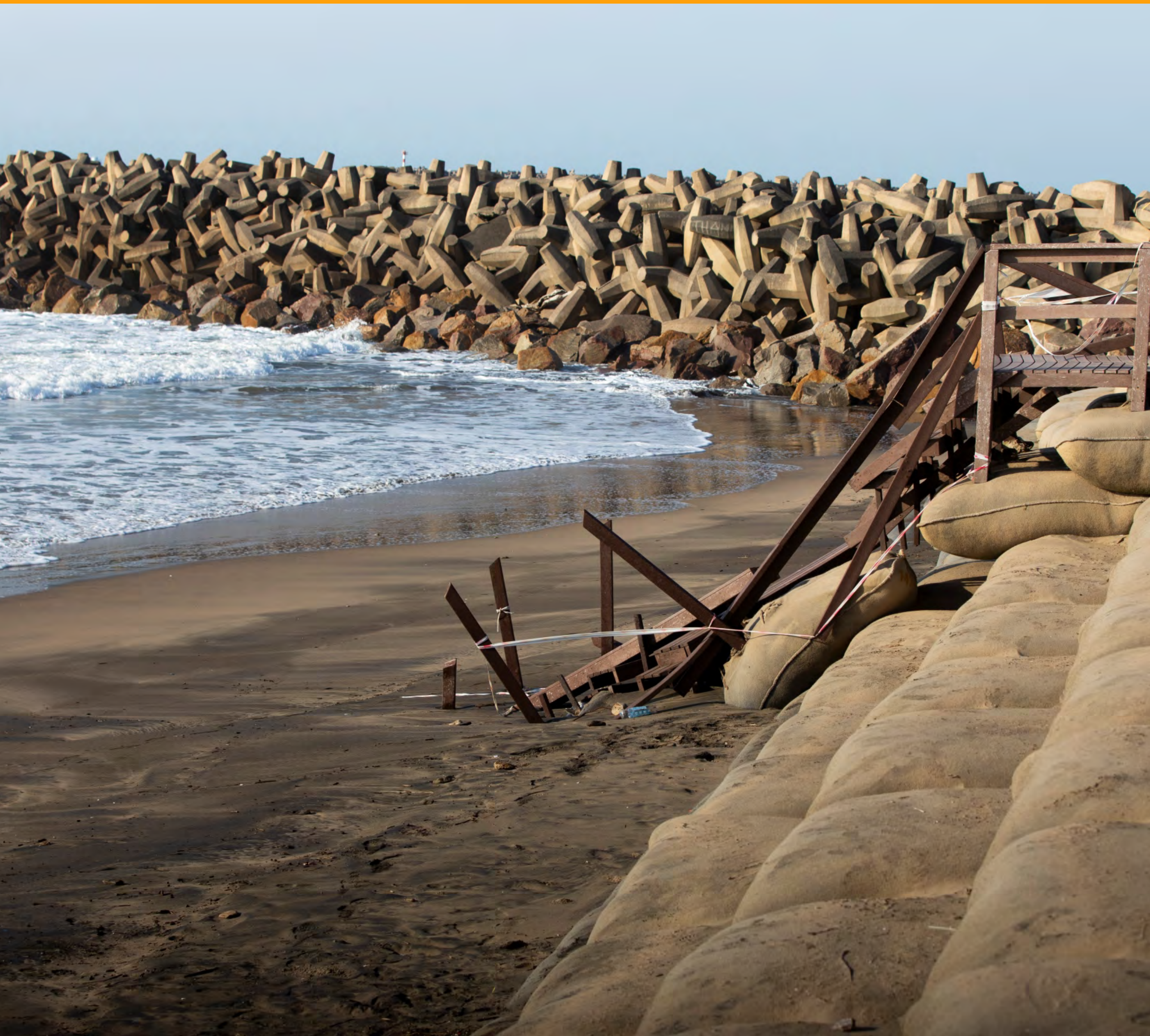
Data Requirements

Sufficient information is already available to prioritise and guide an informed response to the coastal pollution issues we face. We need action rather than more data. Data will be useful in monitoring the success of management actions. Human health issues are an exception. There are signs that in some systems fish and shellfish are contaminated to levels that may pose a risk to human health. This needs to be investigated, and data collected on consumption rates of local recreational and subsistence fishers to contextualise this risk for the KZN setting.

Table 2.2: Status of legislation, available norms and standards, levels of enforcement and compliance for KZN coastal pollution (●= good, ●= fair, ●= poor, *two symbols imply mixed status. E.g., 'good' in some areas, while still in a 'poor' state in other areas*). Modified from Taljaard *et al.* 2019.

SECTOR	KEY ISSUE	STATUS OF LEGAL LANDSCAPE & IMPLEMENTATION		
		Legislation	Norms & Standards	Enforcement & Compliance
Biodiversity	Control of alien & invasive species	good	good/fair	good/poor
Mining	Mineral mining (heavy minerals)	fair	fair	poor
	Sand mining	fair	poor	poor
Water	Environmental flows	good	good/poor	poor
	Sewage treatment	good	good	fair/poor
Land-based pollution	Stormwater runoff	fair	poor	poor
	Municipal wastewater disposal	good	good	fair/poor
	Industrial wastewater disposal	good	good	good/poor
	Agricultural runoff	good	fair	poor
	Solid waste	good	good	fair/poor
	Dredge spoil disposal	good	good	good
Shipping	Pollution from ships	good	good	good/poor
	Ballast water	good	fair	fair/poor
Tourism	Safe recreation	good	good	good/poor

3 CLIMATE VARIABILITY



Coastal erosion, the Port of Richards Bay
Photo: Kierran Allen

CHAPTER 3:
CLIMATE VARIABILITY

3.1 Climate Change
3.2 Extreme Events
3.3 Oceanographic Events

3.1 CLIMATE CHANGE

Dr Andrew Mather (eThekwini Municipality)

INTRODUCTION

Climate change is manifesting itself in different ways across the world. Foremost, are increased air and water temperatures, which in turn lead to an increase in the rate of ice and snow melt in the colder regions of the world. Increasing air temperatures also cause a rise in ocean temperatures, albeit at a slower rate. An increase in water temperature leads to thermal expansion of the ocean water. These two processes lead to an increase in water volume. As our oceans are bounded with basins, this increase in volume results in water levels rising relative to the land.

Clearly, changes in sea-level are important for the world's coastlines, particularly from a planning point of view. Around the world many places regularly record increases in sea-level, as does South Africa. However, some places experience a decrease or 'falling' of sea-levels, due to changes in the earth's crust and elevation driven by plate tectonic movements. Sea-level change is a very useful indicator that can be calculated from existing data. This change has been used by global researchers to determine the rate of change and likely impacts on shorelines globally.

DRIVERS

Sea-level change is being driven by the following processes, the first two account for most of the sea-level changes we observe:

1. Increasing atmospheric temperatures causing ice melt and contributing to the increase in volumes of the oceans.
2. Absorption of heat from the atmosphere into the ocean causes thermal expansion of the ocean.
3. Changes in the elevation of the Earth's crust because of plate tectonics and Post Glacial Rebound when the ice overburden on land melts and the land moves back upwards.
4. Changes in atmospheric pressure. Increasing trends in atmospheric pressure depress the

Coastal erosion at Umdloti
Photo: ORI

ocean surface and result in a sea-level drop as has been observed in the Southern African region (Mather *et al.* 2009, Wunsch and Stammer 1997).

PRESSURES

In KZN, most of our shoreline is sandy and highly mobile. Rising sea-levels allow the wave energy to penetrate further inland than before, resulting in the loss of sand off beaches, leading to long-term erosion. For a province known for its beach tourism offering, this is of great concern.

STATE

Historic perspective

Sea-levels have changed over millennia and will continue to do so into the future. This is due to the changing position of the sun relative to the earth in time. During so called "ice ages," the earth cools and evaporated ocean water becomes ice and snow deposited above the ocean water levels, which results in increasing ice and falling water levels. These cycles can be as much as ~100 000 years with sea-levels dropping by as much as 120 m (Bezverkhnii 2019).

South African sea-levels have also varied in time, with long-term changes exceeding modern human history, but with short-term impacts on present populations. Ramsay and Cooper (2002) have indicated a low sea-level of 130 m below present 17 000 years ago and a high of +6 m approximately 5 000 years ago.

Detailed research and analysis into the short-term impacts of sea-level rise along the KZN coastline has historically been constrained by insufficient reliable records. Mather (2007) published the first detailed analysis of the linear and non-linear sea-level changes at Durban. Using a 33-year record, Mather determined that the rate of sea-level rise at Durban was 2,7 ± 0,05 mm/year. Mather *et al.* (2009) expanded their work to the whole South African coastline. Their findings were that the Eastern region (Port Elizabeth to Richards Bay) exhibited differences in the rates at individual sites. The trend and rate of sea-level change was that regional sea-levels are rising by 2,74 mm/year.

Current state

Sea-level change is a large-scale climate change process. As a result, the sea-level changes being measured are relatively small, but likely to continue for a long time to come. For this reason, it is not necessary to re-analyse sea-level changes every few years, but rather to do the re-analysis every two decades or so. In the case of KZN, the linear rate of sea-level rise of 2.74 mm/year is sufficient to aid planning over the next two decades. Longer tidal data sets for the region are needed to track changes in sea-level over time. Many of the current tidal data sets available for South African ports cover a period shorter than 50 years and therefore are not at a length of record where there is a high confidence level in the analysis of sea-level changes. In time these will improve provided the collection of data continues and is validated.

IMPACT

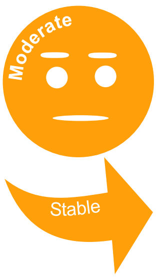
Rising sea-levels along the KZN coastline will have physical, ecological and economic impacts. An increase in sea-levels will result in a narrowing of our sandy beaches, erosion of our natural dune systems and coastal vegetation. The loss of sand on our beaches and the reduced beach width will reduce the space for tourists and visitors to use.

Additionally, dunes are nature's self defence system. During storm events, coastal sediment is eroded into the nearshore and has the effect of slowing down the rate of erosion by helping form underwater offshore bars which in turn break some of the wave energy. A loss of dunes means this mechanism will not function naturally and other means of defence will be needed if the shoreline is to be protected. This loss of the dune system and associated biodiversity will reduce the resilience of the shoreline to protect the built infrastructure at the back of beach. This will mean premature replacement of infrastructure before it has reached the end of its economic life.

Long-term coastal erosion at Richards Bay lighthouse
Photo: Kierran Allen

Data Requirements
The South African Navy's Hydrographic office has tide measuring stations at most of our Ports and this data is available on request (www.sanho.co.za). This data is also freely available on the Permanent Service for Sea-level (www.psmsl.org). Ideally the data accessed to perform a sea-level rise trend analysis should be at the shortest time steps, (hourly), and extend for as a long a period as records permit. The most confidence is assigned to records exceeding 50 years. However, KZN does not have tide records exceeding 50 years and so it is important to take this into account in the presentation of results.

RESPONSE



Despite the problems of having shorter periods of tide data to work with, it is critical to start translating the results into a preliminary risk assessment of the impacts rising sea-levels could have on the KZN coastline. One of the key tools in preparing this is the determination of risk lines associated with scenarios of sea-level rise. The Integrated Coastal Management Act (36 of 2014) provides for Coastal Management Lines (CMLs), and it is critical that these lines are defined and gazetted, so that informed planning around coastal development as well as strategies to manage a changing coastline can be developed.

3.2 EXTREME EVENTS

Dr Andrew Mather (eThekwini Municipality)

INTRODUCTION

As sea-level rise continues to increase there will be more frequent events along the coastline where damage is caused to public and private infrastructure. In the context of the KZN coastline, the most destructive extreme events to date relate to high wave energy. These events erode the coastline and often result in significant damage.

DRIVERS

High wave energy events are generated by two main processes in our region. In summer, the prevailing wave direction is from a North Easterly direction. In summer, cyclonic events in the Indian Ocean (e.g., Mozambique Channel) generate high wind speeds, which, depending on the duration and intensity of the cyclone, generate a wave field which moves outward and may eventually reach our shores.

In winter, swells from the Southern Ocean move up past the Cape and arrive at our shores. In general, the winter period is the stormiest season on the KZN coast as waves are bigger due to longer fetch and more energy.

PRESSURES

Wave statistics are a very useful indicator that can be easily calculated from existing data and from dedicated instruments specially designed and moored in strategic sites. These records are used by global researchers to determine the rate of change and likely impacts on shorelines globally.

STATE

Historic perspective

The KZN coastline is classified as a high energy coastline, thus large wave energy events are relatively frequent. These events have become more and more destructive to infrastructure that has increasingly been located along the shoreline within the hazard zone. The earliest reports of damage for bathing infrastructure occurred in 1928 when the Durban anti-shark bathing enclosure was permanently damaged, and the decision was taken that any further repairs would be fruitless (Barnett 1999).

Probably the most destructive wave event of recent times was the March 2007 wave event. This was in fact a series of three tropical cyclones all occurring relatively close together; Cyclone Dora was followed by Cyclone Favio. These two cyclones, while they were not the most intense of the three, had started to erode sediment along the coastline and to weaken the natural dune system defenses. Cyclone Gamede which occurred on the 19th March 2007 was the most intense. The highest offshore (deep water) wave height recorded at Richards Bay was 14 m.

In the aftermath of this event there was significant damage to both private and public facilities. The damage costs are difficult to determine as the quantum of private claims was never determined. However, the damage valuation by the eThekwini Municipality area at the time indicated an amount of R98,182,340 (Mather and Vella 2007).

It has already been established that the West Indian Ocean (WIO) is warming faster than any other tropical sea. Based on extensive coral coring at several sites in the WIO it has been shown that the SST (sea surface temperature) has substantially increased over the past 334 years. (Pfeiffer *et al*. 2019, Zinke *et al*. 2019). Persistent increasing temperatures globally and the abnormally higher level of warming of the Indian Ocean are certain to result in an increase in cyclonic activity and possibly more frequent and more severe storm events in KZN.

Current state

The two existing wave recorders in KZN, located off the ports at Richards Bay and Durban, are owned by Transnet. Both have been collecting long-term wave data. Clearly, it is important that this is continued so that detailed analysis of changing wave patterns can be understood.

IMPACT

The impact of the two wave regimes on the KZN coast plays out in different ways. The direction of the origin of these wave events affects the littoral drift or sediment transport processes. Sediment transport on beaches is an important process that moves sand along the shoreline and creates the distinctive sandy beaches along the KZN coast. The analogy is that there is a river of sand along our coastline which moves either

Erosion because of an extreme wave event
Photo: Simon Bundy

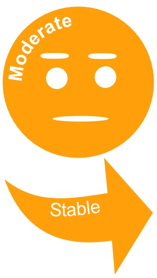
northwards or southwards depending on the prevailing wave direction. It also expands and contracts depending on how much wave energy is present.

In summer, the north-easterly swell generally dictates a calmer period in the year, and these waves move sediment inshore from deeper water and moves sediment southwards. This period, from a coastal protection point of view, is good as this rebuilds beaches and dunes, providing the buffers for storm events.

In winter the opposite happens. The swell from the southern oceans gives rise to a different pattern. As this is generally the more energetic time of year, the beaches are exposed to more energy and as a result the beaches and dunes erode. The eroded sediment is transported in a northerly direction as well as offshore. Sediment that is moved offshore forms bars, which are like underwater dunes which are nature's way of allowing wave energy to disperse offshore.

Regardless of the season, the impact of these events reduces the buffer of sand on the beaches and nearshore region. This has the effect of increasing the vulnerability of built infrastructure and natural systems to potential failure and/or complete loss.

RESPONSE



While a monitoring system is important for early warning of extreme events so that human life loss can be prevented, it is just as important that the potential loss of assets and property is minimised. Stricter development controls are needed to reduce the number and value of buildings and non-essential infrastructure within the hazard zone of these events. CML's are an important step in demarcating the hazard zone and informing the public and property owners of the risks associated with their properties. The roll out of CML's and an awareness drive should be undertaken in conjunction with stricter adherence to CML's.

While there are no measures to address the weather patterns causing these storm events, which is warned will increase under climate change, there are several practical measures, which can be considered to "storm proof" the shoreline as much as possible.
In addition, the following steps should be implemented:

1. **Measures to reduce the impact of human damage to infrastructure and buildings:**
   a. The implementation of CMLs based on a long-term view of the coastline. eThekwini Municipality has this in place based on a 1:50 year storm data and 50 years of sea-level rise data, and this has been shown to have been exceeded in many locations along our coast during the 2007 storm and the sea's subsequent readjustments to the shoreline. This CML is not in place for the entire coastline at present but should be completed timeously.
   b. Good practice should see the development of shoreline management plans at the municipal level. These should outline a specific retreat policy that should be implemented for all partially and totally damaged or lost infrastructure, facilities and buildings. This will result in the relocation of infrastructure and facilities back to a less vulnerable position. There are likely to be many buildings within the new CML and it is strongly recommended that a policy of expropriation or land exchange be put in place to address inappropriately situated infrastructure. At this point in time, many of these owners have no choice but to defend their property.

2. **Measures to replenish the sand available to the coast:**
   a. The sustainability of beaches is affected by the practice of sand mining from our rivers and estuaries. This is having a negative effect on the quantity of sediment arriving at the coast and which would normally be available for the coastal processes to supply sand to beaches and dune systems. The approach to sand mining needs to be revisited so that we are not making the situation on the coast any worse than it already is.
   b. The damming of rivers for potable water for human consumption is necessary; however, the dams are also trapping sediment destined for the coast. Not only is this accumulation of sediment in our dams creating less storage capacity of water, prompting the raising of several dam walls recently to counter this loss, but it is also effectively cutting off the supply of sediment to the coastline. An extreme example is the uMgeni catchment: prior to dam building the maximum sediment yield was 6 800 000 tonnes per year. However, the construction of the Inanda Dam now traps approximately 90% of the catchments' sediment (Garland and Molefi 2000). The balance of sediment is extracted by a licensed sand mining operation, which effectively reduces the sediment yield to zero. The problem can be addressed by the bypassing of this sediment around the dams and thereby reinstating the sediment flow. This has been raised with officials in the Department of Water Affairs and Forestry in the recent past, but the issue has not yet been addressed. The issues of reserve determination in our catchments have received much attention in recent years, particularly around its contribution to ecosystem health. Unfortunately, the sand contribution has been neglected although it is equally important.
   c. Importation of "new" marine sediment from offshore. If the supply of sediment from land sources is not possible, impractical, or too slow to replace the lost sediment, then this is a further option. This practice is common in America. It consists of dredging marine sediments from offshore and then pumping these back into the beach zone. This acts to build up the beach profile and reverse erosion trends in the re-nourished areas. However, this process is normally expensive and would only suit areas of coastline with high value infrastructure, i.e., beachfront areas. The downside is that this re-nourishment would need to be redone periodically to replace sediment, which is lost northwards and seawards.

Data Requirements
Wave recorder data, off the ports at Richards Bay and Durban collect long-term data and provide information on wave conditions and trends in wave height.

3.3 OCEANOGRAPHIC EVENTS

Dr Laura Braby (SAEON, Egagasini Node)

INTRODUCTION

Western boundary currents moderate the Earth's climate by transporting heat polewards (Hu *et al.* 2015). The wind stress curl above the Indian Ocean gives rise to the Agulhas Current, the strongest western boundary current in the Southern Hemisphere (Renell 1832, Lutjeharms 2006). The Agulhas Current begins off the coast of Ponta do Ouro in southern Mozambique and transports approximately 70 ± 22 Sv (1 Sv = 1 million $m^3.s^{-1}$) of warm water south-westwards along the east coast of Southern Africa (Figure 3.1; Bryden *et al.* 2005). Mesoscale ocean eddies, which form in the Mozambique Channel and in the region south of Madagascar are known to propagate towards the start of the Agulhas Current and contribute to the total flow of the current (Figure 3.1; Schouten *et al.* 2002, de Ruijter *et al.* 2004). Western boundary currents, including the Agulhas Current, are sometimes referred to as "eddy graveyards" because they are sinks for eddy energy (Zhai *et al.* 2010). Past research has shown that source region eddies can affect the speed and position of the Agulhas Current (Braby *et al.* 2016).

The northern Agulhas Current is relatively stable and flows along the edge of the continental shelf. The arrival of an anti-cyclonic eddy in the Natal Bight region, however, can cause a large cyclonic meander of the Agulhas Current. This meander, known as a Natal Pulse, propagates down the coast and plays a significant role in the variability of the Agulhas Current (de Ruijter *et al.* 1999, Schouten *et al.* 2002). Meanders are known to drive cross-shelf exchanges (Malan *et al.* 2018) which drive nutrients onto the shelf with implications for many commercially important fish species in South Africa (Hutchings *et al.* 2002, Roberts *et al.* 2010).

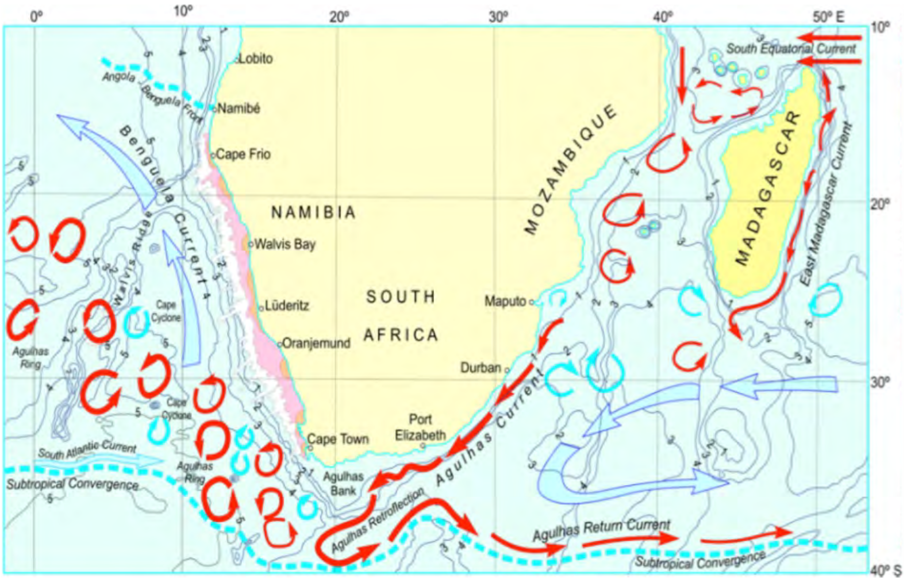


Figure 3.1: A schematic of the major oceanographic features surrounding southern Africa, from Lutjeharms and Ansorge 2001.

DRIVERS

Many climate models show the continued poleward expansion and intensification of global wind systems (McGregor *et al.* 2012, Yang *et al.* 2016). Several studies indicate that an intensification in winds does not necessarily lead to an intensification of currents but could rather lead to an increase in the eddy kinetic energy (EKE) of western boundary currents, including the Agulhas Current (Backeberg *et al.* 2012, Beal and Elipot 2016). It is hypothesised that the warming trends that have been observed in the Agulhas Current, and other western boundary currents, can be explained by a poleward shift in the ocean gyres (Beal and Elipot 2016).

The Agulhas Current plays an important role in both local and global climate. Regionally, the temperature and proximity of the Agulhas Current to the coast impacts the rainfall on the East Coast of South Africa (Walker 1990, Jury *et al.* 1993). The Agulhas Current has also been shown to exacerbate storms and extreme flooding events (Rouault *et al.* 2002). Depending on its response to climate change, it is possible that the Agulhas Current could either intensify or reduce extreme weather or warming events.

PRESSURES

The Agulhas Current has a direct influence on coastal KZN. Aside from its impact on regional ecosystems and the climate, several local industries and activities are subjected to the state of the Current. Examples include the renewable energy (Meyer *et al.* 2017), fisheries and shipping industries, as well as tourism. This is particularly true when a meander is present. For these reasons, investigating possible changes in mesoscale variability of the Agulhas Current as well as changes in the Agulhas Current itself, are important features of coastal planning.

STATE

Past studies showing the trends in Sea Surface Temperatures (SST) indicated a warming trend to be concentrated around the western boundaries of ocean basins (Wu *et al.* 2012). The Indian Ocean is also warming faster than all other ocean basins (Cheng *et al.* 2017). A study by Rouault, *et al.* (2009) indicates that despite an increase in regional heat fluxes, the SST of the greater Agulhas Current system has increased significantly since the 1980's, with a trend of up to 0.7 °C per decade (Figures 3.2 and 3.3).

Previously, it has been shown that EKE, which measures the energy of mesoscale activity including meanders and eddies, is increasing

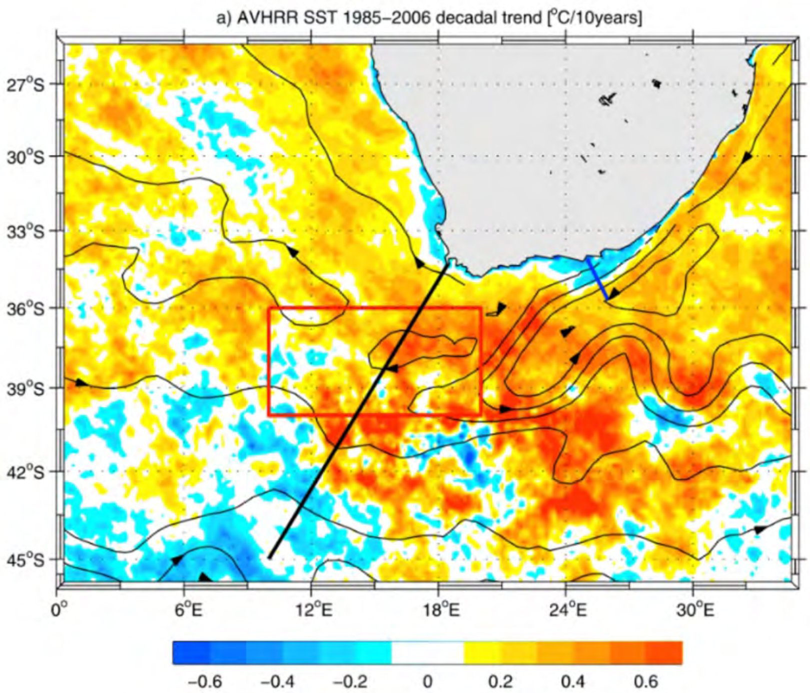


Figure 3.2: The decadal trend in SST for the period of 1985 to 2006, from Rouault *et al.* 2009.

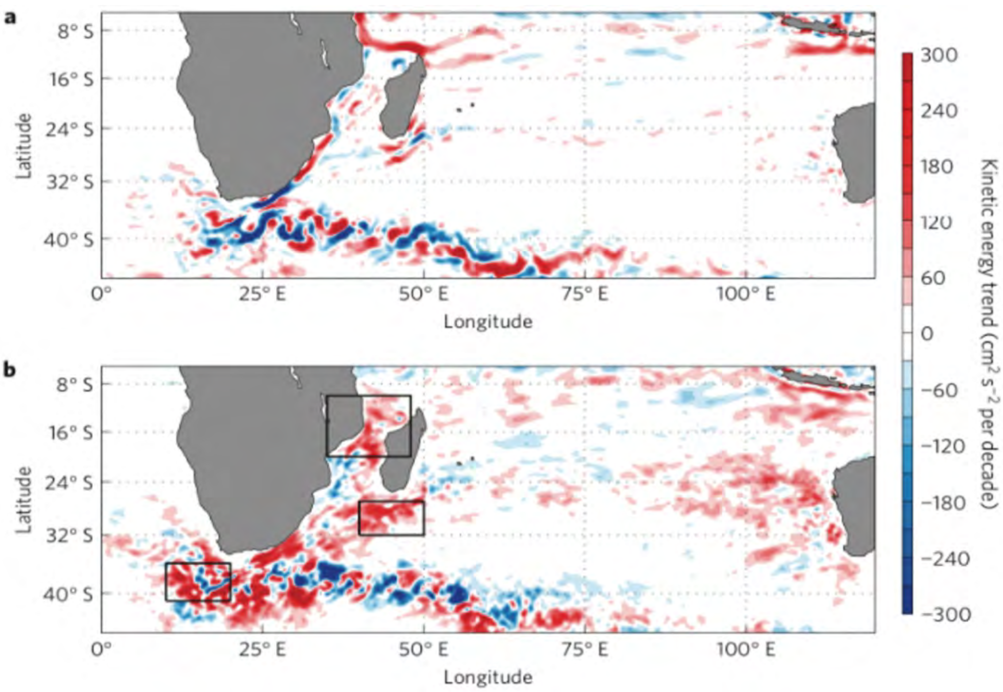


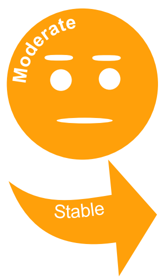
Figure 3.3: The decadal trends in a) MKE and b) EKE (cm^2.s^{-2} per decade) for the period of 1993 to 2009, from Backeberg *et al.* 2012.

in the source regions of the Agulhas Current (Backeberg *et al.* 2012). Additionally, the mean kinetic energy (MKE) trends, which show the trends in kinetic energy of the mean flow, show an increase in the MKE of the northern Agulhas Current (above 32°S, along the coast of KZN) but a decrease below 32°S (Figure 3.3; Backeberg *et al.* 2012). This is corroborated by the findings of Beal *et al.* (2016), which reveal that the Agulhas Current is broadening, likely due to increased eddy activity, rather than strengthening over time in the region of the Agulhas System Climate Array (ASCA) (34°S). Much of the research over the Agulhas Current indicates that the Agulhas Current is warming and becoming more turbulent at the mesoscale level over time (Backeberg *et al.* 2012, Beal and Elipot 2016).

IMPACT

The intensification of the changes that have, to date, been observed in the Agulhas Current could impact KZN, South Africa and the South African population in many ways. Anthropogenic climate change over the Agulhas Current has the potential to influence regional weather patterns and extreme events such as storms or flooding. Beal and Elipot (2016) highlight how a broadening of the Agulhas Current could result in an increase in the cross-shelf exchange of nutrients and potentially pollutants from the shelf to the deep ocean.

RESPONSE



To better understand the behaviour of the Agulhas Current and its response to anthropogenic climate change, more long term *in- situ* observations of the Agulhas Current are needed (Beal and Elipot 2016, Morris *et al.* 2017). Sustained measurements are the best way to monitor any changes in the Agulhas Current off the coast of KZN. The greater Agulhas Current System is larger than just the KZN coastline, and any changes would impact the whole east coast of South Africa. Whilst not situated in KZN, the

A mooring being deployed in the Agulhas Current
Photo: Laura Braby

redeployment of the ASCA mooring array (formerly the Agulhas Current Transect array in the same location, nominally 34°S) would build on our existing knowledge of the current and create a very good dataset in one location. Other instruments, such as gliders and Argos, would also improve our understanding of eddies and other forms of submesoscale variability inshore of the Agulhas Current.

Data Requirements
As a result of the global bearing of the Agulhas Current, much research has been done and is currently being undertaken, to understand how the Agulhas Current is changing over time. Many of these studies investigate the temperature and transport of the Agulhas Current (Rouault *et al.* 2009; Wu *et al*. 2012; Cheng *et al.* 2017; Beal and Elipot 2016). Whilst numerical models can capture many aspects of the greater Agulhas Current System correctly, few are able to correctly simulate the mesoscale variability in the Agulhas Current (Braby *et al.* 2020). There is also very limited in-situ monitoring of the Agulhas Current off the coast of KwaZulu Natal. Satellite altimetry data can be used to study variability in the Agulhas Current. However, given that there are some limitations to altimetry data (de Vos *et al.* 2018; Backeberg *et al.* 2014), the most accurate way to monitor long term changes in the Agulhas Current is with full depth, in-situ mooring arrays such as the Agulhas System Climate Array (ASCA) which was deployed across the Agulhas Current at nominally 34°S from 2016 to 2018 (Morris *et al.* 2017). The data collected from the ASCA array can be used to determine heat, salt and volume transport across the Agulhas Current (Morris *et al.* 2017).

4 COASTAL ENVIRONMENT

KZN coastal environment, North Coast
Photo: Kierran Allen

CHAPTER 4:
COASTAL ENVIRONMENT

4.1 SANDY SHORES

Dr Linda Harris (Coastal and Marine Research and Department of Zoology, NMU)

INTRODUCTION

Dunes, beaches and the surf zone function as a single unit called the littoral active zone, within which there are constant exchanges of sand, nutrients and animals between land and sea (McLachlan 1990). Waves and tides sculpt grains of sand into a continuum of beach types, from wide, fine-grained dissipative beaches with gentle slopes and wide surf zones, through a series of intermediate types, to narrow, coarse-grained reflective beaches with steep slopes and narrow surf zones. KZN has three beach ecosystem types:

1. Natal-Delagoa Dissipative-Intermediate,
2. Natal-Delagoa Intermediate, and
3. Natal-Delagoa Reflective Sandy Shores (Figure 4.1).

Beach biodiversity is surprisingly higher than expected, and many of the species are unique to South Africa (Harris *et al.* 2014). Under a single beach towel on the KZN beach, there are approximately 30-50 animals buried in the sand

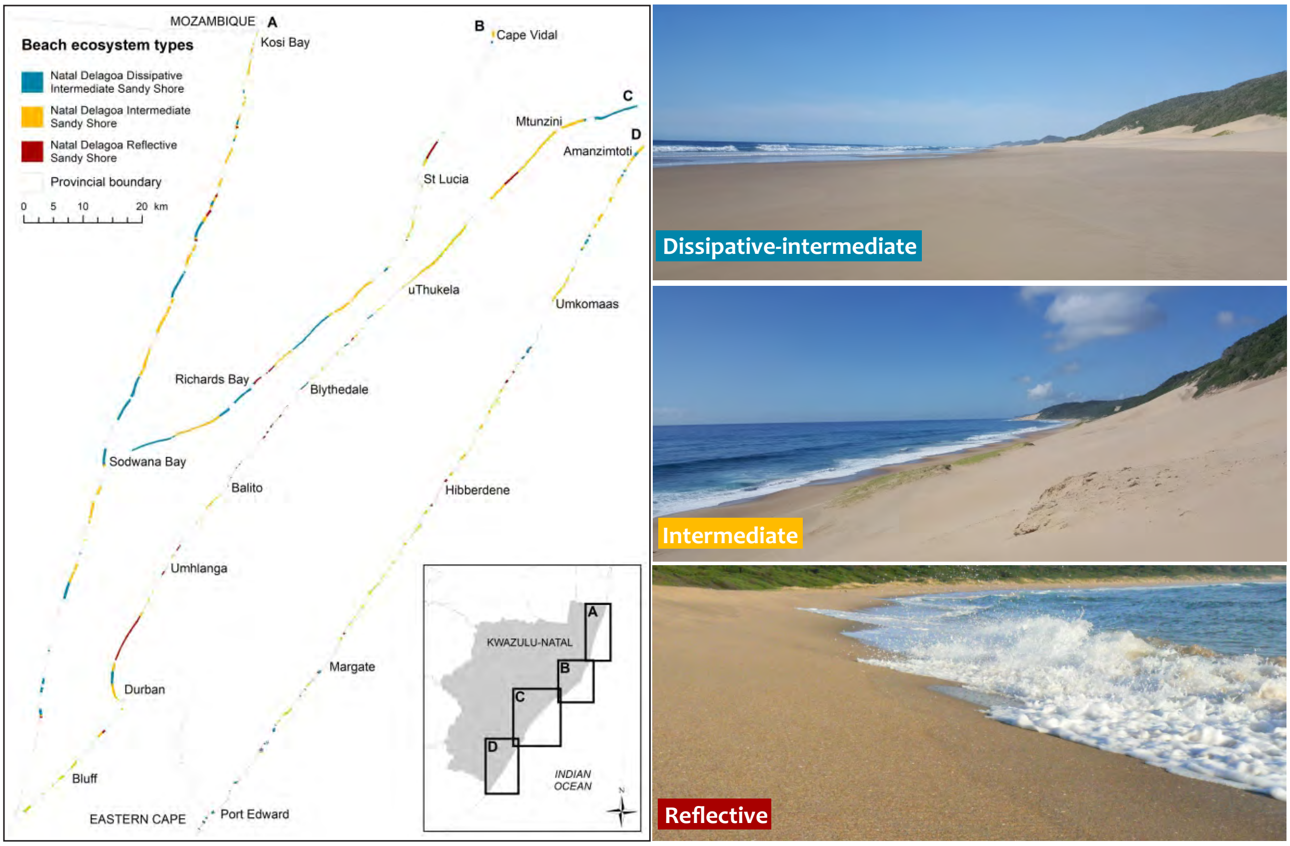


Figure 4.1. There are three beach ecosystem types in KZN. 1) Natal-Delagoa Dissipative-Intermediate Sandy Shores; 2) Natal-Delagoa Intermediate Sandy Shores; 3) Natal-Delagoa Reflective Sandy Shores (Harris *et al.* 2019a; *photos: Linda Harris*)

from a total of about 70 different species (Harris *et al.* 2014).

When sandy shores are in good ecological condition, they provide many benefits, including food and other resources, playgrounds for sports and recreation, scenic vistas, sites of cultural and spiritual significance, and protection against large wave events (Harris *et al.* 2019b). They also perform key services such as nutrient cycling and water purification (McLachlan 1979, McLachlan 1982).

This section focuses on sandy shores, defined as the area spanning the dune base to the back of the surf zone (Harris *et al.* 2019a). However, because sandy shores are part of the littoral active zone, their condition depends strongly on the state of the adjacent foredunes. Thus, four indicators are considered.

COASTAL DEVELOPMENT

Landcover change (Skowno 2020, Skowno *et al.* 2019b), especially coastal development, is an important indicator of the state of sandy shores because it is a direct driver of habitat loss. Further, development prevents the natural inland migration of beaches as sea levels rise, and they are gradually inundated and lost through a process called coastal squeeze.

ECOLOGICAL CONDITION

Ecological condition is estimated from an assessment of cumulative pressures to beaches (Sink *et al.* 2019a, Harris *et al.* 2015). The premise is that the higher the intensity of a greater number of pressures, the poorer the ecological condition. Ecological condition also informs the ecosystem threat status and ecosystem protection level (Skowno *et al.* 2019a).

ECOSYSTEM THREAT STATUS

Ecosystem threat status is assessed based on the criteria of the IUCN Red List of Ecosystems (Bland *et al.* 2017, Keith *et al.* 2013), providing an indication of the risk of ecosystem collapse. Ecosystem types are classified as either Data Deficient, Least Concern, Near Threatened, Vulnerable, Endangered, Critically Endangered or Collapsed (Bland *et al.* 2017, Keith *et al.* 2013).

ECOSYSTEM PROTECTION LEVEL

Ecosystem protection level is a measure of how well each ecosystem type is represented in South Africa's protected area network, which together with ecosystem threat status, helps to prioritise ecosystem types in greatest need of protection. Ecosystem types are classified as Well Protected, Moderately Protected, Poorly Protected or Not Protected, with habitat in only good ecological condition counting towards the Well Protected category (Sink *et al.* 2019b).

DRIVERS

The strongest direct driver of beach ecological condition is the state of the adjacent foredunes. Keeping the dune-beach connection intact, unconstrained and maintaining natural sand storage and transport are critical for resilience in sandy shores. Hence, coastal development, coastal squeeze and mining cause the greatest impact to beaches. However, freshwater-flow reduction and impacts from less destructive pressures like fishing and other resource harvesting are widespread and contribute to cumulative declines in ecological condition.

The root driver of change to sandy shores is population and economic growth. The ongoing development in prime seaside locations results in increased pressure through increased demand, such as sand for construction (increased sand mining), and more abstraction of water from catchments to support the growing population. These effects contribute to disrupting natural flows of sand between land and sea and result in sand-starved shores. Further, as coastal population densities increase, so too do recreational activities and the number of beach visitors, heightening impacts from disturbance and resource extraction, with dune trampling contributing to increased erosion. Superimposed on this are stressors from climate change, particularly sea-level rise and storms, which synergistically contribute to habitat loss in sand-starved systems by accelerating erosion and contributing to coastal squeeze.

PRESSURES

Sandy shores face two types of anthropogenic pressures: high-impact pressures that contribute to habitat loss (e.g., coastal development and mining); and low-impact pressures that collectively contribute to declines in ecological condition through cumulative effects (e.g., pollution, trampling and harvesting). The latter can easily go unnoticed because beach biota is generally very small, live buried in the sand or in the surf zone, so the impacts are not visually obvious. Further, the dynamic nature of sandy shores makes it difficult to distinguish long-term declines in sand supply to beaches from natural periods of heightened erosion without monitoring data.

STATE

Historic perspective

Refinement of the national classification and mapping of beach ecosystem types (Harris *et al*. 2019a), together with a change in the methodology by which ecological condition, ecosystem threat status and ecosystem protection level were assessed in the NBA 2004, 2011 and 2018, precludes a trend analysis of these indicators for beaches. However, habitat loss, especially from coastal development, can be tracked over time. Coastal development is significantly correlated with the sum of all other pressures on beaches (Harris *et al.* 2015), suggesting that it is also a good surrogate for a trend analysis of ecological condition.

The National Landcover datasets aid in tracking habitat loss over time, showing clear trends, in spite of the coarseness of the data (Skowno 2020, Skowno *et al.* 2019b). From 1990–2014, natural habitat was converted mostly to plantations, buildings and croplands (Figure 4.2). However, from 2014–2018, there has been a marked increase in coastal development and mining (Figure 4.2). Differences in habitat loss

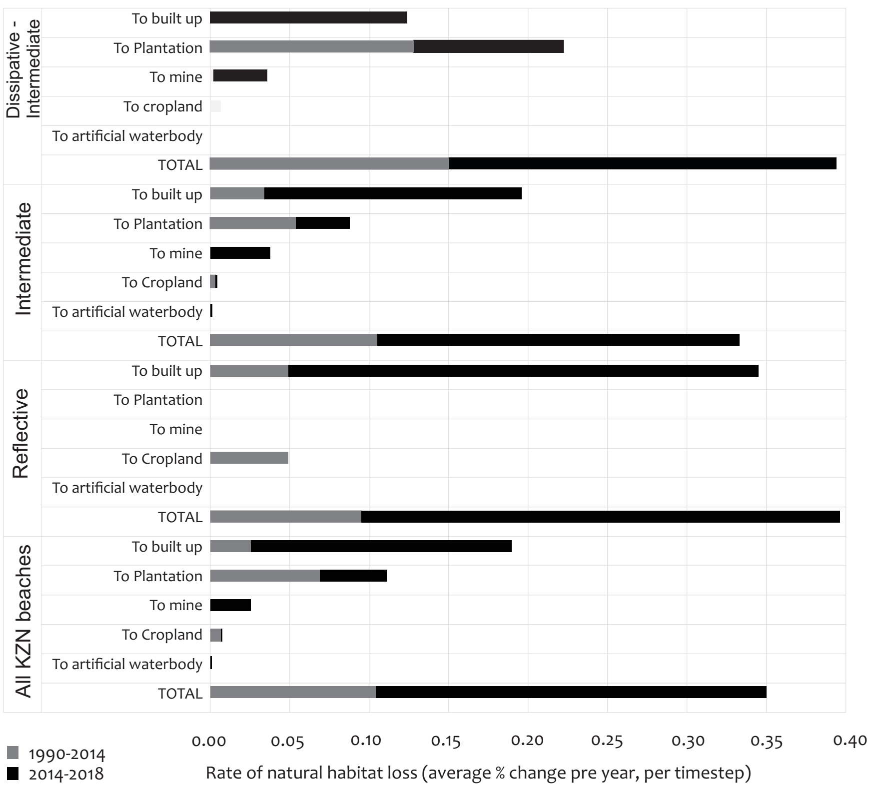


Figure 4.2. Rate of natural habitat loss (average percent of whole area: annually converted from Natural to another landcover class: 1990-2014 (grey) and 2014-2018 (black)) within area spanning the shore to 200 m inland of the dune base for the three beach ecosystem types in KZN, and for all KZN beaches.

among beach types relates to their geographic distribution along the KZN coast (Figure 4.1), but overall, coastal development is the greatest driver of natural habitat loss (Figure 4.2).

Current state

Ecological condition is estimated by assessing cumulative pressure from human activities on beaches at a site level and determining the proportion of an ecosystem type in each of four condition classes, from Natural to Very Severely Modified (e.g., heavily developed beaches with numerous pressures). This cumulative pressure assessment was undertaken by Sink *et al.* (2019a) and Harris *et al.* (2015) following the same methodology but including different pressures. Neither of these assessments have been ground-truthed, which will need to be addressed in future. Therefore, both assessments are presented because the results are slightly different and the true proportion of sandy shore habitat in each ecological condition class is likely somewhere between the two estimates (see Sink *et al.* 2019a and Harris *et al.* 2015 for details).

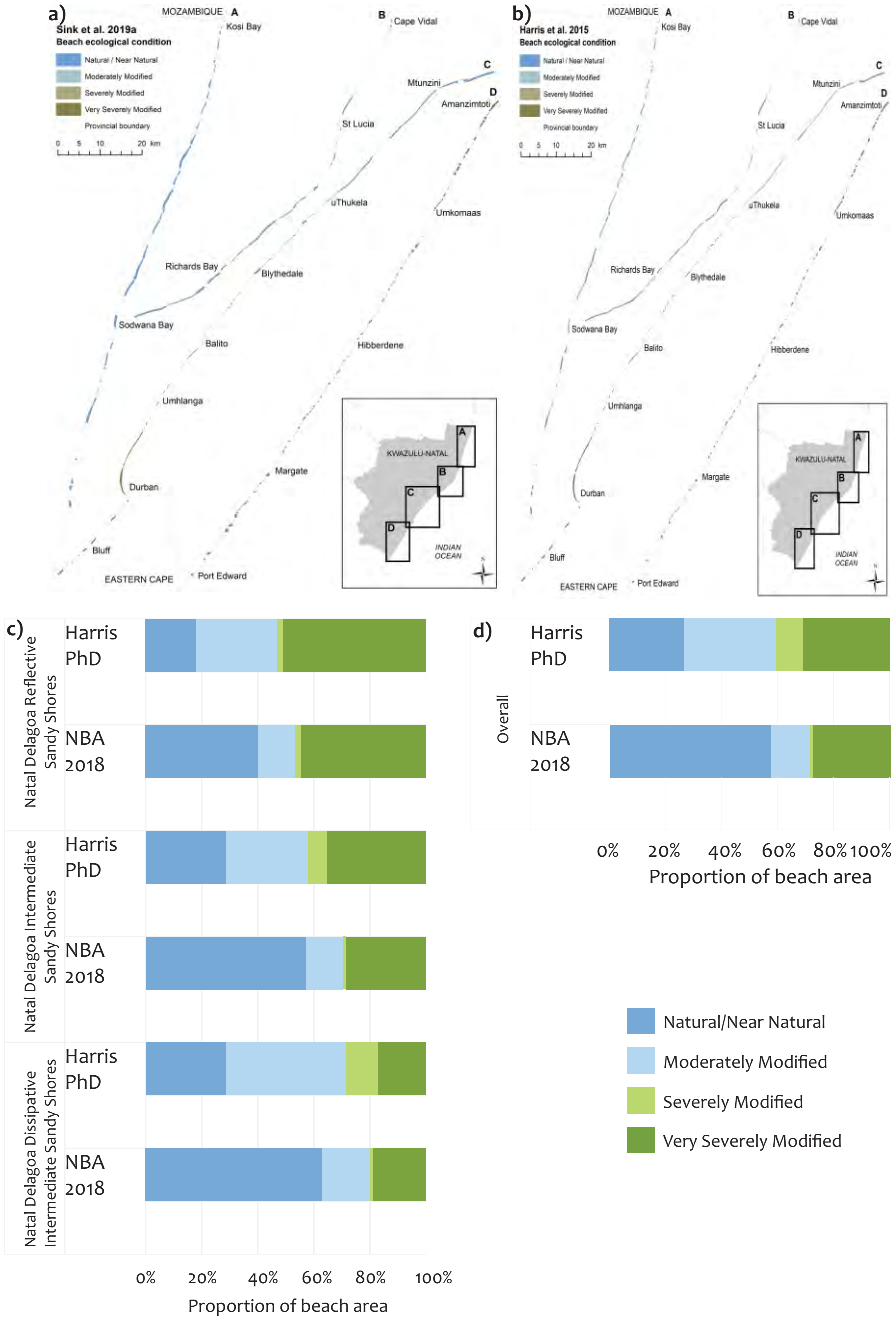


Figure 4.3. Ecological condition based on a cumulative pressure assessment from (a) the NBA 2018 (Sink et al. 2019a) and (b) data from Harris et al. (2015) for the KZN beaches (c) by beach morphodynamic type, and (d) for all beaches collectively. Data are given as a proportion of the area in each ecological condition class.

Notwithstanding, the broad trend in both assessments shows that beaches north of uThukela Estuary are in much better ecological condition than the beaches further south (Figure 4.3). This matches the footprint of coastal development (more intensive south of the uThukela Estuary) and coastal protection (most coastal protection is north of the uThukela Estuary) in KZN. All ecosystem types have some habitat in each of the four classes of ecological condition, but about a third (30-41%) of the

Sandy shore dunes and sensitise dune vegetation
Photo: Kierran Allen

beaches overall are Severely to Very Severely Modified (Figure 4.3). It is also salient to note that the Natal-Delagoa sandy shores are under significantly more cumulative pressure than sandy shores in the rest of South Africa (Harris *et al.* 2015).

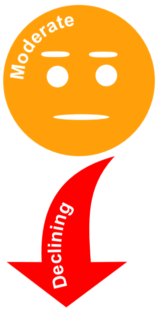
The amount of ecosystem modification, as estimated by the ecological condition, informs the ecosystem threat status (Sink *et al.* 2019a). The Natal-Delagoa Reflective Sandy Shores are the only threatened beach ecosystem type in KZN, with a status of *Vulnerable* (Sink *et al.* 2019a). Given the excellent coastal protection in KZN, all three beach types have an ecosystem protection level of *Well Protected* with at least 20% of each type in good (Natural) ecological condition located in protected areas (Sink *et al.* 2019b). iSimangaliso and uThukela MPAs contribute most to protecting sandy shores in KZN. Importantly, both MPAs offer land-sea protection because of contiguous terrestrial protected areas that safeguard the adjacent dunes, particularly in iSimangaliso. Protecting the adjacent dunes is imperative for providing effective protection to sandy shores.

IMPACT

As coastal development increases, particularly when constructed within the littoral active zone, it decreases the beaches' adaptive capacity to respond to stressors from climate change, including sea-level rise and extreme storms. Sand erodes from beaches until they are gradually narrowed and lost through coastal squeeze.

Urban beaches backed by seawalls also become inaccessible to tourists during high tides because the sea fully inundates the shore. The impacts are therefore both ecological: where high-shore species are extirpated due to habitat loss, and social: where beach-visiting is not possible at certain times, and development immediately behind the shore is at increasing risk of wave damage. Further, reduced supplies of terrigenous sand to the coast through estuaries from sand mining, dams and weirs can result in erosion and inland realignment of the shore, also placing development at risk.

RESPONSE



Ten priority actions for managing and conserving coastal biodiversity are identified in the NBA 2018 (Harris *et al.* 2019c). For KZN beaches, the most salient are:

1. Restore and maintain coastal ecological infrastructure to strengthen climate resilience and sustain ecosystem services and benefits. This includes implementing conservative coastal management lines and carefully planning future development to ensure the littoral active zone remains intact; rehabilitating dunes; and addressing pollution.
2. Re-establish natural sand supplies to the coast, where possible, to replenish sand-starved beaches and dunes and thereby maintain benefits of coastal protection, sustain South Africa's most important biodiversity asset for tourism, and safeguard our unique beach biodiversity. This critically includes ensuring sufficient freshwater and sediment flows through estuaries to the coast.
3. Reduce the impacts of mining by stopping illegal mining, avoiding biodiversity priority areas, and improving rehabilitation and developing a sand mining policy.

Particularly important is the revising and ground-truthing of the methodology for measuring beach ecological condition. This may require identifying ecological or biological indicators that could be monitored for temporal analyses of the state of sandy shores in addition to the physical metric of coastal development and other landcover change.

Data Requirements

Harris, *et al.* (2019a) provides on overview of beach extent in KZN. Indicator data comes from the NBA 2018 (ecosystem threat status: Sink, *et al.* (2019a); ecosystem protection level: Sink *et al.* (2019b)). Ecological condition is important and information from NBA 2018 (Sink, *et al.* 2019a) and Harris, *et al.* (2015) has been used in this assessment. Data on habitat loss is included based on the National Landcover 1990, 2014 and 2018 (Skowno, 2020; Skowno, *et al.* 2019b).

4.2 SWAMP FORESTS

Dr Taryn Riddin and Prof. Janine Adams (Institute for Coastal and Marine Research, NMU)

INTRODUCTION

Swamp Forest is a freshwater habitat found in estuaries, freshwater lakes and drainage areas in subtropical and tropical regions of KZN and the Eastern Cape. It occurs as pockets and ribbons at altitudes between 20 m to 60 m and includes common tree species such as *Hibiscus tiliaceaus*, *Syzygium cordatum*, *Barringtonia racemosa*, *Voacanga thouarsii* and *Ficus trichopoda* with an understory of ferns (*Microsorum punctatum* and *Nephrolepsis biserrata*) and creepers (*Stenoclaena ternifolia*). *F. trichopoda* (swamp fig) and *B. racemosa* (powder-puff tree) are protected under the National Forests Act of 1998, and cannot be cut, disturbed, damaged or destroyed. The endemic *Raphia australis* (raffia, giant palm) is restricted to Maputaland, where it occurs at Kosi Bay and the Siyaya Estuary (Obermeyer and Strey 1969). Trees often overhang the open water, shading out reed and sedge habitat. In the absence of submerged macrophytes, their leaf litter contributes substantially to the detritus food chain in estuarine ecosystems. Swamp Forest soils are generally fine, muddy, waterlogged, and anoxic with organic humus and a peat-like layer, except in St Lucia Estuary where they are sandy, sandy loam or loamy sand with moderate to high organic content. The habitat is classified as Critically Endangered with only 67% occurring in protected areas (Van Deventer *et al.* 2021). It was recently recognised as an integral part of the Estuarine Functional Zone, which has improved its level of protection countrywide.

Mdloti Estuary, January 2019
Photo: Janine Adams

DRIVERS

Alteration of normal water flow patterns in the estuary and removal, or destruction of habitat are the main threats to Swamp Forests. Species such as *F. trichopoda* are sensitive to fluctuations in hydroperiod and soil moisture, in contrast to *B. racemosa* which tolerates greater hydrological change. Salt-water intrusion has caused mass mortality of trees in the Richards Bay area because of changes in water dynamics following port development. Swamp Forest is harvested for building materials and traditional medicines and is cleared to make way for subsistence farming. Illegal and unsustainable slash-and-burn practices have destroyed large areas of Swamp Forest in the Kosi Bay Estuary. Habitat removal for residential and industrial developments, roads and bridges has reduced tree cover in many south coast estuaries. Altered soil conditions encourage habitat invasion by terrestrial and alien plants such as *Chromalaena odorata*, *Lantana camara*, and *Pereskia* species, as evident in the Mpenjati Estuary. Fungal disease can affect species, such as *B. racemosa* causing the loss of unripe fruit.

PRESSURES

Swamp Forest is threatened by draining land to cultivate agricultural crops, and by prolonged inundation from fresh or saltwater following closure of an estuary mouth. In rural areas, forest trees are sources of food, construction material, and medicine, and are often harvested excessively. Illegal slash-and-burn agricultural practices in northern KZN, particularly in the iSimangaliso Wetland Park, have removed large Swamp Forest areas and threaten the survival of this sensitive habitat.

STATE

Historic perspective

In 1972, early surveys of KZN estuaries recorded the presence of Swamp Forest but gave little estimate of scale. Van Niekerk *et al.* 2019 measured estuary habitat change over time and recorded loss of Swamp Forest in the uMhlangomkhulu (10 ha), iFafa (2,6 ha), uMkhomzi (10 ha), aMamzanamtoti (3,3 ha), aManzimtoti (1 ha), uMhlali (19,1 ha), uThukela (1,5 ha), uMgobezeleni (452 ha) and Kosi (52 ha) estuaries, accounting for about 16% of the total. This loss results from encroachment by sugar cane farming, industrial development, recreational infrastructure and roads. Swamp Forest habitat has been lost to the Mzumbe (described in 1972 as a remnant forest), Mhlabatshane (originally noted as an established Hibiscus fringe), Mhlungwa (described earlier as bordering the system) and Mahlongwana estuaries. In some cases, the habitat has increased because closed mouth conditions have led to gradual freshening of the system that encourages colonisation by some tree species. The uMgobezeleni Estuary experienced an extensive die-back of mangroves after the construction of a causeway that reduced saltwater intrusion. Swamp Forest has since increased in this estuary as the water body became less saline.

Current state

Total Swamp Forest area in KZN estuaries is estimated to be 3430,5 ha (Table 4.1; Van Niekerk *et al.*, 2019). Those with more than 100 ha cover are the iMfolozi (1683,1 ha), Kosi (869 ha), uMgobezeleni (416,6 ha) and uMlalazi (104 ha) estuaries. The largest cover occurs at the iMfolozi/uMsunduze Estuary with extensive cover in the Kosi Bay Estuarine Lake system. These systems need to be protected and monitored because of their high biodiversity importance. The other 70 estuaries have cover ranging from 0,01 ha (Mnyameni Estuary) to 17 ha (St Lucia Estuary) (Table 4.1).

The IUCN Red Data List categorised the conservation status of the dominant Forest Swamp species as of least concern largely because of their wide global distribution (*Hibiscus tiliaceaus, Syzygium cordatum, Barringtonia racemosa, Voacanga thouarsii and Ficus trichopoda*). However, this does not safeguard local stocks of these species which requires a more localised assessment.

Table 4.1: Area cover and presence/absence of two dominant swamp forest species in KZN estuaries where area > 1 ha (source NBA 2018, Adams *et al.* 2019).

Code	Estuary name	Area (ha)	Dominant species		Code	Estuary name	Area (ha)	Dominant species	
			B. racemosa	*H. tilaceus*				*B. racemosa*	*H. tilaceus*
1	Kosi	869.0	x	x	33	uMahlongwane	4.0		
2	uMgobezeleni	416.7	x	x	37	uMzimayi	2.8		
3	St Lucia	17.4	x	x	38	uMuziwezinto	4.5	x	x
4	iMfolozi/uMsunduze	1683.1	x	x	43	iFafa	6.6	x	x
4	Port of Richards Bay	16.0	x	x	46	uMnamfu	4.0		x
6	uMlalazi	104.0	x	x	47	uMakhosi	7.0		x
8	iSiyaya	3.7	x	x	48	uMfazezala	5.0		x
9	aMatigulu/Nyoni	195.0	x	x	49	uMhlungwa	1.0	x	x
10	iZinkwazi	11.3		x	50	uMhlabashana	11.5		x
13	iNonoti	1.0	x	x	52	iNjambili	6.3	x	x
14	uMdlotane	12.3	x	x	53	iKhoshwana	6.0	x	x
15	uMvoti	2.0	x	x	54	iDombe	9.0	x	
16	uSetheni	4.0		x	56	uMthente	2.0		
18	uMhlali	7.0	x	x	57	uMzimkhulu	4.5		
19	uThongathi	3.4		x	58	uMbango	15.0		x
20	uMdloti	7.8	x		59	iBilanhlonhlo	1.1		
23	Durban Bay	5.0	x		60	iZotsha	5.0	x	
24	iSiphingo	16.0		x	67	iMbizana	3.0		x
26	aManzimtoti	2.5	x		68	iKhaba	1.1		x
27	aManzanamtoti	6.5	x	x	69	uMhlangomkhulu (S)	4.0		x
28	iLovu	5.0		x	70	iMpenjani	6.0		x
29	uMgababa	2.6	x	x	71	iKhandalendlovu	5.2	x	
32	uMkhomazi	10.0		x	72	iKhandalendlovu	3.0		x
						Overall total	3430.5		

IMPACT

The destruction of Swamp Forest up to the water's edge in Kosi Bay Estuary, for example, has resulted in serious erosion to the estuary banks and considerable loss of trees. The absence of litter fall negatively affects detrital trophic pathways and nutrient flows in the estuarine ecosystem. The loss of trees also represents a loss of carbon storage capacity (Swamp Forest can store 0,046 to 0,06 t C/m^3). The removal of vegetation cover causes oxidation of the peaty soils, reducing organic matter, making the soil infertile, and limiting its ability to hold water. The erosion of surface sediment has caused siltation in the Kosi Bay lakes, changing water flow patterns and increasing turbidity that affects the growth of submerged macrophytes and, in turn, fish and invertebrate communities that depend on these beds for shelter and food. Factors impacting the production of these groups ultimately affect the livelihoods of subsistence fishers and their families who depend on the estuary for food.

RESPONSE

Being critically endangered, swamp forest cover should be tracked through focused monitoring programmes that quantify change in habitat area and species composition. Factors driving change, such as those related to human activities, should be incorporated to identify cause-effect relationships so that measures can be taken to avoid irreversible habitat loss. Education and awareness can be improved with signboards, and citizen science participation encouraged to ensure ownership and protection.

Data Requirements

Data is needed on changes over time in the extent of swamp forest cover. Traditionally, cover was tracked using digital aerial images. Results were sometimes inaccurate because swamp forest often lies interspersed with mangrove and coastal forest, leading to under- or over-estimations. Multispectral satellite imagery is useful in inaccessible areas and allows mapping to species level. Leaf spectral signatures combined with remote sensing techniques enable change in plant biomass and health to be measured. Multispectral satellite imagery should be used to determine the current baseline and track changes over time.

4.3 ROCKY SHORES

Dr Kaylee Smit (UCT and SANBI)

INTRODUCTION

Rocky shores in KZN support a great variety of flora and fauna, each physiologically adapted to a harsh and dynamic physical environment, driven by large environmental gradients at the land-sea interface (Blamey and Branch 2009, Sink 2001, Sink *et al.* 2005). The tidal-driven inundation by waves and the different physical environments this creates is reflected in the zonation of plants and animals in this intertidal strip; well described by Branch and Branch (2018). Vertical zonation patterns can be readily distinguished on most rocky KZN shores, from the upper layers dominated by minute periwinkles to the lowest levels where redbait, echinoderms and seaweeds dominate. These zones are usually most obvious when encountered along a steep shoreline. More detailed descriptions can be found in Steyn and van der Elst (2014) and Branch and Branch (2018).

KZN intertidal rocky shores are a valuable ecosystem that have contributed to the food security of coastal communities for millennia, evidenced by coastal middens of shellfish harvested from KZN rocky shores (van der Elst 2020). Although this widespread subsistence harvesting continues, it is much patchier and more inconsistent (Kyle *et al.* 1997, Sink 2001, Tomalin and Kyle 1998). Extensive research has been conducted on the subsistence fisheries of KZN and the dynamics of important harvested species including mussels (mostly *Perna perna*), redbait (*Pyura stolonifera*) and oysters (De Bruyn *et al.* 2009, Kyle *et al.* 1997, Kyriacou 2017, Mead *et al.* 2013). Rocky shores and their associated micro-habitats and rock pools are also important nursery grounds for nearshore coastal and estuarine fish species (Steyn and van der Elst 2014, Strydom 2008).

The KZN intertidal zone is divided into two distinct biogeographic regions, namely the northern Delagoa ecoregion and the Natal ecoregion in the South (Sink *et al.* 2019a, Sink *et al.* 2005). Recently, these zones were further divided into sub-sections based on wave exposure, which is an important driver of rocky shore ecology and a key determinant of long-shore biodiversity patterns (Sink *et al.* 2019a, Menge and Branch 2001, Blamey and Branch 2009, Branch and Branch 2018). A total of 23 rocky and mixed shore ecosystem types have been mapped for the South African coastline, including five in KZN: the Delagoa Very Exposed Rocky Shore, Natal Boulder Shore, Natal Exposed Rocky Shore, Natal Mixed Shore and the Natal Very Exposed Rocky Shore (Sink *et al.* 2019b).

DRIVERS

URBANISATION

It has been reported that (2019) 62% of South Africans are living in urban areas (Section 2.2). In KZN, most reside in the coastal municipalities around Durban and Richards Bay (EDTEA 2017). Population growth in KZN results in an increased need for food to feed the growing population putting increased pressure on the natural environment (EDTEA 2017).

POVERTY

High levels of poverty in KZN, exacerbated by poor service delivery often results in untreated waste and effluent (including rubbish and debris) being introduced to rivers and streams; ultimately ending up in coastal environments (EDTEA 2017). High levels of unemployment may put non-sustainable pressure on intertidal resources, threating the resource as well as leading to conflicts with other fishing sectors (Sink *et al.* 2019b).

COASTAL DEVELOPMENT

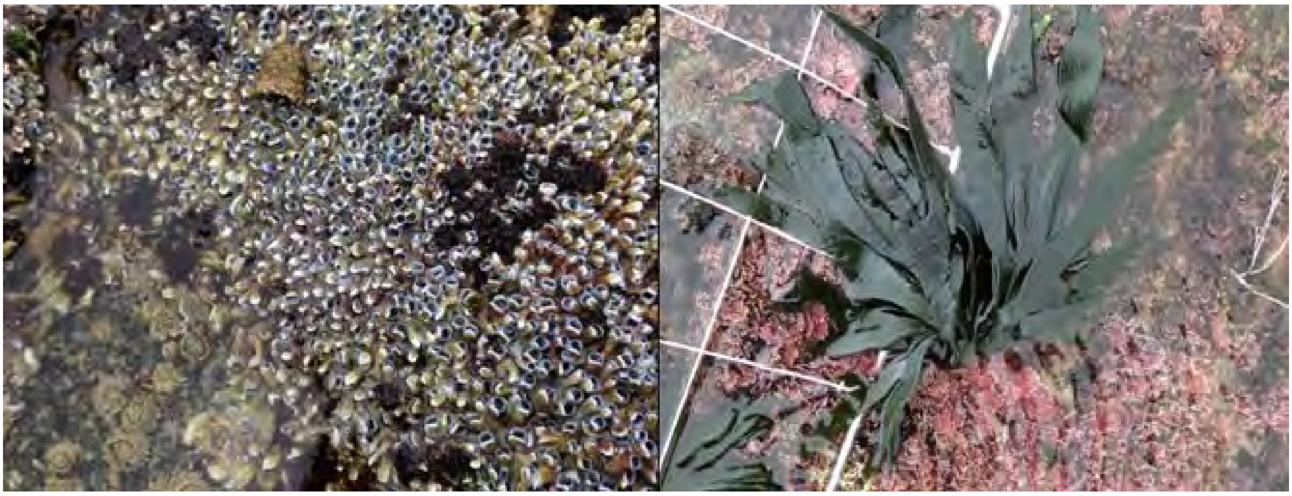
Poorly planned coastal development, often associated with urbanization or tourism, can be a significant driver of change in rocky shore ecosystems. While some of these drivers have a direct impact, such as causing direct reef damage, there are also several indirect consequences: waste discharge into the intertidal zone, runoff from large, paved areas, altered sand dynamics smothering reefs, shading of reefs from natural sunlight as well as increased harvesting and foot-pressures from growing coastal populations (Sink *et al.* 2019a).

CLIMATE CHANGE

Predicted climate-induced changes include more frequent storms and high destructive seas, flooding, rainfall variability, increased air and sea surface temperatures and sea-level rise (EDTEA 2017, Kelly *et al.* 2019). Any of these factors can potentially disrupt ecological processes in the rocky zone. While in some cases this may directly destroy mussel and redbait beds, in others this may be more subtle and longer term. For example, temperature induced changes may alter fecundity, species composition, or facilitate invasions of alien species (Sink *et al.* 2019a, Mvula, 2020).

GOVERNANCE

Living resources fall primarily under the Marine Living Resources Act (1998; MLRA); coastal zone



Left: A blue coral worm, *Pomatoleios kraussi*, showed an increased abundance at the Ballito rocky shore monitoring site during the Ezemvelo 2014/2015 period. Right: A macroalgae species, *Codium platylobium*, at the Trafalgar sampling site.
Photos: Jennifer Olbers 2015

issues fall under the ICM Act while mining is answerable to the Mineral and Petroleum Resources Development Act of 2002. While the MLRA is the main legal instrument for living resources, confusion reigns over legal responsibilities, resulting in fragmented governance and implementation by government departments, threatening the effectiveness of these mechanisms in protecting coastal ecosystems (Goble *et al.* 2014).

PRESSURES

Some of the main pressures affecting rocky shore ecosystems include subsistence harvesting/ overexploitation, recreational harvesting, poaching, pollution, invasive alien species, mining (including sand mining), sand inundation and climate change. Many of these pressures are attributed to an overall higher level of coastal development (EDTEA 2017, Olbers 2017, Sink *et al.* 2019a, Steyn and van der Elst 2014).

Rocky shore biota are excellent indicators of water quality in that they are sessile filter feeders and hence bio-accumulate substances attributable to a specific site (Burrows *et al.* 2014). Furthermore, trends in rocky shore resources, such as key harvested invertebrate species (e.g., *Perna perna*) can serve as good indicators of the impacts of human pressures on rocky shores ecosystems, while changes in size, composition and other community assemblage patterns are important indicators of rocky shore processes and functioning (Kyle *et al.* 1997, Sink 2001, Olbers 2017). Using a combination of these indicators will advance our understanding of the pressures subjected through natural and anthropogenic drivers of change of rocky shore ecosystems.

STATE

Historic perspective

Subsistence harvesting of intertidal rocky shore species dates back 160 000 years (Marean 2007), with most effort targeting mussels (*P. perna* on the east coast of KZN) but significant quantities of limpets were taken too (Mead *et al.* 2013). Historically there is evidence of higher levels of exploitation in Maputaland on the north coast of KZN (Kyle *et al.* 1997, Tomalin and Kyle 1998, Sink 2001). Sink *et al.* (2005) found that *P. perna* was much less abundant on Maputaland shores but that this area demonstrated higher abundances of redbait, *Pyura stolonifera*, another important harvested species, compared with the southern biogeographic region of KZN (Kyle *et al.* 1997). However, these patterns in Maputaland could be inflated by a few monitored sites that have high densities of *P. stolonifera* (Kyle *et al.* 1997). Kyle *et al.* (1997) suggested that generally, subsistence harvesting in Maputaland was sustainable, based on stable catch per unit effort (CPUE) rates between 1988-1994 and no decline in availability and size of mussels. This appears to have changed in recent years though, based on declining stocks throughout KZN (discussed in the following section). In contrast, CPUE of limpets showed a marked decline at Rabbit Rock (a specific monitoring site in the Maputaland area) from 1989, despite a downward trend of harvesting effort (Mead *et al.* 2013). Limpets appeared to be overexploited in Maputaland; however, there are signs of recent recovery at Rabbit Rock (Mead *et al.* 2013). Redbait is a common bait species for anglers, which may account for the low densities observed in the southern parts of KZN.

A commercial rock oyster (*Striostrea margaritacea*) fishery has been operational in KZN since the late 19th century, with initial declines in biomass observed in the early 1900's, which appeared to stabilise once a rotational harvesting approach was implemented in 1955 (De Bruyn *et al.* 2009). All management zones in KZN were depleted to 30-40% of 1984 stock levels; however, exploitation rates have decreased in the last 20 years and oyster populations seem to have stabilised (De Bruyn *et al.* 2009, DEFF 2020).

Current state

Recent studies have shown an overall decline in intertidal species catches (Mead *et al.* 2013, Mvula 2020). However, additional monitoring and data are required to fully understand the drivers of these patterns, whether it's overexploitation, changes in harvesting effort (or methods/technology) or environmental causes. Despite an initial decline in biomass of the cape rock oyster, *S. margaritacea*, improved management of this species has resulted in sustainable exploitation of this resource (De Bruyn *et al.* 2009, DEFF, 2020) however, a detailed stock assessment is required to fully understand the status of oysters. The latest report of the status of marine fishery resources in South Africa suggests that oysters in KZN are fully and optimally exploited but harvesting rates have still declined in recent years (DEFF 2020), which should be monitored closely. Ezemvelo conducted rocky shore biodiversity monitoring surveys between 2008-2019 at multiple sites along the KZN coast, spanning the Delagoa and Natal ecoregions (Olbers 2017). Overall, results from these studies have shown that rocky shores in the Natal ecoregion appear to be highly resilient and demonstrated good condition with relatively high abundance of key functional groups and diverse communities (Figure 4.5 and Figure 4.6; Olbers 2017, 2015). However, plastic pollution and marine debris appear to be having negative impacts on the rocky shores at Isipingo (Olbers 2017).

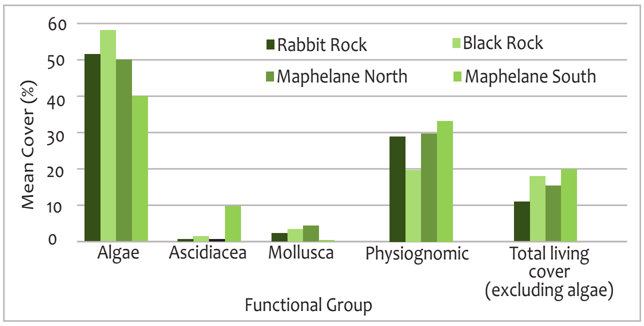


Figure 4.4: Percentage cover of four main functional groups and the total living cover (excluding algae) of biota from rocky shore monitoring sites from the iSimangaliso Wetland Park in Northern KwaZulu-Natal. Source: Ezemvelo KZN Wildlife Monitoring programme (Olbers 2017).

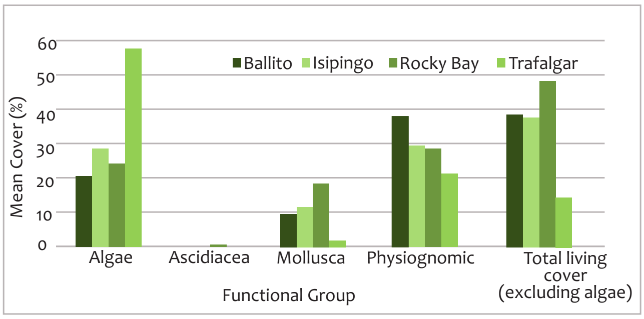


Figure 4.5: Percentage cover of four main functional groups and the total living cover (excluding algae) of biota, from four sites in the Natal ecoregion on the south coast of KZN. Source: Ezemvelo KZN Wildlife long term rocky shore monitoring programme (Olbers 2017).

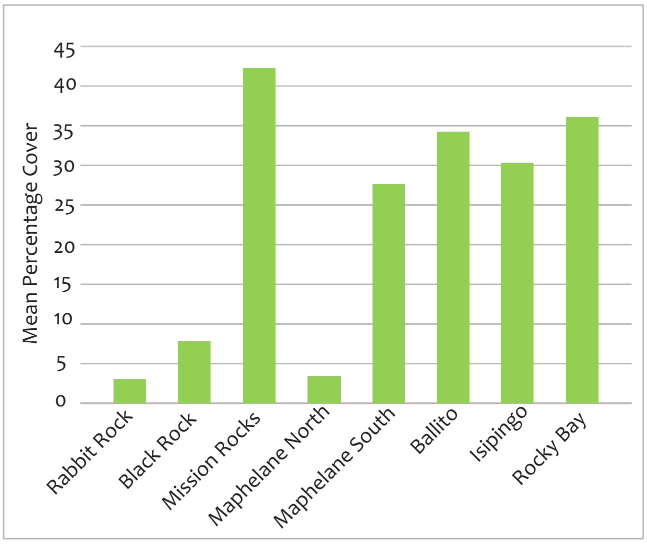


Figure 4.6: Mean percentage cover of the brown mussel, *Perna perna*, from monitoring sites along the KZN coast. Source: Ezemvelo KZN Wildlife long term rocky shore monitoring programme (Olbers 2017).

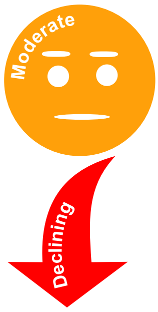
Surprisingly, rocky shores in Maputaland, which occur in established marine protected areas, are not in as good a condition compared with those in southern KZN (Figure 4.4; Olbers 2015, 2017). There is evidence of large declines in mussels, *P. perna*, and redbait, *P. stolonifera*, at the Black Rock and Rabbit Rock sites (Olbers 2015). Furthermore, there were much higher abundances (percentage cover) of algae compared with important functional groups such as Ascidiacea and Mollusca (Figure 4.4), which suggests that these sites are overexploited and demonstrate signs of ecosystem degradation (Mead *et al.* 2013, Olbers 2015, 2017).

A recent study compared the community composition of rocky shore ecosystems at 14 (re-sampled) sites in KZN, to surveys conducted in the 1990's (Mvula 2020). Significant changes in community composition were observed, showing an increase in species richness and evenness at most of the sites. However, these changes were a result of a decline in harvested mussels, an increase in coralline algae, an invasion of two new species of alien barnacles and a southward range expansion of a subtropical barnacle species (Mvula 2020). These findings include initial evidence of potential climate-induced impacts on rocky shores in KZN; however, additional monitoring and data analyses are required to support this.

IMPACT

If not managed properly, overexploitation of economically important invertebrate species will reduce the sustainability of these species (e.g., mussels, redbait and limpets), resulting in a decline of resources which support subsistence fisheries and livelihoods of vulnerable coastal communities. Changes in community structure, in combination with impacts from climate change, can decrease the resilience of rocky shore ecosystems resulting in a loss of important ecosystem services such as the provision of diverse microhabitats, nursery sites for coastal fish species and water filtration (Sink *et al.* 2005, Strydom 2008, Mead *et al.* 2013).

RESPONSE



Improved management of rocky shore subsistence fisheries is needed, particularly in the Delagoa ecoregion, where some sites, despite being within marine protected areas (e.g., Black Rock), are showing signs of overexploitation and degradation (Sink *et al.* 2005, Olbers 2015, 2017). Management interventions are needed at Isipingo where wastewater effluent and increased plastic pollution is having a detrimental impact on rocky shore communities (Olbers 2017). Continued and additional long-term monitoring at rocky shore sites along the KZN coast is required to identify the status and trends of rocky shore ecosystems. Biomonitoring such as Mussel Watch should be reinstated in KZN to monitor indicator species for water quality and heavy metal pollution.

Data Requirements
Operation LIMPET currently serves as South Africa's national rocky shore monitoring programme, which aims to detect climate impacts on coastal biodiversity. Results from Mvula (2020) were obtained as part of the national monitoring programme. It is considered important that the programmes currently underway (ORI and EKZN) should collaborate to avoid duplication and maximise benefits.

4.4 COASTAL LAKES

Fiona MacKay (ORI) and Steven Weerts (CSIR)

INTRODUCTION

Lacustrine freshwaters are an important component of the diversity of aquatic habitats in coastal KZN, with 13 coastal lakes in the province (Figure 4.7). These are standing bodies of open freshwater, often surrounded by vegetated wetlands and swamps, and are different from estuaries in that they have no surface water connection with the ocean. They differ in size, but commonly have low surface water inflows and are primarily fed by ground water from primary aquifers. This has implications for the water chemistry and ecological characteristics of these lakes, the threats they face from surrounding land uses.

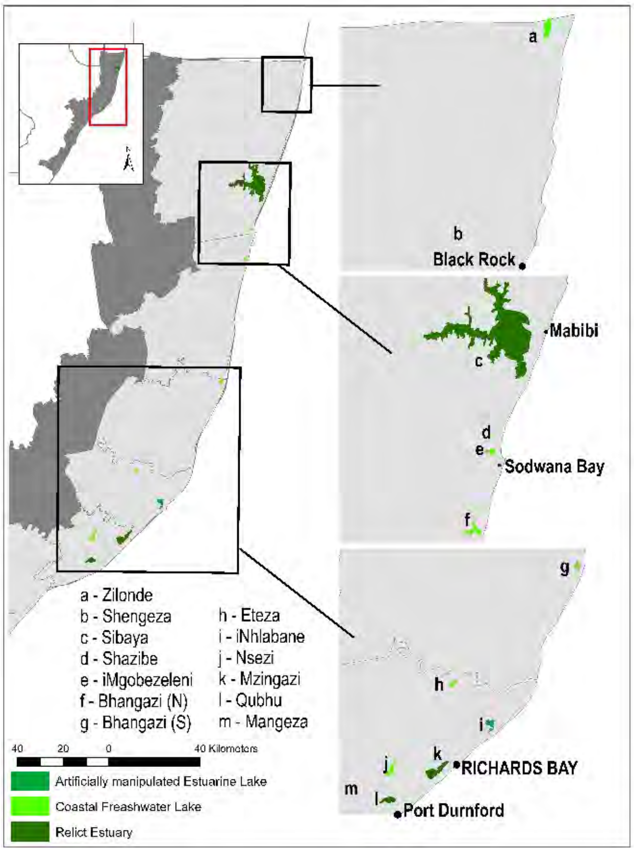


Figure 4.7: Locations of northern KZN coastal lakes around Richards Bay and in Maputaland.

LOCATIONS, ORIGINS AND CHARACTERISTICS

The arid climate and relatively short drainage systems mean that natural lakes are rare in South Africa (Whitfield *et al.* 2017). Coastal lakes in KZN occur to the north of the Thukela River (Figure 4.7), their formation promoted by the topography, porous sandy sediments and high-water table of the flat Mozambique peneplain. All but Shengeza, Nsezi and Mangeza were likely estuarine in the early stages of their evolution (MacKay *et al.* 2014) when during the Holocene rising sea-level flooded coastal river valleys (Hill 1975). Lakes were separated from their original estuaries by segmentation (Qubhu, Mzingazi, Zilonde) or by sedimentation (iMgobezeleni, Shazibe, Eteza, Bhangazi South). In the case of Sibaya, Bhangazi North and iNhlabane, isolation of the entire former estuary from the marine environment took place through dune accumulation that provided a direct physical barrier between the lake and the ocean (MacKay *et al.* 2014). Around Richards Bay, coastal lakes separation from downstream estuaries has been expedited by anthropogenic activities. Berms and barrages have been constructed at the outlets of Qubhu, Mzingazi and iNhlabane to augment domestic and mining water supplies (Weerts and Cyrus 2001). The lakes differ in morphology (depth ranges from <1 m to 40 m) and size (from 7 to >7000 ha). Although they are freshwater lakes, their coastal location highly influences their hydrological and chemical characteristics and therefore their plant and animal communities are distinctly different from typical freshwater bodies (MacKay *et al.* 2014). Within these systems the different origins, hydrological and morphological characteristics creates a diversity of lake types and habitats with unique ecological characteristics.

ECOLOGY

With little surface water inflow, in their natural states most of these lakes are characterised by clear, oligotrophic water. Their food webs are based on autochthonous sources of primary production, mainly from reeds (*Phragmites*, *Typha*, *Scirpus*) and rooted submerged macrophytes (*Potamageton*, *Stuckenia*, *Myriophyllum*, *Ceratophyllum*) which all occur in the shallows. Connected swamp forests (and peatlands where present, Section 4.2) would have contributed to additional sources of dissolved and particulate organic matter, but these habitats have been destroyed around many systems. The dark, humic waters of Lake iMgobozeleni are an indication of the influence of surrounding drainage through swamp forests. The shallow littoral lake areas, with the greatest diversity of vegetated habitats, have the highest diversities of fauna. The estuarine origin of most of KZN coastal lakes is strongly reflected in their faunal communities with relict estuarine invertebrates (dominated by peracarid crustaceans) and fishes persistent in these disconnected freshwaters (Boltt 1969, MacKay and Cyrus 2000, Weerts and Cyrus 2001, Whitfield *et al.* 2017). It is these faunal components which make these systems biologically unique. They include IUCN endangered species, such as the barebreast goby *Silhouettea sibayi*, a small, cryptic species endemic to Southern Africa (discovered in Lake Sibaya). Other freshwater fishes that occur in these lakes such as the many-spined climbing perch *Ctenopoma multispine*, and the blackspot climbing perch *Microctenopoma intermedium*, are also rare and vulnerable partly because of their high specificity for standing coastal freshwaters. At the community level, fishes are considered unique to each lake as they represent the paleo-ecological history of connectivity and their evolved tolerances to wide salinity ranges and abilities to reproduce in lake environments (Whitfield *et al.* 2017). Larger invertebrates such as the catadromous paddler crab *Varuna litterata* make use of KZN coastal lakes that are still connected with the marine environment. Based on their relative abundance in these systems they appear to be a preferred habitat (Weerts *et al.* 2014).

DRIVERS

Expanding populations in urban and rural coastal KZN have increasingly placed pressures on the province's coastal lakes. This has resulted in state changes that impact the goods and services that people derive from these systems. Concomitant effects of climate change are especially important in the case of these coastal habitats, which are prone to impacts from drought. While these systems are appreciated as sources of freshwater and resources supporting various uses (including basic human needs) they are undervalued for their intrinsic contributions to biodiversity, ecosystem rarity and or as stepping-stone habitats for species that move across the floodplain via aquatic systems.

PRESSURES

WATER USE

Water use is the main pressure on these systems, either through direct abstraction of surface water for domestic, agriculture, forestry and mining purposes, or indirectly through groundwater impacts, with forestry being especially problematic. The recent extreme low lake levels in Lake Sibaya were a result of prolonged drought (2001-2016) over much of Maputaland. However, this was exacerbated by water used by commercial forestry. Estimates are that 35% of the drop in lake levels since 2001 were caused by forestry which covers a quarter of the lake's catchment (Smithers *et al.* 2017). Domestic water use, dune mining and various industrial activities requiring water have placed similar pressure on coastal lakes in the south. Lake iNhlabane is adjacent to extensive dune mining activities and it was completely impounded in 1977 to provide water for dredge mining of heavy minerals (MacKay *et al.* 2014).

POLLUTION

Coastal lakes are sensitive to water quality impacts given their naturally clear, oligotrophic states but historically they have been subject to low loading of nutrients and other potential contaminants because they are predominantly groundwater rather than surface water fed. However, various land-use activities have increased the pollution pressures. In the Richards Bay area pollution from failing sewerage infrastructure, municipal wastewater and stormwater inflows are the most problematic sources of pollution in the lakes that occur there. Agrochemicals (herbicides and insecticides) for subsistence farming and agriculture are likely pollutants in lakes to the north. Concentrations of DDT in Sibaya are amongst the highest reported in South Africa (Humphries 2013).

HABITAT DESTRUCTION

In northern KZN, coastal lakes are largely restricted to rural areas with lower population densities, but they are subject to pressures from rural sprawl, forestry (including small-scale growers) and agriculture. Coastal and swamp forests and critically important peatlands have

Lake Sibaya (2020) at critically low water levels due to drought and extreme water use pressures. ***Photo: Fiona MacKay***

been cleared for small-scale food production (Van Deventer *et al.* 2018). Lakes Qubhu and Mzingazi are under greater pressure from habitat destruction from urban development, agriculture and forestry, all of which encroach onto the shores of these systems.

RESOURCE EXPLOITATION

Direct exploitation of freshwater lakes resources includes harvesting of reeds, sedges and other vegetation for various uses. Fishing is conducted, in some cases using sustainable traditional methods, but increasingly resorting to dip nets and gillnets. Productivity in these systems is not high and they are prone to the effects of over-exploitation.

ALIEN INVASIVE SPECIES

The freshwater lakes present an ideal environment for the coastal freshwater invasives, and a set of alien invasive species including plants, invertebrates and the vertebrates similar to those that are problematic in the freshwater reaches of KZN estuaries, occurs. The invasive gastropod *Tarebia granifera* is well established in all systems. Water hyacinth (*Pontederia crassipes*) almost completely covers Lake Nsezi. Vermiculated sailfin catfish (*Pterygoplichthys disjunctivus*) has been found in Lake Mangeza, and carp (*Cyprinus* carpio) and bass (*Micropterus* spp.) are likely present in some systems outside of iSimangaliso Wetland Park. Largemouth bass (*Micropterus salmoides*) was introduced into Lake Sibaya in 1935 but subsequently has not been reported in scientific surveys of the system (Bruton 1979). Given the considerable effort spent by researchers sampling and studying the system in the 1970's it is likely that this early introduction was unsuccessful.

STATE

Good historic information exists for Sibaya based largely on research activities by the Institute for Freshwater Studies (Rhodes University) from 1965 to 1977, but for most KZN coastal lakes, basic information on lake levels and water quality are not available to assess present day, let alone historic conditions. In 2015 water levels in Lake Sibaya dropped to the lowest level in living memory and the southern basin separated from the main lake. Similar low lake water levels were experience in the Richards Bay area, with Mzingazi dropping to its lowest levels in over 50 years and fragmenting into separated north and south basins. The catchments in both systems are heavily afforested, and in the case of Sibaya water use by deep-rooted commercial trees exacerbated drought impacts to the limits of non-sustainable use of groundwater.
Limited nutrient data from Lake Sibaya suggest that rural development and forestry have influenced conditions in the western arm and southern basin, especially in the shallower peripheral areas. While causality is difficult to prove, increased sediment nutrient concentrations in the western arm of the lake are coincident with human settlement and the development of Mseleni Town and forestry development (Humphries and Benitez-Nelson 2013). Nutrient loading in Lake Nseleni undoubtedly contributes to the invasion of that system by water hyacinth, and other pollution tolerant biota. In addition to sources in stormwater and agricultural return flows this lake is subjected to pollution from municipal wastewater. Bacteriological data from Lake Mzingazi indicate that this is not a new phenomenon (Van der Wateren, 1998) but there is also little doubt that levels and frequency of pollution are increasing in these systems.

The information and trends from these can be broadly extrapolated to other systems. A uniform set of indicators of ecosystem state, and a method of integrating these has not been developed nor applied to coastal lakes in South Africa. However, using methods developed for lentic systems and last collectively evaluated for the 2018 National Biodiversity Assessment, coastal lakes in KZN were considered Critically Endangered and under-protected. The ecological condition of Lake Sibaya was 'Heavily to Severely/Critically modified' under assessment criteria adopted (Van Deventer *et al.* 2018). Given the similarity in pressures faced, other KZN coastal lakes are likely also modified and those systems outside of formally protected areas can be considered heavily modified. Although the geophysical origins of lakes have permitted select estuarine macrobenthic taxa (isopods and amphipods) to maintain good populations (Mackay and Cyrus 2001), weirs at the outlets of most of these systems are barriers to natural movement and migrations between lakes, estuaries and the ocean. This has compromised the full range of biodiversity capacity of these unique ecosystems, their connectivity with downstream systems and reduced the ecological function of these systems (Weerts *et al.* 2014).

Current pressures on coastal lakes in KZN are all increasing, and without management response the state of these systems will continue to decline. This will be exacerbated by climate change effects, especially widely fluctuating lake levels, and with an increasing threat of sea level rise on the flat coastal topography. Ultimately rising sea levels will likely re-connect systems to the marine environment and re-establish many of them as estuaries. Along the way to this end point, salinisation by groundwater intrusion is likely to impact these freshwater bodies causing largescale and permanent changes to their ecology and capacity to deliver freshwater supply.

Currently, some lakes are apparently well protected, with several located in areas under the management and compliance control of conservation authorities (iSimangaliso, Ezemvelo KZN Wildlife). However, no work has been done to assess whether all, or what proportions of representative coastal lake types, habitats or biota are protected, and what is the *threat status of the ecosystem subtypes*? Lake Sibaya, the largest coastal lake in KZN, and South Africa, for example, is a designated RAMSAR site and forms part of the iSimangaliso Wetland Park. However, legal protection applies only to the lake surface and not the littoral and surrounding terrestrial components (Combrink *et al.* 2011).

IMPACT

Connectivity impacts (biodiversity and system function losses) caused by barriers to faunal migration at coastal lake outlets in KZN are now well understood (MacKay and Cyrus 2001, Weerts *et al.* 2014). Other forms of habitat alteration invariably cause loss of biodiversity and reduce systems resilience to future anthropogenic and natural (climate change) pressures. Falling lake water levels have already been shown to result in large losses of marginal habitats which are the most ecologically significant areas in these lakes. Extreme lake level reductions result in habitat fragmentation, with some lakes already seen to separate into isolated basins at low levels. This results in population fragmentation and increases the propensity for edge effects (resulting in increased pollution and erosion impacts and increasing the introduction of invasives species). While vegetation tends to follow lake levels down at a pace that support continued ecosystem function this biomass is drowned when lake levels increase and widely fluctuating water levels can lead to high loads of decaying organic matter, with water quality impacts. Loss of supporting marginal habitats (wetlands, swamp forest and peatlands) contributes to this.

Low lake levels also exacerbate pollution threats as lower lake volumes have lower assimilation capacity. The oligotrophic nature of KZN coastal systems is easily impacted by nutrient inputs, and at the extreme eutrophication impacts are possible. Accumulation of DDT has been detected in the sediments of Lake Sibaya and other nearby water bodies (Buah-Kwofie *et al.* 2017) and is being passed in the food chain to higher trophic levels (Humphries 2013) and carried by groundwater seepage to coral reefs off Sodwana Bay (Porter *et al.* 2018). Pollution impacts not only have biodiversity and ecosystem function impacts, but also impact human health, particularly for communities that are reliant on coastal lakes as sources of drinking water, or for livestock waters and subsistence agriculture.

The impacts of resource exploitation in KZN coastal lakes are little studied, except for those associated with water use. Given the increase in population and the use of gillnets in these systems it is highly likely that populations of larger fish species are declining. The crocodile population of Lake Sibaya has undergone marked decline since 1990, likely due to the perceived threat posed to life and livestock, destruction of crocodile eggs, harvesting for medicinal/

economic purposes, gillnet mortalities and nest disturbance by livestock (Combrink *et al.* 2011). This is likely true for other large fauna (notably hippos) and at other coastal lakes outside of formally protected areas. Invasive alien plants are present in lakes around Richards Bay. Lake Nsezi is the most impacted with water hyacinth almost completely covering the water surface. This floating macrophyte has known long term water quality impacts, reducing oxygen available for biota and, in Lake Nsezi, has a significantly negative impact on aquatic macroinvertebrate biodiversity (Coetzee *et al.* 2014). The invasive gastropod *Tarebia granifera* outcompetes local mollusc species in KZN coastal lakes and occurs in abundances high enough to be considered habitat altering. Dead shells dominate the sediments in shallow littoral areas of some systems, altering the sediment granulometry and benthic community composition.

RESPONSE

Coastal lake water use, pollution, habitat destruction, resource exploitation and alien species can be summarily addressed by the *development and implementation of a set of integrative management tools* and *supporting monitoring programmes*. None exist, or are mandated, in specific legislation.

- As rare ecosystems in South Africa, *a strategic conservation plan* for coastal lakes needs to be developed and adopted. Particularly as many systems are in KZN, which has high development pressures and increasing socio-economic issues.
- A protocol for developing *Lake Management Plans* (comparable with EMPs) must be established and implemented. For these to be effective, a method of *identifying and protecting buffer areas* around lakes will be needed (such as the EFZ and CMLs). These tools should be used to aid land use management and inform spatial development plans around coastal lakes.
- Plans must *address compliance and enforcement*, which at present is weak.
- *Environmental water requirement* studies have been conducted on some coastal lakes around Richards Bay and Lake Sibaya, but the protocols and methods for Resource Directed Measures (RDM) are better for rivers and estuaries. Lacustrine freshwater requirement methods are a priority.
- Underpinning all the above, should be *systematic monitoring of lakes* to include abiotic and biotic components. This should include lake water levels and selected basic physico-chemical water quality parameters (continuous monitoring), as well as regular (monthly) discrete sampling for water quality parameters requiring laboratory analyses. Monitoring of sediments for metals and persistent organic pollutants can be done at much longer time intervals. Biological monitoring should include vegetation, diatoms, invertebrates, fishes and birds, with crocodile and hippo counts conducted on a regular basis in formally protected areas.

Data requirements

All lakes require morphology surveys to quantify lake volumes for lake water management and for predictive capabilities when considering climate change. Data should be collected and integrated with surveys that are conducted around neighbouring EFZs. There is a dearth of biological information on the lakes, even basic biodiversity inventories. Campaigns to collect specimens for species lists and genetic material may reinforce the rarity of these critically endangered ecosystem types. Associated vegetation and vegetated wetlands represent a possibly significant source of teal carbon. Climate change indicators are needed to use in risk evaluation, particularly given KZN's dependencies on coastal lakes. Lake-specific pressure assessments that evaluate e.g., harvesting, fishing, land-use are required to evaluate ecosystem state and impacts.

4.5 WETLANDS

Dr Heidi van Deventer (CSIR and WITS)

INTRODUCTION

The diversity of coastal rivers and inland wetlands provide essential ecosystem services to sustain life and ensure resilience against climate change. When these ecosystems are in good ecological condition and well-connected, they serve as ecological infrastructure offering a range of services, such as water provision (particularly during droughts), flow regulation, infiltration of rainfall to groundwater aquifers and sediment budget for the coast. However, when degraded, the impacts of climate change exacerbate the negative impacts of existing pressures.

A diversity of river and inland wetlands occur within KZN, with 76 rivers covering a length of 2 313 km along the KZN coast. While the areal extent of inland wetlands totals 84 526 ha within the coastal zone (National Wetland Map version 5; Van Deventer *et al.* 2020). About half of the rivers are perennial in nature, flowing throughout the year, the others are seasonal. These systems supply nutrient-rich waters to the fluvial-dependent marine ecosystem (Figure 4.8; Sink *et al.* 2019), and sediments which sustains beaches (Harris *et al.* 2019).

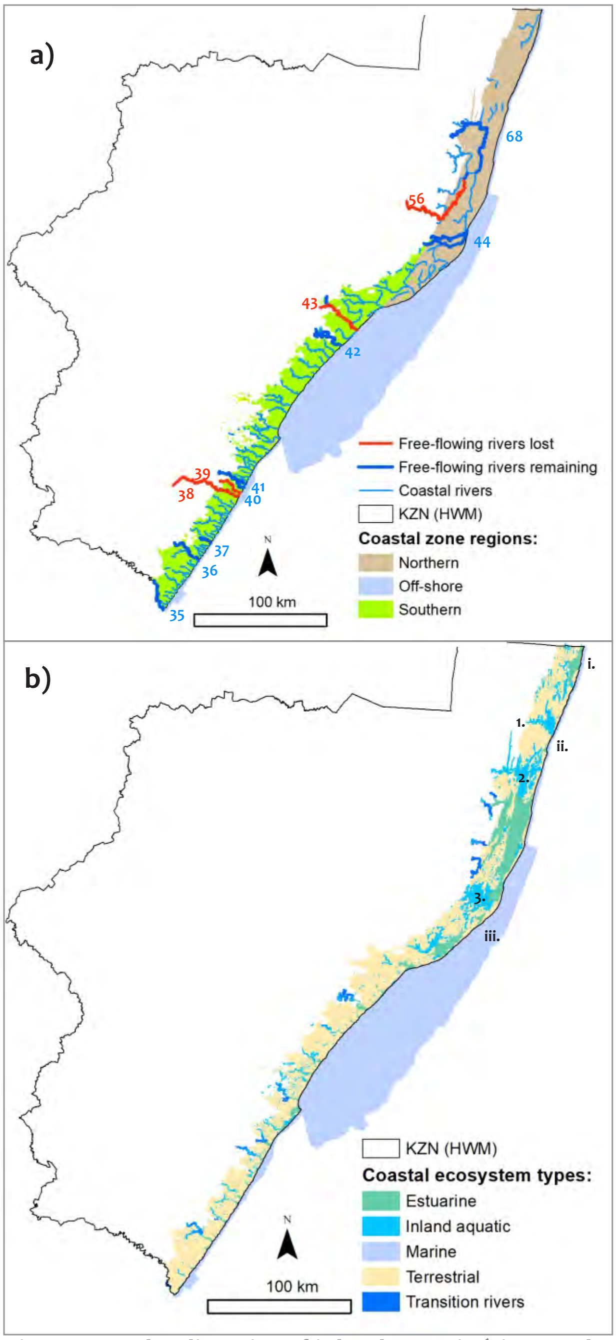


Figure 4.8: The diversity of inland aquatic (river and inland wetland) ecosystems of the KZN coast

A rich diversity of inland wetlands is found along the KZN coast, with two distinct regions being recognised. The southern region, along 304 km of the southern coast, covering a total areal extent of 546 208 ha, is home to 27% of coastal wetlands and 88% of KZN rivers. The northern region, which is generally referred to as the *Maputaland Coastal Plain (MCP)*, extends along the northern 273 km of the coast and covers an aerial extent of 516 426 ha (Figure 4.8a). The MCP is dominated by large, extensive floodplains feeding into estuaries. Inter-dune depressional wetlands intercept rainfall and cause it to percolate slowly through the sandy soils to more extensive wetland systems throughout the year. The MCP hosts 73% of the total areal extent of coastal KZN wetlands (Figure 4.8), while aquatic systems (rivers, inland wetlands and estuaries) are laterally connected through shallow groundwater aquifers, estimated to be 1-3 m below the surface (Kelbe *et al.* 2016).

It is important to note, that due to KZNs subtropical climate there is a higher prevalence of riverine and coastal swamp forests than the rest of the country. Swamp forests form a natural ecotone across the estuarine and inland wetland ecosystems (Figure 4.9, Section 4.2). Additionally, KZN is home to the largest peatland of South Africa and the oldest in the world. Peatlands in general offer exceptionally high ecosystem services and their climate change resilience functions are critical for the region.

DRIVERS

- **Water abstraction:** Increasing demands for fresh water both for increasing population and agricultural activities.
- **Water pollution:** Increasing nutrient addition from Wastewater Treatment Plants not functioning properly.
- **Loss of habitat:** Habitat transformation and fragmentation due to coastal development and land cover change.
- **Climate change:** Climate change can potentially drive changes. However, there is uncertainty as to whether the MCP is getting wetter or drier (Snaddon *et al*. 2019, Van Niekerk *et al*. 2019).
- **Dune Mining:** Mining at Richard's Bay has had a detrimental effect on water flow.
- **Farming practices:** Subsistence farming in the freshwater swamp forests have been changing to commercial operations. The use of foreign crops is not suited for these wetland areas.

PRESSURES

Several pressures have contributed to the deterioration and losses of rivers and inland wetlands and their associated freshwater species. Habitat transformation to agricultural food production has the most extensive impact on the surface cover of inland wetlands. Dune mining is expected to have a detrimental impact on the hydrological regime of surface and groundwater resources (Section 8.7). To date, no study has been published to elucidate the impact on rivers, wetlands and water quality during mining operations or after rehabilitation of dunes. At a smaller scale, sand mining in KZN coastal rivers is becoming an emerging pressure, with an estimated 50% of the coastal river systems impacted (Section 8.8; McKelvey and MacKay 2019/2020). These operations result in habitat transformation, loss of riparian and in-stream habitat, an increase in erosion and sediment load. They also result in a reduction in the infiltration of rainfall into the groundwater aquifer, which is critical for water provision during the dry season and particularly droughts. Slash and burn operations within the swamp forest of the MCP occurs with the draining of the substrate peat. This practice is often done for subsistence farming of the indigenous taro (*Colocasia esculenta*), locally known as *amadumbes*. These practices have increased in extent and intensity; the extent of swamp forest being cleared has drastically escalated and agriculture activities are more commercial. Foreign and more tropical crops, such as bananas, cassava and rice are being cultivated for sale. Drained peatland is prone to erosion and emissions of greenhouse gases since the organic material is no longer sequestered through inundation. Under persistent drought periods or poor land use management these peatlands can collapse.

***Nymphaea nouchali* var. *caerulea*, an aquatic plant found in KZN wetlands**
Photo: Fiona MacKay

STATE

Historic perspective

Wetlands, including inland wetlands and estuaries, are considered the most threatened ecosystems globally and in South Africa (Van Deventer *et al*. 2019, Van Niekerk *et al*. 2019). It is estimated that >85% of their extent has been lost to date, while the rate of current losses exceeds those of forests (IPBES 2019). Most of the river and inland wetland ecosystem types assessed at a national scale in the *National Biodiversity Assessment of 2018* (Van Niekerk *et al.* 2019, Van Deventer *et al*. 2019), are predominantly threatened and poorly protected. By the 1980s, 57% of the lower iMfolozi River catchment was transformed to sugarcane (Begg 1988), reducing the ecosystem service of this floodplain to buffer the area against intense storms.

Current state

Most rivers exiting the KZN coast (64%) originate within the coastal zone and are dominated by coastal climatic influences and the surrounding land uses in these catchments. The others (36%) are larger rivers, where the ecological condition is influenced by pressures outside the coastal zone. In terms of the *National Freshwater Ecosystems Priority Areas (NFEPA)*, 12 of the 78 rivers are assigned a free-flowing status (Nel *et al.* 2011), serving as examples of rivers in a good condition, sustaining ecological processes from source to sea. Five of the 12 were identified as priority rivers, called *"Flagship Rivers"*, namely, Mtamvuna (35), Mzimkhulu (36), uThukela (42), iMfolozi/Msunduzi (44) and Mkuze (68) (numbers in brackets: ID of the river in Figure 4.8a).

The drought of 2015/6 had a major impact on the wetlands of the MCP. An increasing trend in the number of wetlands with predominantly peat substrate (peatlands) have been burning within the past five years, compared to the decade pre-2015 (Grundling *et al.* 2021). Vasi Pan is, however, one of the exceptions, where 233 ha, or 67% of the whole wetland extent has burnt twice in the past 20 years due to the lowering of the water table, primarily by forest plantations. Such a draw-down can remove available surface water from an area as far as 2 km around the perimeter of the plantations (Bate *et al.* 2016).

A loss of natural and near-natural rivers due to loss of flow, water pollution and habitat transformation is a national concern (Nel and Driver 2015). The Ecological Condition Index of mainstem rivers showed an alarming loss of 49% of its total extent in a natural ecological condition since 1999. Only 12% of the extent of mainstem rivers on the KZN coast now remain in a natural ecological condition. River flow from source to estuaries has been reduced by at least 20% because of water abstraction, inter-basin transfers and trapping in upstream dams. Similarly, the sediment budget to the coast has also reduced by at least 20%, negatively impacting the coastal ecological processes and tourism (Section 4.1). The deterioration of the ecological condition of the coastal rivers, and loss of connectivity because of building dams, have also resulted in four of the 12 free-flowing rivers of the KZN coast losing their status (Van Deventer *et al.* 2019). Critical intervention is required to curb these concerning trends. Should rivers be left to decline at the rate of the current loss indicated by the Ecological Condition Index, the KZN coast is likely to lose their natural mainstem rivers by 2024.

Surveys conducted in the past three years showed that rivers are a major pathway for solid waste pollution (Naidoo *et al.* 2015, Verster and Bouwman 2020). The DFFE has a Source-to-Sea-Initiative in five rivers of the eThekwini Municipality (uMgeni, Umlazi, uMbilo, uMhatuzana and aManzimnyama rivers) to type the solid waste washing out through rivers to the beach and sea (DEA and WRC 2018). Minimising illegal and informal dumping and the urgent restoration of our Waste Water Treatmtent Works will contribute to the reduction of this emergent pressure.

IMPACT

Loss of habitats of rare and endangered species increase their risk of extinction. Urban, agricultural and mining development have also resulted in a decline in habitat for the Pickersgill's Reed Frog (*Hyperolius pickersgilli*), which is endemic to the coastal reed-bed wetlands of the KZN coast (Tarrant and Armstrong 2013). In 2016, the species was listed as Critically Endangered, but through ongoing survey efforts, the number of known sites increased from 8 to 38. Funding by the former DEA - Natural Resource Management, through the Working for Water programme, saw the removal of invasive species covering an area of approximately 1 000 ha, the replanting of indigenous wetland species, and a captive breeding program with the Johannesburg Zoo and Ezemvelo. These interventions resulted in the successful down listing of the status of this frog to Endangered (IUCN 2016).

South Africa's largest freshwater lake (one of only eight), Lake Sibaya, is found on the northern coastal plains of KZN (Figure 4.9). Lake Sibaya extends to 8 361 ha and has an average depth of 13 m and maximum depth of 41 m (Miller 1998) (Section 4.4).

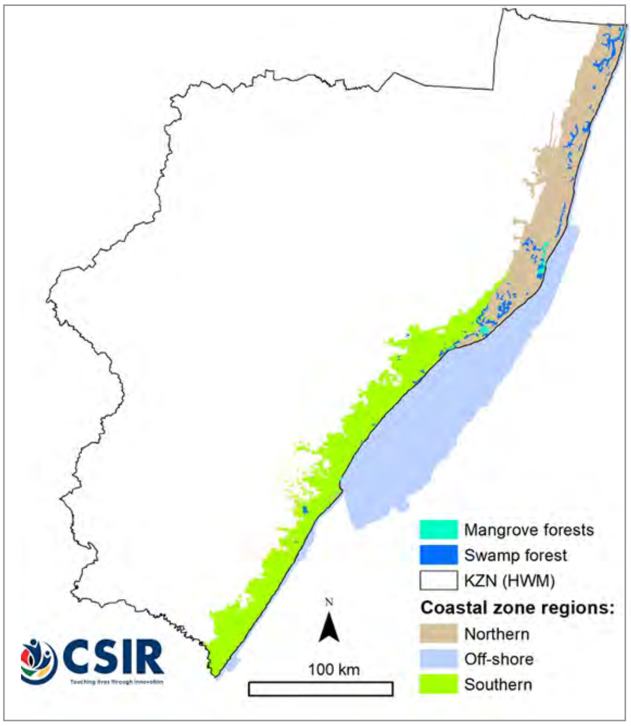


Figure 4.9: Estuarine and freshwater swamp forests of the KZN coastal zone.

Peatlands of the KZN Coast

Contributors: Dr Piet-Louis Grundling (DFFE & UFS), Dr Althea Grundling (ARC- Soil, Climate and Water & UNISA), Dr Heidi van Deventer (CSIR & WITS) and Jason le Roux (WETREST)

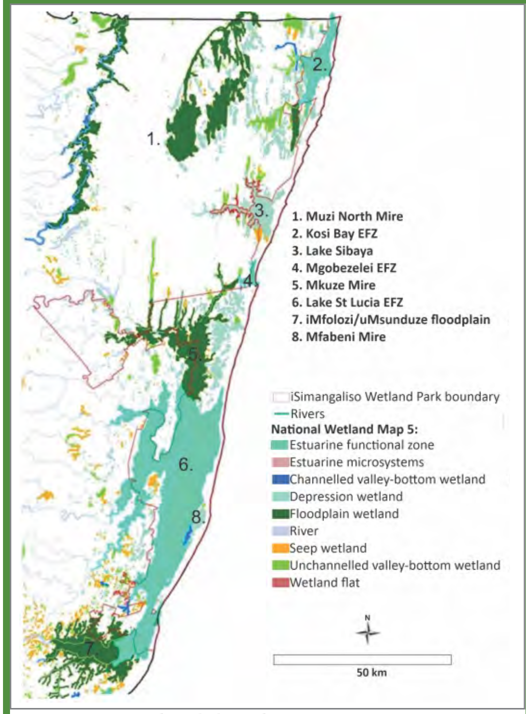


Figure A: Peatland distribution

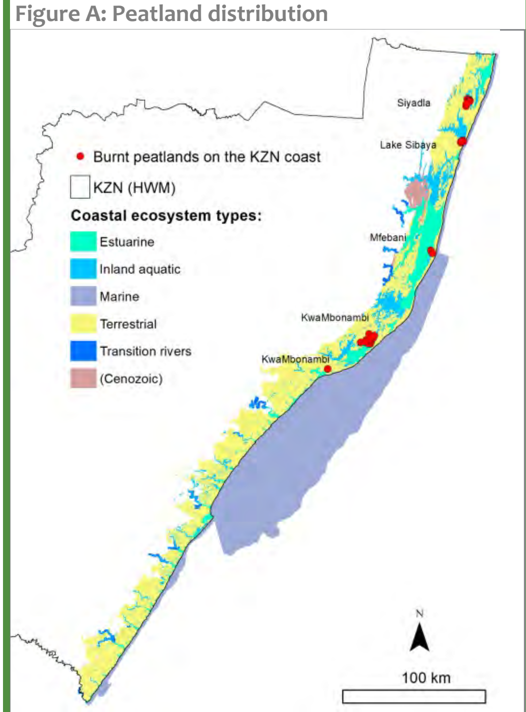


Figure B: Peatland fires recorded

Peatlands are wetlands which have a naturally high percentage (>30% dry mass) organic substrate (Joosten and Clarke 2002). The KZN coast presents some of the most unique and high-valued peatlands, with the MCP hosting the highest density of peatlands in South Africa (Thamm *et al.* 1996, Grundling *et al.* 1998). These peatlands started to form as early as 47 000 years before present, spanning the Late Pleistocene and Holocene periods (Thamm *et al.* 1996, Grundling *et al.* 2013, Baker *et al.* 2017). The world's oldest known peatland, the Mfabeni Mire (Figure A, 8) is 47 000 years old and is still accumulating peat (Grundling *et al.* 2013, Elshehawi *et al.* 2019).

The MCP peatlands are associated with inland wetlands, rivers and estuaries, and provide a high number of ecosystem services. These peatlands have the highest estimated carbon sequestration values for South Africa (estimated at almost 19 million t) and have recorded the highest rates of carbon accumulation 37 542 t/yr (Grundling *et al.* 2017) and are valued at R 8.8 billion (in 2017). The iSimangaliso Wetland Park alone is estimated to store 7 160 000 t of carbon (Grundling *et al.* 2000), being an asset to the country.

The Mkuze Floodplain (Figure A, 5) is the largest peatland in South Africa with 83% of its areal extent (8 800 ha) containing peat (Grundling *et al.* 1998, 2000). The carbon in this is estimated to contain 25% of the carbon deposited in South Africa's peatlands. However, the smaller Mfabeni Peatland (Figure A, 8; 1 462 ha) has a higher storage capacity of 1 768 t C/ha than the Mkuze (589 t C/ha). This is because it formed earlier than the Mkuze (Grundling *et al.* 2000, 2013).

The wetlands of the MCP are laterally connected through the groundwater that is on average 1-3 m below the surface (Kelbe *et al.* 2016). Rainfall infiltration connects inland wetlands, rivers and estuarine systems to one another. These resultant interconnected systems are difficult to define protection zones for. Eucalyptus plantations pose the biggest threat to peatlands, with deep rooting zones up to 28 m below surface and high evapotranspiration rates (Dye 1996, Bates *et al.* 2016), resulting in a large loss of available water and lowering of the groundwater table for a distance beyond 2 km around these plantations. Of concern, is that forestry increased by 4 557.7 ha [45.6 km^2] between 1990 and 2013/4 (Janse van Rensburg 2019). The lowering of the water table caused by these plantations resulted in a peat fire of 233 ha or 76% of the extent of Vasi Pan in 1996 (Grundling and Blackmore 1998) and more recently in 2014. After the recent drought of 2015/6, six of the 20 peat fires recorded in the country to date, occurred in the MCP region (Figure B, Grundling *et al.* 2021). The peat fires at KwaMbonambi, Lake Sibaya, Mfabeni, Siyadla, Vasi Pan and Vasi Pan North on the MCP have contributed an estimated amount of 437 581 t CO_2 emissions (Grundling *et al.* 2021).

Considering the uncertainty of climate change, which is expected to increase evapotranspiration rates and intensify droughts, the likelihood of permanent collapse of our peatlands are high and imminent. The complete eradication of forest plantations within MCP where it intercepts rainwater recharge or tap into the groundwater table is considered a top priority for the protection of our ecological infrastructure and peatlands.

RESPONSE

Even though 37% of the extent of the MCP falls within National Protected Areas (NPAs) or Ramsar sites, pressures outside these reserves continue to degrade rivers and inland wetlands within these protected areas. This is evident by the increasing burning of peatlands, decline of the extent and intactness of the swamp forests and deterioration of the ecological condition of rivers. Only 2.2% of the southern region falls within NPAs while this region has the highest rate of land transformation in the country (Skowno *et al.* 2019) and it is likely that large amounts of wetlands in this coastal region have been completely lost. Cooperative governance is therefore key to manage and rehabilitate the landscape inside as well as outside of reserves, to ensure sustainability of our freshwater resources, our most valuable national capital asset.

Using a buffer policy of 500 m around wetlands when screening any development applications is insufficient for the MCP because wetlands are interconnected through the groundwater. Further groundwater studies are therefore required to better map the groundwater compartments and determine more accurate water budgets before the Reserve Determination and Resource Quality Objectives and further water licenses can be issued.

Data Requirements

- Inventory of rivers and wetlands - spatial layers which includes the required classification of lacustrine/palustrine and ecosystem type level.
- The ecological condition of rivers - derived from the River Eco-status Monitoring Programme (REMP) for this report.
- Department of Water and Sanitation (DWS) - REMP and the National Eutrophication Monitoring Programme (NEMP).
- Percentage of effluent and flow needs to be mapped over the months.

4.6 COASTAL VEGETATION

Dr Debbie Jewitt (Ezemvelo KZN Wildlife)

INTRODUCTION

The biome called the Indian Ocean Coastal Belt (IOCB) (Mucina and Rutherford 2006) is a rich vegetation with distinctive climatic, ecological and biogeographical features. It represents the southernmost extent of coastal subtropical forests, thickets, hygrophilous grasslands and bush clumps of the wet, tropical and subtropical seaboard of East Africa (Figure 4.10a) and consists of the following vegetation types (Figure 4.10b):

1. KZN Coastal Belt Grassland
2. Maputaland Coastal Belt
3. Maputaland Wooded Grassland
4. Pondoland-Ugu Sandstone Coastal Sourveld
5. Subtropical Dune Thicket and
6. Subtropical Seashore Vegetation

Part of the KZN Coastal Belt Thornveld occurs in the Mucina and Rutherford (2006) biome boundary; however, the provincial vegetation map classes this vegetation type as savanna. Interspersed in this biome are a myriad of wetlands, estuaries and forest patches. The area forms part of the Maputaland-Pondoland-Albany biodiversity hotspot.

Various local and international legislation and conventions require the monitoring and

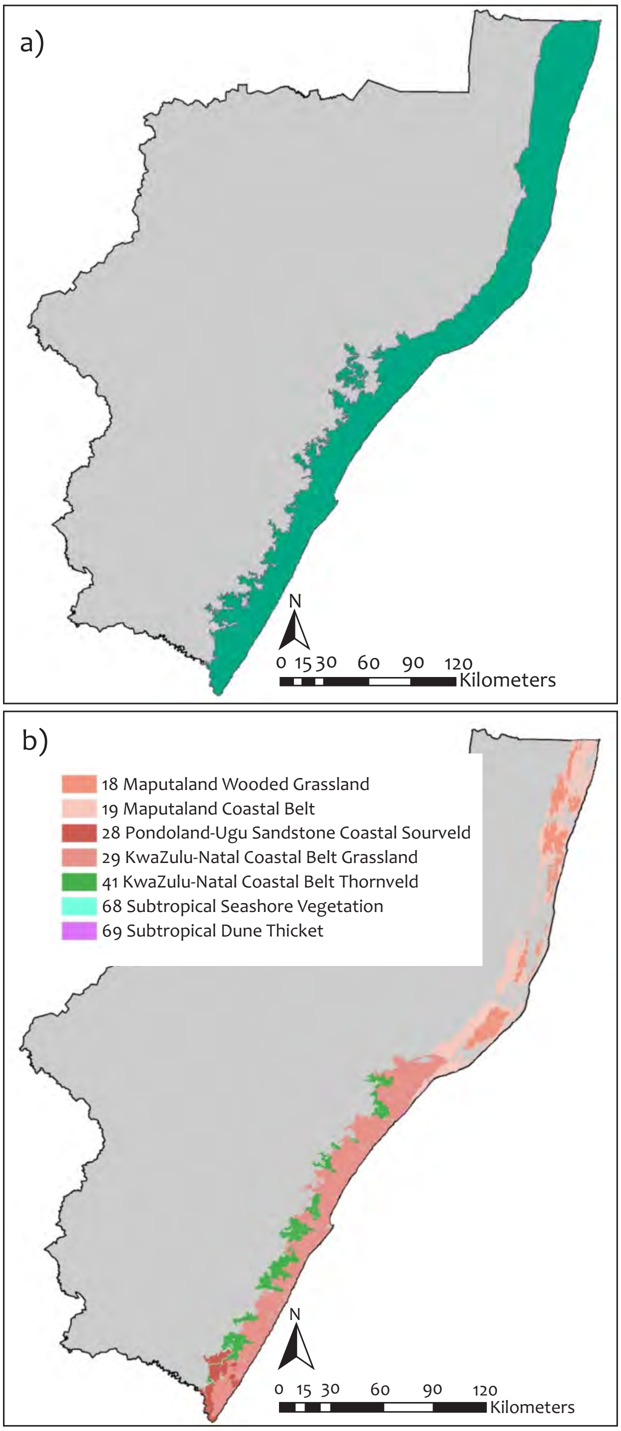


Figure 4.10: a) The boundary of the Indian Ocean Coastal Belt (Mucina and Rutherford 2006) and b) the major vegetation types excluding forests, wetlands and estuaries (EKZNW 2011).

reporting of the environment. The National Environmental Management: Biodiversity Act No. 10 of 2004 and the National List of Ecosystems that are Threatened and in Need of Protection (Act No. 1002 of 2011)[1] lists threatened ecosystems. The coastal grasslands of KZN are listed as threatened.

South Africa is a signatory to the Convention on Biological Diversity (CBD). Biological diversity underpins ecosystem functioning and the provision of ecosystem services essential for human well-being. It provides for food security, human health, the provision of clean air and water, contributes to local livelihoods, economic development and is essential for the achievement of the Millennium Development Goals, including poverty reduction. Strategic goals have been set, known as the Aichi Biodiversity Targets. Target 5 requires that the rate of loss of all natural habitats is at least halved or brought close to zero by 2020. Many of the other 20 targets are applicable too.

Measuring the loss of habitat in the coastal environment is a good indicator of the amount of habitat remaining and the rate of loss of natural habitat. This can inform the achievement of the various goals, provide a threat status and indicate the level of sustainability and resilience achieved.

DRIVERS

Habitat loss and land cover change are currently the leading cause of biodiversity loss worldwide (Jetz *et al.* 2007, MEA 2005, Vitousek 1994). In KZN, 7.6% of natural habitat was lost to anthropogenic conversion in only six years (Jewitt *et al.* 2015a). The major drivers of habitat loss are agriculture, timber plantations, the built environment, dams and mines. The main drivers of land cover change are human responses to economic opportunities which are mediated by institutional factors (Lambin *et al*. 2001). Markets and policies constrain or encourage land-use change. It is essential that decision and policy makers are cognisant of the full implications that decisions and policy development may have on the rate of habitat loss. It is critical that a longer-term decision and planning framework, that is cognisant of constitutional and international agreements, be adopted.

Greenhouse gas emissions and land conversions are some of the leading causes of anthropogenic climate change, and increasingly has a marked influence on species distributions, phenology and ecosystem composition (Jewitt *et al*. 2015b). Climate change is expected to become the next greatest driver of biodiversity loss.

PRESSURES

The coastal area is very densely populated and is also a popular holiday destination. It is suitable for agricultural production, particularly sugarcane, bananas, cashew and macadamia nuts production and timber plantations. The dunes in the north are mined for titanium, ilmenite, rutile and zircon.

Dune vegetation
Photo: Kierran Allen

[1] *The new threatened ecosystems are out for public comment and are likely to be gazetted following this publication.*

The coastal zone is an important interface between the terrestrial and marine environment. Pollution from the terrestrial environment may be carried to the marine environment via the many rivers entering the Indian Ocean. The estuaries and mangroves are important nurseries for fish, whilst the mangroves and coastal vegetation protect against rising sea-levels and wave damage from storm surges.

STATE

Historic perspective

Historically the area would have been continuous natural vegetation, interspersed with wetlands, grasslands, forests, estuaries and rivers. It would have supported a full complement of biodiversity and ecosystem services. Due to the suitable climatic conditions and arable soils however, the area is highly suited to human settlement and agriculture, leading to massive losses of natural habitat. Remaining portions of natural habitat, outside of Protected Areas, are largely fragmented and small.

Current state

Over time the IOCB has been highly transformed by anthropogenic activities (Table 4.2, Figure 4.11), causing the KZN Coastal Belt Grassland and the Pondoland-Ugu Sandstone Coastal Sourveld to become Critically Endangered in the province. The Maputaland Wooded Grassland and Coastal Belt are Endangered. Only the Subtropical Seashore Vegetation and Dune Thickets are adequately protected in the north, primarily by the iSimangaliso Wetland Park World Heritage Site.

In KZN in 2016, the IOCB had the least remaining natural habitat (24.9%) (Figure 4.12) and the highest annual average rates of habitat loss (2.9%) of the provincial biomes and only 8.2% formally protected (Jewitt 2018). The IOCB requires urgent conservation action. To ensure representivity, each vegetation type should be adequately protected and have the target amount of habitat formally protected. High grazing pressure, unsustainable indigenous resource harvesting as well as alien invasive plants also contribute to the degradation of intact ecosystems and are a major concern for the future.

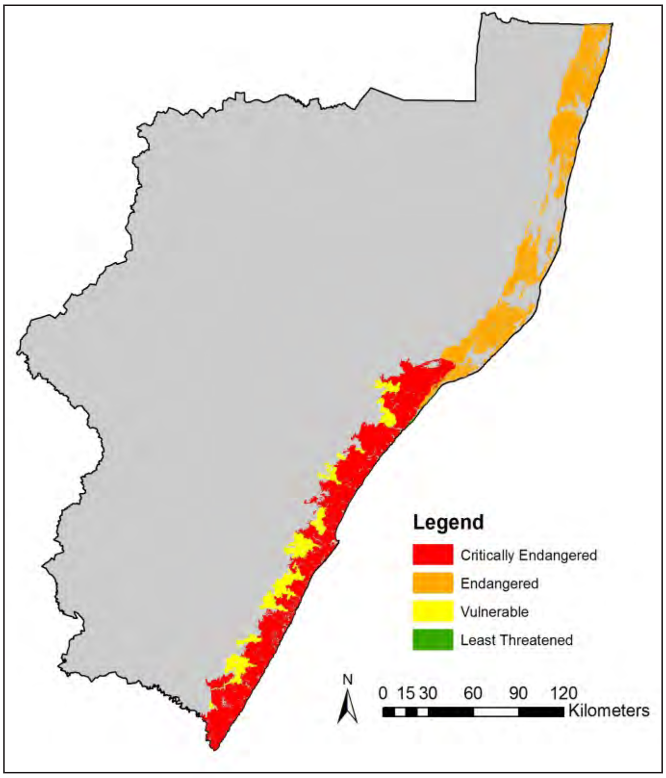


Figure 4.11: The conservation status of the Indian Ocean Coastal Belt vegetation types.

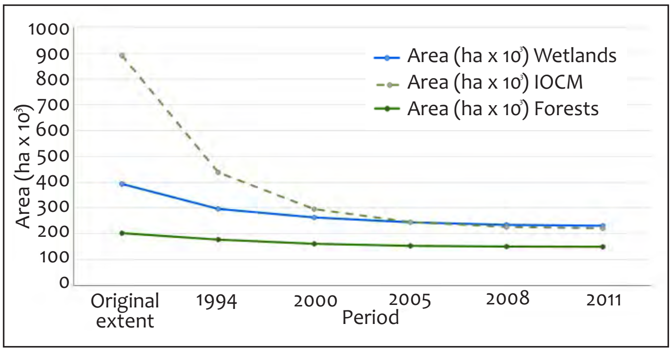


Figure 4.12: The loss of natural habitat over time for the IOCB, Forests and Wetlands in KZN (Jewitt 2018).

Table 4.2: The conservation status, degree of protection and extents of the vegetation types occurring in the IOCB (Jewitt 2020).

KZN VEGETATION TYPE NAME	Conservation target	Provincial area (ha)	Remaining natural habitat (ha)	Conservation status	Degree of protection	Target met by PAs
Maputaland Wooded Grassland	25	1079 29	37 704	Endangered	Moderately Protected	No
Maputaland Coastal Grassland	25	211 194	73 867	Endangered	Moderately Protected	No
Pondolan-Ugu Sandstone Coastal	30	37 245	9 551	Critically Endangered	Poorly Protected	No
KZN Coastal Belt Grassland	25	411 500	55 420	Critically Endangered	Nominally Protected	No
Subtropical Seashore Vegetation	20	52	24	Vulnerable	Fully Protected	Yes
Subtropical Dune Thicket	20	1 245	1 150	Least Threatened	Fully Protected	Yes
KZN Coastal Belt Thornveld	25	111 926	53 657	Vulnerable	Nominally Protected	No

Climate change impacts are substantial in the province: by 2050, an average increase of between 1.5°C and 2.1°C can be expected (Lewis 2011). A generally drying trend is expected by 2050 (Jewitt *et al*. 2015b), although the models are not consistent in their predictions of precipitation responses. Models of environmental domain changes demonstrate a southward latitudinal movement and a westward altitudinal movement (Figure 4.13). The ability of species to track changing environmental domains will be hampered by habitat loss and land cover change, exemplified in fragmented coastal grasslands.

IMPACT

Habitat loss has large, consistently negative effects on biodiversity including loss of species richness, decreased population abundance and distribution, loss of genetic diversity, altered population growth rates, reduced trophic chain length (upper trophic levels are lost first), altered species interactions, reduced number of specialist, large bodied species, negative breeding success, limited dispersal success, altered predation rates and altered animal behaviour that affects foraging success rate (Fahrig 2003).

Habitat loss and transformation may lead to fragmentation which causes numerous small patches. Species that are unable to cross the non-habitat portion of the landscape (matrix) will be confined to small patches, ultimately reducing the overall population size and probability of persistence. These patches contain more edge for a given amount of habitat which may increase overall mortality rate and reduce overall reproductive rate of the population. This indicator is therefore a surrogate for the many other elements of biodiversity and ecosystem goods and services (Jewitt 2020).

Pathogen emergence is linked to anthropogenic land conversion (Faust *et al*. 2018). Close to a third of the zoonotic diseases (transmissions from animals to humans) that emerge are linked to large scale land-use change (Padma 2020) with severe negative consequences for conservation, public health and economic prosperity.

Loss of habitat and a fragmented landscape will negatively impact the ability of species to respond to climate change impacts. Ecosystems will need to shift temporally and spatially. The interaction and cumulative impacts of multiple global threats will lead to mass extinctions, a loss of human well-being and a decrease in the provision of free ecosystem services.

RESPONSE

A target of 50% natural habitat remaining in each vegetation type should be adopted. This will allow for an acceptable level of human livelihoods and simultaneously protect biodiversity and ecosystem service targets.

1. The CBD targets should be implemented, particularly target 5 (by 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation significantly reduced). This will require extensive governmental interaction across all sectors and stakeholders.
2. Protected Area expansion should occur in vegetation types that are not adequately protected, either by formal state protection or by well-funded Stewardship mechanisms, with skilled human resources.
3. The securing of agreements with KZN Department of Agriculture and Rural Development and other government departments, that further transformation of highly threatened ecosystems will not be supported.
4. A high-level awareness campaign focussing on human population growth and engagement with provincial and national government to develop plans to curtail human population growth rates.
5. New business and financial models need to be developed that consider biodiversity and fully account for the environment including the resulting degradation and pollution.

Data Requirements

To report on the amount of natural habitat remaining, the rate of loss and the threat status of the Indian Ocean Coastal Belt biome, the following data are required:

- The KZN provincial vegetation map (EKZNW, 2011).
- The KZN provincial boundary map (EKZNW, 2010).
- A series of land cover data – either the provincial or the national datasets could be used, or a combination thereof. Caution must be applied to the choice of land cover dataset used as some have considerable errors associated with them. The transformation occurring in the landscape needs to be accumulated over time to identify the best remaining natural habitat and to exclude secondary grasslands which have a reduced biodiversity compliment (Jewitt *et al*., 2015a). In this analysis a combination of the following land cover datasets were used: 1990, 1994, 2005, 2008, 2011 and 2017.
- The latest climate change data will indicate possible future threats to the environment which will allow for proactive planning (Jewitt *et al*., 2015b). Similarly, the latest protected area coverages will indicate how well the biome is protected.

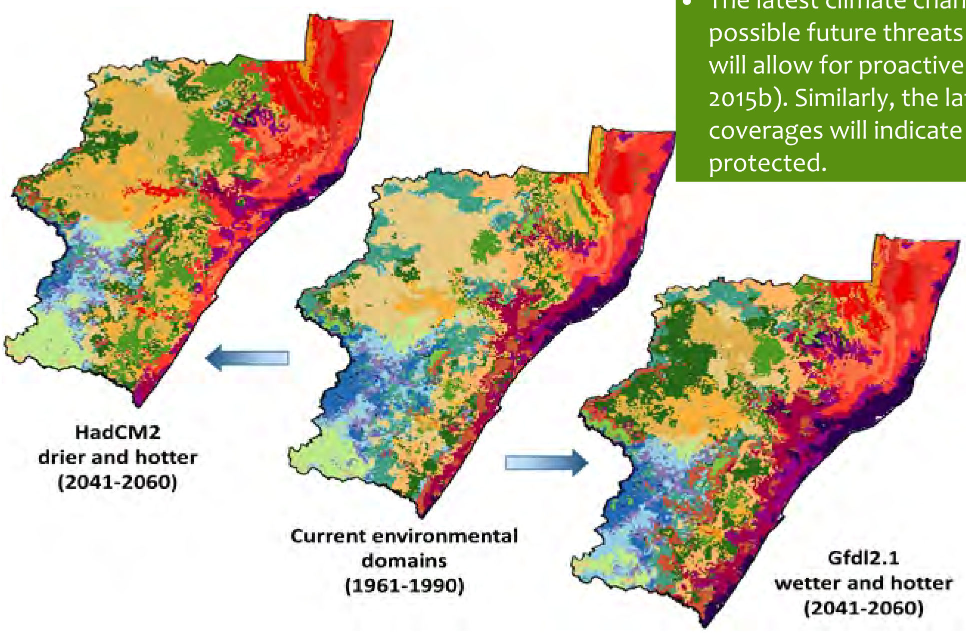


Figure 4.13: Projected climate change impacts on environmental domains in KZN by 2050 (Jewitt *et al.* 2015b).

5 ESTUARINE ENVIRONMENT

KZN's unique estuarine environment
Photo: Kierran Allen

CHAPTER 5: ESTUARINE ENVIRONMENT

5.1 ESTUARIES

Fiona MacKay (ORI) and Steven Weerts (CSIR)

INTRODUCTION

Estuaries are amongst the most productive and ecologically important environments. They provide critical ecological services, acting as nurseries for fish species, filtering land-derived nutrients and pollutants, delivering freshwater and sediments to the coast and sequestering and storing carbon. They have high socioeconomic value, providing resources for coastal communities, and support various recreational and tourism activities. Coastal towns in KZN and its two major port cities have developed around estuaries. Dynamic estuarine processes naturally maintain a complex ecological balance, but these are easily damaged by human activities (Borja *et al.* 2011).

DEFINITION OF KZN ESTUARIES

Estuaries can be categorised based on a variety of typologies, but no two estuaries support the same plant or animal communities. The 2018 NBA provides a more expansive description that incorporates back-flooding and other characteristic conditions. It defines an estuary as: "*a partially enclosed permanent water body, either continuously or periodically open to the sea on decadal time scales, extending as far as the upper limit of tidal action, salinity penetration or back-flooding under closed mouth conditions. During floods an estuary can become a river mouth with no seawater entering the formerly estuarine area or, when there is little or no fluvial input, an estuary can be isolated from the sea by a sandbar and become fresh or even hypersaline*" (Van Niekerk *et al.* 2019a).

aMatigulu/iNyoni Estuary, North coast. The northward migrating mouth closes regularly, creating a back-flooded estuary (Summer 2019). *Photo: Kierran Allen*

The estuary and the immediate surrounding areas that support its functioning, including the riparian zone, connected wetlands and swamp forests, back-flooded areas when the mouth is closed and areas that are inundated during periodic flooding (runoff), form the estuarine functional zone (EFZ). This boundary is listed in the NEMA EIA Regulations (2010) and recognises the sensitivity of estuaries in their entirety. Any future activity in these habitats requires environmental authorisation. The EFZ is incorporated into planning processes involving estuaries such as conservation plans and Integrated Development Plans (IDPs). Describing the ecological support and ecosystem processes associated with the estuary, the 2018 NBA states that "*the EFZ encapsulates the most dynamic areas influenced by long-term estuarine sedimentary processes, allows for natural variability on decadal timescales, encompasses all floodplain and estuarine vegetation that contributes detritus (food) and provides refuge during flood events. Most estuarine-associated biota occur within the EFZ. This is as far as the influence of the sea can be detected on land; represents 'climate change accommodation space*" (Van Niekerk *et al.* 2019a).

The KZN climate, the coastal profile, and the size of coastal rivers contribute to the diversity of

Table 5.1: List of KZN estuaries per type, ecosystem threat status, protection levels, biodiversity priority and EMP status

KZN Estuary No.	SA Estuary No.	Estuary Name	Estuary Type	Ecosystem Threat Status (NBA 2018)*	Ecosystem Protection Levels (NBA 2018)*	Biodiversity Priority	KZN EMP Status Levels (03.2022) / Managing Authority+
1	290	Kosi	Estuarine Lake	Vu	Mo	P	D (IWP)
2	289	uMgobezeleni	Estuarine Lake	Vu	Mo	P	D (IWP)
3	288	St Lucia	Estuarine Lake	En	Po	P	D (IWP)
4	287	iMfolosi / uMsunduze	Large Fluvially Dominated	En	Po	P	
5	286	iNhlabane	Small Temporarily Closed	En	Po	P	
6	285	Richards Bay	Estuarine Bay	En	Po	P	G (DFFE)
7	284	uMhlathuze	Predominantly Open	En	Po	P	
8	283	uMlalazi	Predominantly Open	En	Mo	P	
9	282	iSiyaya	Small Temporarily Closed	Vu	Mo	P	
10	281	aMatigulu / Nyoni	Predominantly Open	En	Mo	P	
11	280	uThukela	Large Fluvially Dominated	En	Po	P	
12	279	iZinkwazi	Large Temporarily Closed	En	Po	P	ID (EDTEA)
13	278	iNonoti	Large Temporarily Closed	En	Po		
14	277	uMdlotane	Large Temporarily Closed	En	Po	P	
15	276	uMvoti	Large Fluvially Dominated	En	Po	P	
16	275	uSetheni	Small Temporarily Closed	Vu	Mo		
17	274	Bob's Stream	Small Temporarily Closed	Vu	Mo		
18	273	uMhlali	Large Temporarily Closed	En	Po	P	
19	272	uThongathi	Large Temporarily Closed	En	Po		ID (EDTEA)
20	271	uMdloti	Large Temporarily Closed	En	Po		
21	270	uMhlanga	Large Temporarily Closed	En	Po	P	
22	269	uMngeni	Predominantly Open	En	Mo	P	
23	268	Durban Bay	Estuarine Bay	CE	Not Protected	P	G (DFFE)
24	267	iSiphingo	Predominantly Open	En	Mo		ID (eThekwini)
25	266	iZimbokodo	Large Temporarily Closed	En	Po		
26	265	aManzimtoti	Large Temporarily Closed	En	Po		
27	264	aManzanamtoti	Small Temporarily Closed	Vu	Mo		
28	263	iLovu	Large Temporarily Closed	En	Po	P	ID (EDTEA)
29	262	uMsimbazi	Large Temporarily Closed	En	Po	P	
30	261	uMgababa	Large Temporarily Closed	En	Po	P	
31	260	iNgane	Small Temporarily Closed	Vu	Mo		
32	259	uMkhomazi	Predominantly Open	En	Mo	P	

KZN Estuary No.	SA Estuary No.	Estuary Name	Estuary Type	Ecosystem Threat Status (NBA 2018)*	Ecosystem Protection Levels (NBA 2018)*	Biodiversity Priority	KZN EMP Status Levels (03.2022) / Managing Authority+
33	258	uMahlongwane	Large Temporarily Closed	En	Po	P	
34	257	uMahlongwa	Small Temporarily Closed	Vu	Mo	P	ID (EDTEA)
35	256	uPhambanyoni	Small Temporarily Closed	Vu	Mo		ID (uMdoni)
36	255	Rocky Bay	Small Temporarily Closed	Vu	Mo		
37	254	uMzimayi	Small Temporarily Closed	En	Mo		
38	253	uMuziwezinto	Large Temporarily Closed	En	Po		ID (uMdoni)
39	252	iNkomba	Small Temporarily Closed	Vu	Mo		
40	251	uMkhumbane	Small Temporarily Closed	Vu	Mo		
41	250	iSezela	Large Temporarily Closed	En	Po		
42	249	uMdesingane	Small Temporarily Closed	Vu	Mo		
43	248	iFafa	LargeTemporarily Closed	En	Po		ID (uMdoni)
44	247	uMvuzi	Large Temporarily Closed	En	Po		
45	246	uMthwalume	Large Temporarily Closed	En	Po		ID (uMdoni)
46	245	uMnamfu	Small Temporarily Closed	Vu	Mo		
47	244	uMakhosi	Small Temporarily Closed	Vu	Mo	P	
48	243	uMfazezala	Large Temporarily Closed	En	Po	P	
49	242	uMhlungwa	Large Temporarily Closed	En	Po		
50	241	uMhlabashana	Large Temporarily Closed	En	Po	P	
51	240	uMzumbe	Large Temporarily Closed	En	Po		
52	239	iNjambili	Small Temporarily Closed	Vu	Mo	P	
53	238	iKoshwana	Large Temporarily Closed	En	Po	P	
54	237	iDombe	Large Temporarily Closed	En	Po	P	
55	236	uMhlangomkhulu (North)	Large Temporarily Closed	En	Po		D (RNM)
56	235	uMthente	Large Temporarily Closed	En	Po		D (RNM)
57	234	uMzimkhulu	Predominantly Open	En	Mo	P	D (RNM)
58	233	uMbango	Small Temporarily Closed	Vu	Mo		D (RNM)
59	232	iBhobhoyi	Small Temporarily Closed	Vu	Mo		
60	231	iZotsha	Large Temporarily Closed	En	Po	P	
61	230	oHlangeni	Large Temporarily Closed	En	Po		D (RNM)
62	229	uVunguza	Small Temporarily Closed	Vu	Mo		
63	228	iKongeni	Small Temporarily Closed	Vu	Mo		ID (EDTEA)
64	227	uVuzana	Small Temporarily Closed	Vu	Mo		
65	226	iBilanhlonhlo	Small Temporarily Closed	Vu	Mo		D (RNM)
66	225	iMvutshini	Small Temporarily Closed	Vu	Mo		
67	224	iMbizana	Large Temporarily Closed	En	Po		
68	223	iKhaba	Small Temporarily Closed	Vu	Mo		
69	222	uMhlangomkhulu (North)	Large Temporarily Closed	En	Po		
70	221	iMpenjani	Large Temporarily Closed	En	Po	P	ID (EKZNW)
71	220	iKhandalendlovu	Small Temporarily Closed	Vu	Mo		
72	219	uMuntongazi	Small Temporarily Closed	Vu	Mo		D (RNM)
73	218	iMbhoyibhoyi	Small Temporarily Closed	Vu	Mo		
74	217	iSandlu	Small Temporarily Closed	Vu	Mo		
75	216	iSolwane	Small Temporarily Closed	Vu	Mo		
76	215	uMthavuna	Large Temporarily Closed	En	Po	P	

*[#]Vu-Vulnerable, En-Endangered, CE- Critically Endangered I * Mo-Moderate, Po-Poor I [+]G-Gazetted, D-Developed, ID-In Development,*
DFFE – Department of Forestry, Fisheries and the Environment I EKZNW – Ezemvelo KZN Wildlife I IWP – iSimangaliso Wetland Park I
uMdoni – uMdoni Municipality | RNM – Ray Nkonyeni Municipality

estuarine types in KZN. South Africa has nine types of estuary (Van Niekerk *et al.* 2020) and six of these occur in KZN: Estuarine Lakes, Estuarine Bays, Predominantly Open-, Large Temporarily Closed-, Small Temporarily Closed- and Large Fluvially Dominated systems. The 76 estuaries in KZN account for two thirds (400 km^2) of the total 600 km^2 of South African estuarine area (Table 5.1, *Map – Page vi*). The North Coast has the greatest diversity of estuarine types and estuarine areas with the St Lucia and Kosi Estuarine Lake systems accounting for 90% (365 km^2) of KZN's estuarine area. The KZN estuaries support important and critical habitats: salt marshes, mangroves, submerged macrophytes, reeds and sedges and many have associated swamp forests. These habitats, the species and communities they support are under threat and contribute to the ecosystem threat status of the estuaries they characterise. In KZN, 45 estuaries are Endangered, 30 are Vulnerable and Durban Bay is Critically Endangered (Table 5.1, Van Niekerk *et al.* 2019b).

DRIVERS

Development and population growth are the main drivers of pressures on KZN estuaries; high levels of poverty and unemployment may also lead to high demands on natural environments and resources. The need for freshwater, that should otherwise flow into estuaries, has stressed estuary function and compromised resilience. Inadequate access to sanitation and poor performing waste management services results in pollution and litter being introduced into KZN estuaries (EDTEA 2017). As the cumulative impacts of global change to ecosystem function and biotic communities are nonlinear (Griffen *et al.* 2016, Halpern *et al.* 2017) they are difficult to predict and manage. The natural drivers underpinning estuarine health and condition include processes such as water mixing, circulation, flushing, sediment dynamics, mouth dynamics nutrient cycling and connectivity of adjacent ecosystems.

PRESSURES

KwaZulu-Natal estuaries face multiple, often interacting threats which can be attributed to direct and indirect pressures on these systems.

FLOW ALTERATION

Although catchments are already water-stressed, freshwater demand in KZN has increased with the spread of residential developments. This has led to the development of Bulk Water Supply schemes involving large storage dams and schemes transferring water across catchments. These have affected the ecosystem function of most of KZNs large, important estuaries. Flow modification caused by alien plant infestation is under-recognised (Van Niekerk *et al.* 2019a) and is significant, particularly around urban estuaries. In KZN all activities contributing to altered freshwater flows to estuaries are increasing.

POLLUTION

Estuaries are the most polluted coastal habitats in KZN (Section 2.3). In KZN, wastewater discharges, urban runoff and agricultural return flows are considered most significant pollution pressures. Of KZN estuaries, 39% are under high to very high pollution pressure. Apart from estuaries in the far north all other systems experience moderate pollution pressure (Van Niekerk *et al.* 2019a). The frequency of major pollution incidents in estuaries has increased significantly in the past few years. While most are wastewater spills into estuaries, others are much larger pollution events (as highlighted in Section 2.3). These involved pollution inflow volumes that should have been considered disastrous; and many spills result in die-off events of estuarine organisms, commonly referred to as *fish kills*. These are particularly common, but not isolated to, systems in the eThekwini metropolitan aera.

RESOURCE EXPLOITATION

Living resource exploitation pressures in KZN arise primarily from fishing (recreational, subsistence, artisanal and include poaching with illegal gillnets) and bait collection. These have a significant impact on estuarine (and coastal) populations of estuarine associated biota (Van Niekerk *et al.* 2019a). The incidences of estuarine poaching (including in protected areas) and bait collection (without permits) for sand prawn (*Kraussillichirus kraussi*) must be highlighted. Estuarine vegetation (reeds, sedges, mangroves) is also harvested, particularly from rural estuaries. There is the annual Ncema grass harvest by Zulu women where *Juncus kraussii* is collected to weave baskets and mats, this is controlled by EKZNW at uMlalazi and St Lucia.

LAND-USE CHANGE

Land-use changes are particularly prevalent around KZN urban centres. In recent years significant land-use change from agriculture to residential has occurred, especially north of Durban. The ecological impacts of development and habitat loss are high and increasing (Van Niekerk *et al.* 2019a). KZN EFZs are all influenced by land-cover changes (ORI unpublished data), with agriculture and development having created the most significant changes around estuaries.

MOUTH MANIPULATION

Artificial breaching is typically requested when property and infrastructure, often inappropriately located, is flooded or at risk of inundation during the natural closed mouth phase. In KZN, breaching has been authoritised in the iKongeni, iLovu, aManzimtoti, iSiphingo, uMgeni, uMhlanga, uMdloti and St Lucia estuaries. However, many other estuaries are breached illegally with a lack of awareness of the dangers posed and the harm to the estuary. Artificial breaching can reduce scouring of the estuary mouth and in so doing result in premature mouth closure and hence repeat the need for breaching. Overall, it results in reduced back flooding of habitats that are important for estuarine function.

Public conducting illegal breach of a KZN estuary (2019).
Photo: EOP, ORI

SAND MINING

Estuaries in the eThekwini area and those near urban centres have extensive sand mines, some covering areas > 90 000 m^2 (9 ha) (ORI unpublished data). Over 50% of the sand mines documented between 2001 and 2018 were in Temporarily Closed Estuaries. In these smaller systems, habitat loss is disproportionately high, and these estuaries are especially vulnerable to the cumulative effects of sand mining during their closed phases when other pressures are at play. Thirty-seven KZN estuaries are affected by sand mining, with some systems impacted by multiple operations and upstream there are significantly more (ORI unpublished data).

ALIEN INVASIVE SPECIES

KZN estuaries are under pressure from several plant and animal alien invasive species (AIS). Degraded estuaries with poor resilience are particularly vulnerable. Flow modification and nutrient input through wastewater promotes alien vegetation proliferation. Biodegradation of this organic matter results in oxygen depletion which can result in *fish kills*. Common invasive weeds are water hyacinth *Pontederia crassipes*, Kariba weed *Salvinia molesta* and water lettuce *Pistia stratiotes* (Nunes *et al.* 2020).

Molluscs (*Tarebia granifera and Corbicula fluminea*) are notable invasive invertebrates as potential habitat changers and influencing nutrient (e.g., Moslemi *et al.* 2012) and trophic and community dynamics (e.g., Miranda *et al.* 2011). Fish AIS are also prevalent in KZN, all the introduced fish in KZN estuaries are freshwater species (Whitfield *et al.* 2021). These include angling species such as bass (*Micropterus spp.*) and carp (*Cyprinus carpio*) and aquarium species such as guppy (*Poecilia reticulata*) and swordtail (*Xiphophorous helleri*).

STATE

The state of KZN estuaries is evaluated by the South African Estuarine Health Index (EHI) which assesses biophysical components relative to pressures (Van Niekerk *et al.* 2013). Estuary health is a measure of the difference in the state of a system between natural (or reference) and present-day conditions. The EHI is used variously in the determination of environmental flows, in planning frameworks for development, conservation planning and protection, to inform land-use planning and in the National Biodiversity Assessment. Estuaries are classified on a scale ranging from A – Natural to F – Extremely Degraded, using available information on

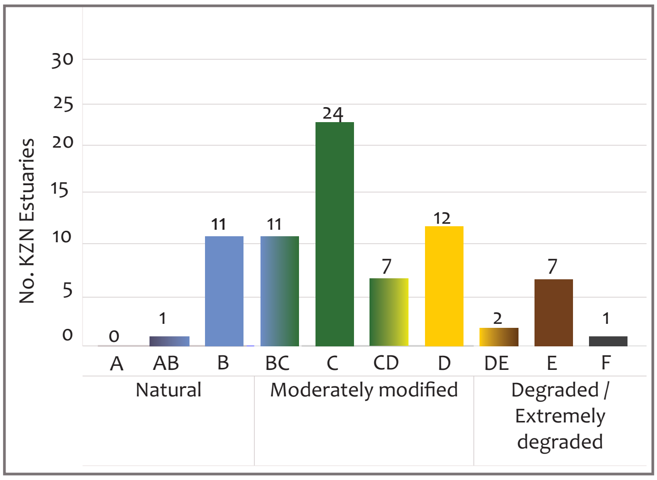


Figure 5.1: The health state of KZN estuaries

hydrology, hydrodynamics, mouth condition, water chemistry, sediment processes, microalgae, macrophytes, invertebrates, fish and birds.

Historic Perspective

The first National Spatial Biodiversity Assessment (NSBA) was conducted in 2004, repeated in 2011 (Van Niekerk and Turpie 2012) and showed a declining health status of KZN estuaries, particularly in the Small Temporarily Closed estuaries. In 2008, eThekwini estuaries were classified as 'good' to 'fair', but 5 of the 16 were 'highly degraded' (Forbes and Demetriades 2008). In 2012, the EHI considered KZN estuaries to be 'fair' to 'poor'. The most compromised in condition were eThekwini estuaries with 72% in a 'poor' state.

Current State

All KZN's estuaries have been impacted to some degree (Figure 5.1) and only 12 (16%) are in a near natural state. Most (56) are moderately degraded to degraded and eight are considered extremely degraded (data from Van Niekerk *et al.* 2019a).

There is a trend of declining health in the province's estuaries. The health of individual estuaries is particularly poor near the larger

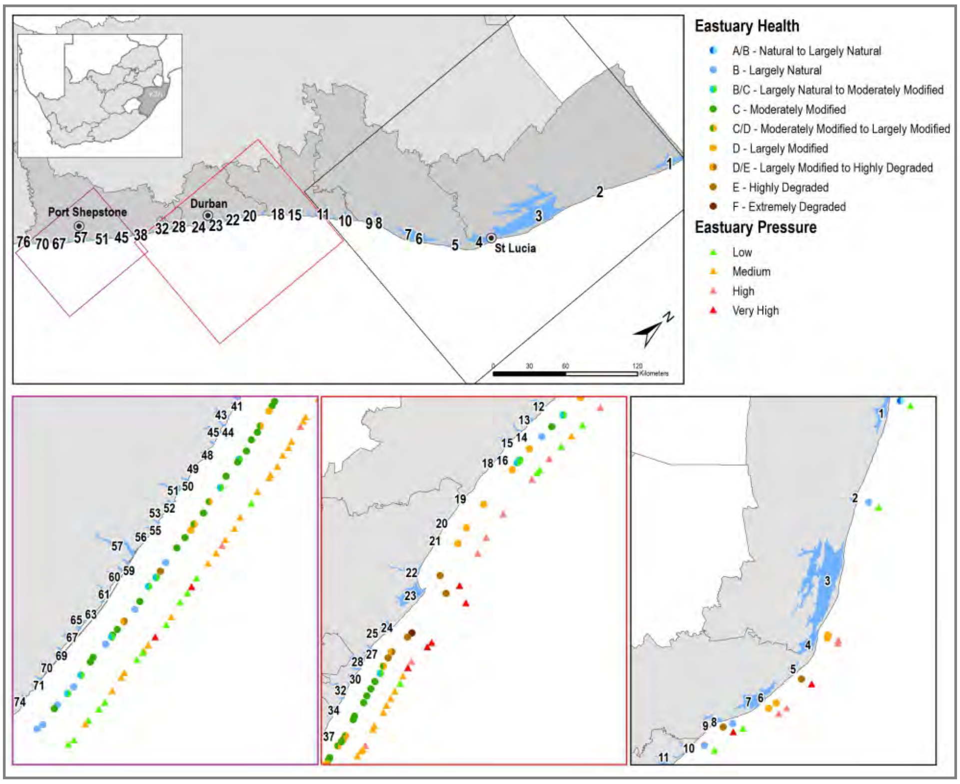


Figure 5.2: Individual estuary health scores (A-F) relative to degree of consolidated anthropogenic pressures on a system (low to very high)

centres (eThekwini and Mhlathuze) where pressures are highest (Figure 5.2). While some estuaries on the KZN south coast are still largely natural, this will change if pressures (which are currently low to medium) increase. Estuaries in the extreme north have fewer pressures and are therefore in a better state (except St Lucia), because they have high protection status.

The St Lucia estuarine lake system has limited to no estuarine function at present, because of its prolonged disconnection from the marine environment through drought, floodplain manipulation and catchment freshwater use. High sediment input from the uMfolozi system has likely altered a large portion of the system, including in the lakes which, without flushing, may have caused semi-permanent changes to some benthic habitats. Aside from Durban Bay (critically modified) and St Lucia (heavily modified) Large Fluvially Dominated estuaries are heavily modified in KZN (88%). Other KZN estuarine types still have representatives that are in a moderate to near natural condition.

While the ICM Act calls for the development of Estuary Management Plans, 75% of KZN estuaries do not have formal management plans. Current monitoring and enforcement is inadequate. For e.g., the 2018 NBA estimates that 60% of fish landings from South African estuaries are via illegal gillnets.

Of concern, the snail *Tarebia granifera* has spread rapidly across the KZN coast in the last 25 years. Although mainly a freshwater species it now occurs in over half of KZN estuaries and was the most notable estuarine invertebrate invader. However, in 2021 extensive clam beds were found in the uMdloti Estuary (S Weerts Pers Obs); considered to be the Asian clam *Corbicula fluminea* (2022, ORI unpublished data). It has a long invasion history in North America and Europe and breeds throughout the year at local temperatures releasing hundreds of juveniles a day (www.cabi.org/isc). As invertebrates are poorly sampled in KZN, it is not improbable that it occurs elsewhere.

IMPACT

The declining state of KZN's estuaries has numerous impacts on estuary function, changes in estuarine biotic communities and habitats, and

iZinkwazi Estuary. Large temporarily closed estuary with a developed south bank.
Photo: Kierran Allen

the goods and services these systems provide. Ecological impacts may be difficult to mitigate and manage, because they may be nonlinear and cumulative, and cascade from organism to ecosystem-level changes (Kennish 2021).

The amount and natural timing of river water reaching estuaries and marine environments has been altered. Certain estuarine types are more susceptible at high to very high flow modification pressure including Estuarine Bays, Estuarine Lakes and Large Fluvially Dominated estuaries (Van Niekerk 2019a).

Polluted inflows cause harmful concentrations of chemicals, nutrients, pesticides and litter. Estuarine Lakes, Large Fluvially Dominated and Large Temporarily Closed estuaries are mostly under pollution pressure (Van Niekerk 2019a). Chronic pollution progressively degrades estuaries making them susceptible to other pressures.

Illegal or irresponsible harvesting of resources leads to critical habitat and species losses and can indirectly influence the health of non-target species. Estuarine Bays, Estuarine Lakes and Predominantly Open systems have been most affected (Van Niekerk *et al.* 2019a).

Removal of natural vegetation because of poor planning, placement of buildings, transport infrastructure, concreted embankments, jetties and bridges has caused habitat losses in KZN estuaries, changed water flow, and caused erosion. Agriculture around estuaries predominantly influences Large Fluvially Dominated, Large Temporarily Closed and Predominantly Open estuaries. Predominantly Open and Small Temporarily Closed estuaries are most affected by development in KZN (Van Niekerk *et al.* 2019a). Artificial breaching results in a sudden and catastrophic lowering of water levels affecting estuarine organisms and disrupts natural functioning of the system. If done at an inappropriate (seasonal) time of year, it can be particularly destructive effect.

The impacts of sand mining stem from habitat loss and a reduction in the amount of sand in the system (Section 8.8). In addition, these systems are critical to the delivery of sand to KZN beaches and mining has resulted in a substantial sand deficit that is linked to coastal erosion on KZN beaches (Section 3.2).

Alien species threaten estuaries by outcompeting important native species and disrupting the natural ecology. *Tarebia granifera* can reduce the abundance of natural sediment fauna by breeding prolifically and is present in mostly degraded estuaries (Whitfield *et al.* 2021).

RESPONSE

Impacts on estuaries are multifaceted and therefore a variety of management actions are required to address them.

- Legislation covering the management of Biodiversity and Water (affecting estuaries) is good, and the relevant norms and standards to support the implementation of legislation are adequate, but compliance and enforcement are mostly poor (Taljaard *et al.* 2019).

- Management responses to specific pressures such as EWRs, EMPs, MMPs, and climate change mitigation have either not been developed or have not been implemented (Van Niekerk et al. 2019a).
- The Ecological Water Requirements (EWR) for KZN estuaries is a priority requiring action.
- Estuarine flow requirements may be considerably greater than those for the river entering the estuary and they disregard the freshwater requirements of river-dependent marine systems (Van Niekerk *et al.* 2019a).
- All existing discharges to estuaries should comply with the provisions of the ICM and the National Water Acts.
- Responses to living resource exploitation is inadequate given the scale of over exploitation of living resources in estuaries that has affected for e.g., nursery function (Section 7.3) and therefore marine species reliant on estuaries.
- The scale of floating macrophyte infestation and the occurrence of the invasive *Tarebia granifera* snails in many KZN systems has been left mostly unchecked. The root cause of plant infestation – excess nutrients, is not considered in management responses, so that infestation is a growing issue. Without control measures the infestation of alien species increases and is compounded by degrading estuary health, due to various other anthropogenic pressures.
- The KZN PCC has not met for several years, and it is strongly recommended that a provincial Estuary Working Group be established to provide scientific and technical support to committees that report to national structures.
- EMPs set out to consider best practice in management, use and protection and to consider ecological sustainability and co-governance. To date (early 2022), 3% (2 estuaries) have EMPs gazetted, 13% (10 estuaries) have developed plans and 14% (11 estuaries) have plans under development (O. Parak EDTEA pers comm, Table 5.1). Seventy percent of KZN estuaries do not have plans for formal management.
- EDTEA formulated the "Protocol for Requests to Breach Estuary Mouths in Kwazulu-Natal: Mouth Maintenance Management Plans" which needs to be implemented effectively.
- New developments should be set well back from the EFZ, also to mitigate against the climate change risks of flooding and sea level rise and should consider the CMLs.
- Water quality monitoring under the National Estuarine Monitoring Programme (NEsMP) of the Department of Water and Sanitation established in 2008 needs to be re-initiated.

Data requirements

- Critical information on estuary physical function is the basis for all estuary investigations.
- The EFZ is consistently refined according to the new acquisition of supporting data (topography, land cover and vegetation surveys).
- The estuarine-associated landscape can change relatively fast with development. To inform the types, scales and impacts of changes, regular land cover/use assessments at an appropriate resolution to quantify change detection are required (every five years).
- Expanding on the existing continuous monitoring network.
- A critical gap is no recent systematic biophysical surveys across KZN estuaries.
- Estuarine invertebrates are poorly reflected in most estuarine assessments because of the skills, time and finances needed to conduct such assessments.
- Alien invasive records of distribution are required per estuary and per estuary reach.
- Estuarine carbon inventories and values to KZN and the national blue economy should be expanded.
- Molecular studies together with typical morphotaxon surveys capture cryptic, under sampled and new species.

5.2 MANGROVES

Prof. Janine Adams (Institute for Coastal and Marine Research, NMU)

INTRODUCTION

Mangroves are woody trees and shrubs that occur at the interface between land and sea along tropical and subtropical coasts. Mangrove ecosystems contain a unique set of fauna such as mudskippers, tree climbing crabs and snails. They are inundated during high tide and exposed during low tide. The unique trees have special adaptations to cope with the harsh tidal and saline environment. For example, white mangrove *Avicennia marina* has pneumatophores (aerial roots) that allow them to survive in sediments that are poorly drained, saline, anoxic and rich in organic matter. Mangroves grow optimally within a mean annual temperature range of 5 to 20°C. In South Africa mangroves are found along the tropical and subtropical coasts of KZN and extend to the warm-temperate coast of the Eastern Cape. Their distribution is controlled by estuary geomorphology and hydrology. They occur in fragmented stands in estuaries that are permanently open to the sea. The open mouths ensure movement of water into and out of the mangroves. The South African populations represent the southernmost distribution of mangroves in Africa, and one of the highest latitudes for this group in the world.

Present mangrove extent in South Africa is 2087 ha recorded for 34 estuaries in the country with the largest coverage in KZN's northern estuaries, the uMhlathuze Estuary (1082 ha), followed by St Lucia Estuary (305 ha). The dominant species are the white mangrove *Avicennia marina*, black mangrove *Bruguiera gymnorhiza* and red mangrove *Rhizophora mucronata*. The black mangrove is more tolerant of basal inundation than the other species, occurring in estuaries that are more frequently closed to the sea. The Kosi Bay Estuary has high biodiversity importance as it is the only South African estuary with six mangrove species. These include the tonga mangrove *Lumnitzera racemosa,* the indian mangrove *Ceriops tagal* and the cannonball mangrove *Xylocarpus granatum,* all of which occur at their southernmost distribution limit.

Mangroves provide numerous goods and services to people such as carbon storage and sequestration, nutrient cycling, nursery habit for juvenile fishes and invertebrates, and shoreline protection from storms and erosion. In South Africa mangroves are harvested for wood, and associated faunal species are collected as a food source or for bait.

DRIVERS

Population growth, poor agricultural management practices, coastal development (including harbours) and high demand for resources in rural areas, such as firewood, have been the main anthropogenic pressures on mangroves. While climate change has resulted in environmental pressures such as changes in estuary mouth dynamics, floods, sea-level rise, sediment erosion/accretion, drought and salinisation which affect mangrove ecosystems. A future threat is the increase in extreme events such as sea storms that could close the mouths of estuaries and lead to sedimentation and smothering of mangroves. Natural events such as floods can also deposit silt, covering the base of the mangrove trees causing die-back.

PRESSURES

Changes in freshwater inflow to estuaries, increased sedimentation due to land degradation and prolonged closed mouth conditions all negatively affect mangroves. The pressures influencing the mangroves in KZN vary for the different estuaries (Table 5.2). Harvesting, cattle browsing and trampling which are prevalent pressures in the Eastern Cape are not as problematic in KZN as the largest areas of mangroves occur in protected areas.

However, extensive areas of mangroves were removed when the ports of Durban and Richards Bay were developed. The intentional separation of the uMhlathuze Estuary from Richards Bay increased the tidal amplitude of the system, thus facilitating a significant expansion of mangroves to form the largest stand in the country (uMhlathuze Estuary mangrove extent: 1082 ha). In the St Lucia and iMfolozi estuaries, mangrove area change has been associated with fluctuating abiotic conditions (salinity, water levels, sedimentation) relating to different mouth management practices. Recent re-connection of St Lucia with the iMfolozi River means the estuary is currently fresh, silty and with high water level that has led to die back of mangroves.

Table 5.2: Changes in mangrove areas (ha) for the largest forests (> 10 ha) in KZN and the associated pressures and protection status of each estuary. Habitat trends are indicated by arrows (↓ decreasing, ↑ increasing) comparing the historic area (1930s/1940s to the present area in 2021; Adams and Rajkaran 2021).

Code	Estuary	Area (1930s-40s)	Area (2021)	Trend	Pressures / Drivers of Change	Protection status / Authority
1	Kosi	60,7	71	↑	Harvesting of wood, construction of fish traps, cattle trampling and browsing. Mangroves increased due to sedimentation around fish traps.	iSimangaliso Wetland Park World Heritage Site
3/4	St Lucia & iMfolosi	331	278	↓	Mouth closure, relinked to iMfolozi catchment, freshening, increased silt, and elevated water levels	iSimangaliso Wetland Park World Heritage Site
6	Richards Bay	267	171	↓	Harbour construction and removal of mangroves.	Echwebeni site of conservation significance
7	uMhlathuze	80	1087	↑	Expansion following separation from Richards Bay - creation of new intertidal areas because of increased tidal amplitude through artificial mouth. Pressures include dredging, silt, and sediment deposition, nutrient pollution from catchments, oil pollution from Richards Bay link.	Ezemvelo KZN Wildlife
8	uMlalazi	4	40	↑	Expansion of mangroves as estuary mouth is artificially kept open. Pressures include sedimentation, reduced flow, and local developments on floodplain (e.g., aquaculture farm).	Ezemvelo KZN Wildlife
22	uMngeni	20.3	33.5	↑	Sedimentation and natural expansion. Pressures include infrastructure development, reduced flows, poor water quality and mouth closure.	Beachwood Mangroves Reserve Ezemvelo KZN Wildlife
23	Durban Bay	451	13.4	↓	Harbour construction and removal of mangroves. Pressures include pollution (nutrients, plastic and heavy metals).	Bayhead Natural Heritage Site
24	iSiphingo	12.5	4.9	↓	Removal for development. Pressures include severe flow reduction (diversion of catchment to build airport), tidal restriction and poor water quality (nutrients, plastic and heavy metals).	None

STATE

Historic Perspective

There has been a long history of research completed along the east coast of South Africa where regular field visits have documented pressures causing abiotic and biotic changes in mangrove ecosystems:

1. Coastal development has removed mangroves.
2. Restriction in tidal exchange caused freshening and decrease in salinity (abiotic change) and loss of mangrove trees and associated biota (biotic change).
3. Heavy metal pollution caused accumulation in anoxic and waterlogged sediments, adversely affecting mangrove tree morphology and physiology.
4. Oil pollution at the Mhlathuze Estuary resulted in oil settling with the tide in low wave energy areas. This smothered roots and reduced mangrove tree photosynthesis and growth.
5. At the Richards Bay and Mhlathuze Estuaries coal dust coated leaves including stomata, reduced incident light and decreased CO_2 uptake, photosynthesis and growth of *Avicennia marina*.
6. Eutrophication caused increase in nutrients (abiotic change) and growth of macroalgae (biotic change) that can smother aerial mangrove roots.
7. Disturbance of riparian vegetation particularly due to sugarcane plantations resulted in bare banks and disturbed open areas that facilitated the spread of invasive alien plants.
8. Freshwater abstraction caused estuary mouth closure and increase in water level and die-back of mangrove trees (*Avicennia marina*).

Current state

Although there was an increase in the total area covered by mangroves in KZN, there has been a decrease in the number of estuaries where mangrove stands occur. Due to catchment and mouth disturbance, mangroves (~7 ha) no longer occur in 10 small KZN estuaries. These losses are attributed to land being converted to sugarcane farms, and to road infrastructure developments, most notable the N2 Freeway.

The largest areas of mangroves in KZN occur in uMhlathuze, St Lucia and Richards Bay (Table 5.2). The smaller areas at other estuaries are important for maintaining biodiversity and connectivity of mangrove forests along the east coast. A large area of mangroves (440 ha) was lost during the construction of Durban Bay harbour. These losses are compensated for by the extensive stand of mangroves at the uMhlathuze Estuary (> 50% of the total area in South Africa: 1082 of 2087 ha). The artificial mouth created for the uMhlathuze sanctuary produced a large intertidal habitat and delta. *Avicennia marina* rapidly colonized this habitat increasing its area cover from 80 ha in 1975 to 793 ha in 2018 and 1087 ha in 2021. This novel ecosystem is nationally important as it supports the largest mangrove stand in the country.

Management interventions have maintained the mouth of the uMlalazi Estuary in an open state that has also promoted mangrove colonization and expansion. Extended mouth closure in the St Lucia Estuary has led to a freshening of the system and replacement of mangrove habitat by reeds and sedges. Mouth closure at the St Lucia Estuary caused high water level, flooding of pneumatophores and mangrove die back. Because of the fresher sediment rich conditions, reeds expanded by 58 % (177 ha) and there was a loss of 60% (42 ha) of the mangrove extent at the St Lucia Estuary between 2010 and 2020. The present state (2022) is a closed, freshwater silty system where mangroves are dying in response to the high water level.

IMPACT

Climate changes such as sea-level rise, floods and increasing temperature are some of the key drivers that result in impacts on mangroves. Sea-level rise causes inundation and waterlogging, the impact of which is either the expansion of mangroves in intertidal areas or flooding, depending on the duration of inundation. An increasing open mouth condition causes a change in sediment biogeochemistry which leads to inland/landward migration of mangroves. An increase in floods results in an increase in nutrient inputs and eutrophication, and an increase in sediment input. This also plays a part in mangrove expansion. An increase in temperature causes warming to take place which results in distributional range shifts and change in habitat diversity as well as mangroves replacing salt marsh.

RESPONSE

There has been local extinction of mangroves in several KZN estuaries caused by changes in freshwater inflow, increased sedimentation due to land degradation and transformation, and prolonged closed mouth conditions.

South African mangroves are at the limits of their latitudinal distribution, and thus susceptible to anthropogenic impacts. Changing the structure and distribution of mangrove forests decreases their natural ability to recruit and regenerate, thereby further decreasing the ecosystem services provided by these systems. Protection of existing stands of mangroves is essential if the people of KZN are to benefit from their goods and services

Research is needed to quantify the importance of our mangrove ecosystems as blue carbon sinks and to study the impact of sea-level rise on mangrove ecosystems to identify areas most at risk and in need of interventions. Mangrove data must be included in a Blue Carbon Sink Register to be updated every five years to reflect change in extent, evaluate the degree of pressure, and report on progress for restoration and protection. Estuary conservation and management plans need to include future changes in climate to ensure the protection of mangrove forests.

There are few areas where mangroves are likely to expand into areas of newly accreted sediment. In areas where the steepness of adjacent terrestrial areas and coastal development prohibit expansion, mangroves may be lost. Mangroves have been lost at St Lucia Estuary highlighting the importance of protecting stands at nearby systems such as the Mlalazi and Kosi Estuary.

To ensure mangrove persistence at these sites the mouth needs to remain open to the sea. A mouth management plan is needed as well as a freshwater baseflow allocation to Mlalazi Estuary to maintain open mouth conditions. The large mangrove stand at Mhlathuze Estuary needs continual monitoring to ensure protection as there are increasing pressures such as silt and sediment deposition from dredging and pollution (Table 5.2). In addition, harvesting of mangroves at Kosi Estuary needs to be controlled. Poor water quality and surrounding catchment activities threaten the survival of mangroves at the uMgeni, Durban Bay and iSiphingo estuaries.

Conservation targets must ensure the current species composition and extent of mangroves are maintained. All mangrove habitats in KZN should be considered critically endangered ecosystems and managed accordingly.

Data requirements
Historical changes in mangrove extent are documented and mapped using aerial, Google Earth or drone imagery in combination with ground truthing at field sites. These images are used to identify pressures such as commercial developments, houses, roads, open grasslands, grazing pastures and agriculture. Detailed 1:3000 fine scale mapping to the edge of the EFZ is used to map changes over time. An assessment of pressures including flow reduction, pollution and artificial breaching should be updated every five years to reflect progress in the management of sensitive mangrove ecosystems.

Long-term monitoring of mangrove tree height, population structure, snail and crab abundance has taken place since 2010 at the St Lucia Estuary (Adams and Human 2016; Raw *et al.* 2018). Long-term datasets are needed to track pressures but are also used to understand the change in the frequency and intensity of climatic cycles such as El Nino. In South Africa, mangrove communities are at the limits of their distribution; thus, we are well situated to investigate mangroves' resilience and response to stressors, and to add to integrated population-level studies of resilience.

5.3 SUBMERGED MACROPHYTES

Prof. Janine Adams (Institute for Coastal and Marine Research, NMU)

INTRODUCTION

Submerged macrophytes are rooted vascular plants whose leaves and stems lie completely below the water surface (e.g., *Stukenia pectinata* and *Ruppia cirrhosa*). Their growth is related to optimum light, depth, and salinity levels and these factors control their distribution especially in the turbid estuaries of KZN. The main seagrass species is the eelgrass, *Zostera capensis* that occurs mostly in the intertidal zone of permanently open estuaries (See Section 5.1). Although this species can be found along much of the east coast of Africa, its distribution is increasingly fragmented through habitat disturbance; it is sensitive to changing estuarine conditions and is classified as endangered based on IUCN criteria (Adams 2016). Other abundant submerged plants are the free-floating hornwort *Ceratophyllum demersum* and various freshwater Charophyte algae. The common duckweed *Spirodela polyrrhiza* was recently found in the St Lucia Estuary where freshwater input from the Mfolozi River had caused salinity in the estuary to decrease, creating optimum conditions for freshwater species.

Leaves and stems of submerged macrophytes provide a growth surface for epiphytic microalgae, which serve as a food source for invertebrates and fish. Macrophyte beds also serve as a refuge for small fish and a habitat for benthic mudprawns. The presence and abundance of these beds signify water bodies with good water quality and rich biodiversity. Seagrasses also play an important role in nutrient cycling in shallow waters and are highly effective in capturing and storing carbon. This process promotes calcification in calcareous epiphytes living on leaf surfaces, increasing their capacity to support higher trophic levels. Macrophyte communities also dissipate wave energy and reduce water current velocities, leading to more stable sediment and improved water clarity.

Free-floating hornwort (*Ceratophyllum demersum*) at St Lucia bridge, June 2018
Photo: Caroline Fox

DRIVERS

Coastal development and habitat destruction, often directly attributable to population growth, are the main drivers of change. Land use changes in the catchment increase sedimentation and nutrient input to downstream waters. Macroalgal blooms and invasive aquatic plants in fresh, eutrophic systems smother submerged plants. Nutrient enrichment causes an increase in epiphytic growth on leaves that limits light penetration. Boat propellers entangle and remove plants reducing their cover, while boat wakes erode banks and increase water turbidity. Bait collectors and fishermen trample mud- and sandbanks, destabilising sediment that elevates turbidity; their activities also result in the physical removal of plants.

More intense rainfall events are expected with future climate change. These will increase run-off from land and reduce water quality. Submerged macrophytes flourish in calm, sheltered environments and flooding can cause them to be flushed out of the system.

PRESSURES

Poor land-use practices in catchments and erosion of riverbanks increase the rate and volume of sediment flowing into estuaries. High sediment loads reduce water clarity and limit the growth of submerged macrophytes and hence epiphytes that support vertebrate and invertebrate food webs. Release of sewage effluent (Section 2.3) into rivers elevates nutrient levels and can create eutrophic conditions that promote microalgal blooms and invasion by fast growing alien plants (Nunes *et al.* 2020). These plants can outcompete indigenous species and change trophic relationships, causing a decline in estuary health. Tracking submerged macrophytes provides an early warning of harmful conditions.

STATE

Historic perspective

Submerged macrophyte habitat in South African estuaries is on a downward trajectory of change. In KZN, losses have resulted from urban and industrial development that has increased sediment loading from catchments, causing elevated turbidity and eutrophication. In the 1970s, large areas of the uMhlathuze Estuary were lost with the construction of Richards Bay harbour. In the late 1990s, dredge spoil from harbour expansion activities that had been deposited on the northern beaches washed into the estuary and smothered 86 ha of indigenous eelgrass (*Zostera capensis*) beds. Seagrass losses also occurred in Durban Bay after similar dredging and land reclamation. More recently, St Lucia Estuary has lost seagrass communities owing to the inflow of fresh silty water from the Mfolozi River. Eelgrass was recorded historically in Mahlongwana and Umgababa estuaries but there are no recent accounts of the seagrass in these systems.

Current state

Submerged macrophytes occur in 14 of KZN's estuaries. The largest beds are found in St Lucia (432 ha) and Kosi (652 ha) estuaries because they include large lakes that provide extensive water surface areas for plant colonisation (Van Niekerk *et al.* 2019). In St Lucia, submerged macrophytes occurred historically in the southern lake because salinity fluctuations in the northern lake inhibited plant establishment. Recent mouth restoration and joining the Mfolozi and St Lucia systems raised water levels creating a freshwater environment where plants such as the sago pondweed *Stuckenia pectinata* are spreading rapidly. Kosi Estuary is unique because it harbours diverse and extensive submerged macrophyte communities in a system of four

Pondweed (*Stuckenia pectinata*) at Charters Creek, St Lucia, January 2019
Photo: Caroline Fox

interconnected lakes. *Ceratophyllum demersum, Najas horrida, N. marina, Potamogeton sweinfurthii* and *Utricularia* spp. occur in the two upper lakes, with salt tolerant species such as *Stuckenia pectinata, Ruppia cirrhosa, Zostera capensis* and *Halodule universis* becoming evident as salinity increases progressively towards the mouth. Macrophyte cover in the other 12 estuaries is < 30 ha in extent and is absent from those in the south because they are small, largely freshwater, and experience frequent flooding and high turbidity. Many estuaries that support submerged macrophyte communities are without formal conservation protection status.

IMPACT

Discharge of treated (and often untreated) effluent into estuaries colonized by submerged macrophytes is a stressor likely to continue in future. The resultant growth of micro- and macroalgae and limits to light penetration in the water column will alter natural trophic relationships in affected estuaries. Run-off from urbanised and agricultural land is also likely to increase, reducing salinity and impacting biodiversity (Nunes *et al.* 2020). Loss of submerged macrophytes results in a loss of important functions such as refugia for other biota, nutrient cycling, water purification and sediment stabilization.

RESPONSE

Monitoring is needed to track the health and survival of submerged macrophytes in the Kosi, St Lucia, uMhlathuze and uMgobezeleni estuaries. Priorities should be the uMhlathuze Estuary to protect its eelgrass beds, and the Kosi Bay estuarine system to maintain the diversity of its submerged macrophyte communities. The integrity of Kosi Bay is threatened by run-off pollution and abstraction of ground and surface freshwater. Run-off to estuaries needs to be reduced to control nutrient input. Restoration efforts should focus on establishing riparian buffer zones and maintaining normal marine connectivity that will conserve estuarine biodiversity. The loss of submerged macrophytes can indicate the establishment of an alternate stable state dominated by micro-and macroalgae. Factors that negatively impact natural estuarine processes need to be addressed so that a functional physical environment can be established before replanting can be introduced as a restoration measure. The aim of restoration is to maintain submerged macrophyte cover and species richness. The data in Table 5.3 have low confidence; the status of the submerged macrophytes in these estuaries needs to be updated.

Table 5.3: Distribution of submerged macrophytes in KZN estuaries indicating total area covered and presence/ absence of three important species (source van Niekerk *et al.* 2019).

	Estuary name	Area (ha)	Dominant species		
			Stuckenia pectinata	*Ruppia cirrhosa*	*Zostera capensis*
1	Kosi	652.0	x	x	x
2	uMgobezeleni	22.64	x	x	
3	St Lucia	431.5	x	x	
5	iNhlabane	1.1	x		
7	uMhlathuze	28.5	x		x
8	Mlalazi	0.01			x
9	iSiyaya	0.08	x		
10	aMatigulu/Nyoni	0.5			x
13	iNonoti	2.5	x	x	
14	uMdlotane	0.71	x	x	
22	uMngeni	1.0	Unknown		
33	uMahlongwane	3.0	x	x	
42	uMdesingane	0.5	x	x	
43	iFafa	1.5	x	x	
49	uMhlungwa	1.5	x	x	
	Total	**1154.5**			

Data Requirements

Data on the cover abundance of submerged macrophytes enable the macrophyte habitat to be mapped and changes over time detected. These data reliably reflect the state of an estuary. Data are obtained from assessments of aerial photographic images and ground-truthing site visits. The resolution of images and hence the accuracy of measurements is affected by cloud cover especially when plant abundance is low. Data collected by remotely controlled underwater drones have improved the accuracy of habitat mapping mainly in large, clear, calm water bodies (Wasserman *et al.* 2020). Aerial drones are also used, and these allow real time assessments of geographic extent. In KZN, submerged macrophyte habitat needs to be regularly quantified using evaluations of aerial images supported by site visits.

6 MARINE ENVIRONMENT

Monitoring photographs being captured along a reef transect at a designated long-term monitoring site at Sodwana Bay
Photo: Nick Ridden

CHAPTER 6:
MARINE ENVIRONMENT

6.1 Coral Reefs
6.2 Rocky Reefs
6.3 Soft Sediments
6.4 Pelagic Environment

6.1 CORAL REEFS

Prof Michael Schleyer and Dr Sean Porter (ORI)

INTRODUCTION

Corals are colonial, reef-building animals that are renowned for their beauty, productivity and biodiversity. They are sensitive to disturbance and perturbation and readily reflect the consequences of climate change and pollution. Coral reefs are found in all tropical seas but in KZN are confined to the northeast waters, where they are less accretive than their tropical counterparts, being at the limits of their southward distribution (Schleyer *et al.* 2018). Relative cover on these reefs will provide the best measure of reef condition, both in terms of the percentage cover of the various benthic components and of the total living cover.
Changes in cover caused by perturbation may be temporary, followed by recovery, or permanent leading to an alternative stable state (e.g., a permanent shift from coral to algal cover) (Celliers 2001). Additional criteria are important when measuring relative reef cover and protocols can be adapted to target problems such as pollution, coral bleaching, increased coral disease, and excessive damage from overuse, episodic storms and ship groundings. The results derived can be interpreted as to cause, but in the case of climate change, must be accompanied by temperature monitoring.

DRIVERS

Climate change or global warming that results in elevated temperatures can cause coral bleaching, the loss of colour by corals as their pigmented symbiotic algae die under stress (Celliers and Schleyer 2002, Porter and Schleyer 2017, Porter *et al*. 2018a), and associated disease (Séré *et al.* 2015), particularly when accompanied by high insolation (bright sunlight, cloudless skies, clear water). Acroporidae (branching corals) are particularly susceptible to this; their branching forms are also fragile and prone to diver damage (Schleyer and Tomalin, 2000). Associated with this, the increased levels of atmospheric CO_2 that underly climate change lead to greater dissolution of CO_2 in the oceans, shifting their pH slightly towards acidity. The consequences of this are not fully understood and possibly not as severe as anticipated. An increase in the frequency and intensity of extreme weather events is predicted to be associated with climate change and stormy seas that accompany such episodic events will add to reef damage.

Corals are sensitive to ecosystem changes and certain indicator species can be monitored to reflect change on coral reefs. Examples of these organisms are the fragile and sensitive *Acropora* spp. and 'weed' species that come and go according to reef condition (e.g., 'swarming' soft corals and macroalgae). Corals are susceptible to natural pests such as Crown of Thorns Starfish (COTS) and the gastropod, *Drupella* spp., both favoring Acroporidae as prey. COTS are conspicuous, whereas *Drupella* spp. are cryptic and difficult to detect. In all such situations, reef communities can shift to an alternative stable state, becoming dominated by soft corals or macroalgae, the latter particularly if herbivores are diminished in number.

PRESSURES

Organochlorine pesticides (OCPs) are believed to be affecting corals significantly. Information published in the last decade has shown that high levels of OCPs are found in freshwater bodies adjacent to the coastal dune cordon of northeast KZN (e.g., Buah-Kwofie and Humphries 2017). A long-term downward trend in soft coral abundance on the coral reefs immediately offshore of the coastline was also noted towards the end of the last decade (Porter and Schleyer 2017; see Figure 6.1). Selected sessile reef organisms were checked for OCP levels as an explanation for the decline of 20% soft coral cover over the last twenty years (Schleyer *et al.* 2008, Porter and Schleyer 2017). Preliminary research considered five sites and spanned 50 km of coastline and showed surprisingly high levels of OCPs (Figure 6.3; Porter *et al.* 2018b).

Theonella swinhoei is a conspicuous, fairly abundant sponge, royal blue in colour. *Photo: Mike Schleyer*

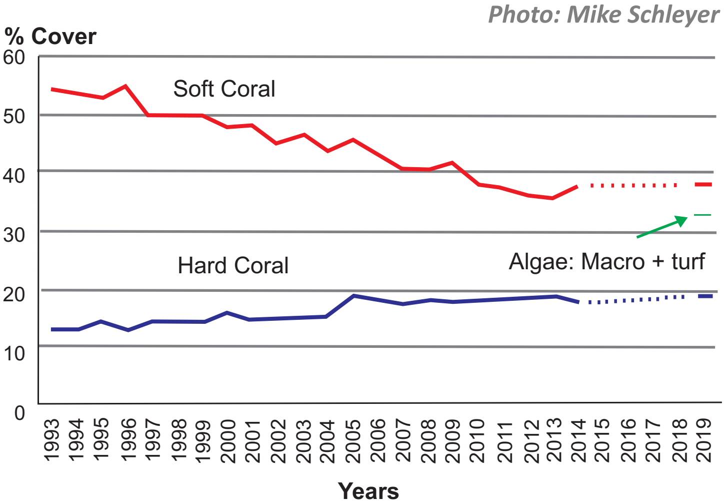


Figure 6.1: Changes in percentage cover of soft (red) and hard (blue) corals from 1993 to 2019 at Sodwana Bay monitoring site (Porter and Schleyer 2017).

Recreational activities (diving, fishing) can damage corals and the associated reef benthos (Schleyer and Tomalin 2000) and affect the reef fish community structure (Floros *et al.* 2013). Intensive diving appears to chase large predatory fish away, allowing preyed species to become more abundant (e.g. Figure 6.2, Floros *et al.* 2013). This can affect the reef benthic structure as small corallivorous and herbivorous fish increase in number. Diving may be accompanied by poaching, which generally targets giant clams (*Tridacna* spp.), certain anemones and triton shells (*Charonia tritonis*) (Schleyer and Porter 2018).

Some reef fish species also provide indicator value of reef condition or extraction and use (e.g., reduced herbivore numbers and extraction or displacement of predators by fishers and divers respectively; e.g. Figure 6.2) (Floros *et al.* 2013). Monitoring the numbers of these animals can provide an indication of such activities, provided the baseline for the reefs under consideration is known.

STATE

Historic perspective

Reef surveys and monitoring have been conducted on the South African coral reefs for three decades (Schleyer *et al.* 2008, Porter and Schleyer 2017). On Nine-mile Reef, in the Central Reef Complex, information has been obtained by extracting percentage cover data of the reef benthos recorded in photo-quadrats, providing a permanent comparative record. This simple technology can include observations on reef condition (coral bleaching, damage, disease), and provides data comparable with local and international records.

Previously mentioned potential indicator species have occurred and remained at background levels on the coral reefs, except for an outbreak of COTS in the mid- to late 90s (Schleyer 1998, Celliers 2001; Celliers and Schleyer 2006), a reduced numbers of giant clams (Schleyer and Porter 2018) and a reduction in indicator fish species on certain of the South African coral reefs (Floros *et al.* 2013). This is probably due to protection and regulated use of the reefs within a conservation area (iSimangaliso Wetland Park). However, reefs within the core of this conservation area, which should receive the greatest protection, are subjected to some of the highest recreational usage.

Current state

Reef cover has been well-documented on all the South African coral reefs and continues to be monitored (Schleyer *et al.* 2008, Porter and Schleyer 2017). Reef surveys have shown that the South African coral reefs are, overall, in good condition, being protected within the iSimangaliso Wetland Park (Schleyer *et al.* 2018).

The reefs are considered marginal as they occur at high latitude, at the limits for coral growth, and are thus not truly accretive like more tropical reefs. In consequence, soft coral cover is higher than that of hard corals (30.4 ±14.4% vs 22.5 ± 14.7%). While sea temperatures rose by 0.15°C p.a. up to 2000, they have since been dropping by 0.03°C p.a. Elevated summer temperatures have caused minor coral bleaching, the worst episode occurring in 2000 when ≤12% of the living cover was affected (Celliers and Schleyer, 2002). More recent bleaching events have affected ≤1% of the cover, which suggests that resilience is possibly emerging in the coral community (Porter *et al.* 2018a). Nevertheless, there have been changes in the community structure at the long-term monitoring site (Schleyer *et al.* 2008, Porter and Schleyer 2017) which has revealed that hard coral cover has been rising by 0.26% p.a. and soft coral cover has been reducing by 0.95% p.a. (Figure 6.1).

Being marginal, the reefs are susceptible to change. The effects of recreational use are evident in the fish communities on heavily dived reefs and in heavily fished areas. Reduced numbers of key predators such as the potato bass, *Epinephelus tukula* (Figure 6.2), and the green jobfish, *Aprion virescens* are noted (Floros *et al.* 2012, 2013). Areas historically infested by COTS have shown slow recovery and some underwent a phase shift in community structure from hard to soft corals (Celliers 2001).

The effects of pollution on the environment are well-established (e.g., Bouwman *et al.* 2013), ranging in corals, for example, from impaired reproduction and stunted growth (Glynn *et al.* 1995; Markey *et al.* 2007) to increased vulnerability to disease (Séré *et al.* 2015) and outright mortality. In the present case, OCPs are known to occur in excessive levels in freshwater bodies adjacent to South Africa's coral reefs (Buah-Kwofie and Humphries 2017). Preliminary

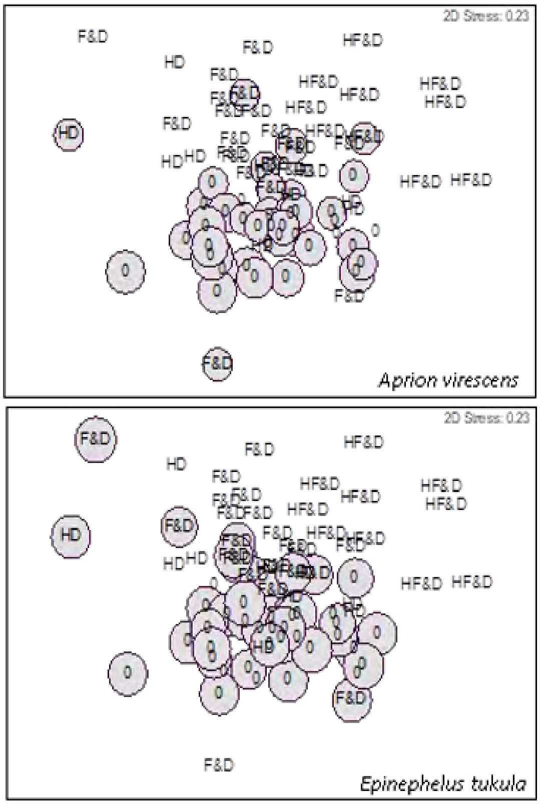


Figure 6.2: Abundance of *Epinephelus tukula* and *Aprion virescens* superimposed on non-metric multi-dimensional scaling (MDS) ordination based on 4th root transformed fish abundance and factored for human activities. 0=no diving or fishing, HD=high diving intensity, F=restricted fishing, HF=high fishing intensity, D=diving. The magnitude of the symbols reflects the number of fish at that sampling site.

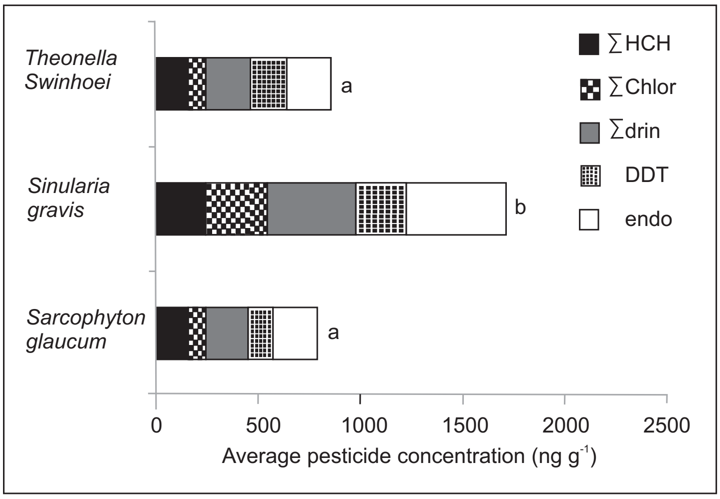


Figure 6.3. Average pesticide concentrations (n = 15) according to pesticide 'family' in organisms (dry weight) sampled on the South African coral reefs (Porter *et al.*, 2018b). Letters adjacent to bars indicate where significant differences were detected in post-hoc comparisons ($\alpha = 0.05$).

research has shown that these pesticides are found in concentrations globally considered high in benthic reef organisms collected on the coral reefs, particularly where seepage occurs through the coastal dune cordon (Porter *et al.* 2018b). This makes monitoring of pesticide levels in the reef benthos an ideal 'state of the coast indicator', particularly as they may be related to changes in reef community structure. There is little information on OCP concentrations in sponges and corals. However, the average ∑OCP concentration recorded in a global analysis of hard and soft corals was 760 ng g^{-1} dry weight; this study included known contaminated sites. An average value of 1100 ng g^{-1} dry weight was recorded for ∑OCPs in preliminary analyses on the South African coral reefs, which was notably higher than this global average. Furthermore, few of the pesticides tested occurred in sponges elsewhere at the concentrations found in the local sponge (*Theonella swinhoei*). Less information is available on soft and hard corals but the same was true of these organisms. Examples of the South African results are presented for the sponge and soft corals (*Sarcophyton glaucum* and *Sinularia gravis*) (Figure 6.3).

IMPACT

A reduction in coral cover, changes in reef community structure or a deterioration in reef condition will affect their biodiversity and economic value. Coral reefs are as rich or richer in biodiversity than tropical rain forests, and, therefore, have irreplaceable biodiversity value. In terms of economic value, coral reefs yield food, pharmaceuticals, coastal protection, cultural benefits and even building materials to otherwise impoverished coastal communities throughout the tropics. In the South African context, coral reefs in Maputaland provide benefits to its coastal communities and support a thriving diving and ski-boat angling industry.

There is some evidence that pesticides at concentrations measured in the tissues of hard and soft corals lead to bleaching and mortality. Insecticides and fungicides have also been shown to affect multiple coral life stages and, at detection limits, negatively affect coral larvae because the larvae are lipid-rich and OCPs are lipophilic.

RESPONSE

Monitoring of proposed indicator organisms and ongoing conservation of the reefs is imperative. Several research initiatives are under consideration to further elucidate the effects of high OCPs on South African coral reefs. This is essential, as well as monitoring of trends in levels of the OCPs to develop sensible responses to and mitigation of this serious form of pollution. Cessation of the use of DDT in malarial control and wiser use of agrochemicals would stop further exacerbation of the problem but dealing with extant deposits of these pesticides is difficult to conceive as they will continue to seep onto the reefs for years. Possibly the only effective mitigation will be to ensure that the reefs suffer no further assaults that would reduce their resilience, e.g., excessive ecotourism and fish extraction, unremedied COTS outbreaks.

Conservation should be accompanied by greater enforcement of compliance and an improved system of closed sanctuaries. While reefs in the 'buffer' zones of the iSimangaliso Wetland Park are well protected, reefs in the 'core', in the Central Reef Complex, are amongst the most heavily used in the world. Nine-mile Reef, the remote, northernmost reef at Sodwana Bay in the Central Reef Complex, should be given sanctuary status. This will improve the security of this reef complex, providing it both a breeding refuge for larval replenishment and a baseline site to validate monitoring results. It remains unknown whether some of the differences in the Central Reef Complex are natural or anthropogenic (human-induced) without such a baseline site. Mitigation must be considered if changes are detected, e.g. by reducing recreational use and the elimination of pest species.

International adherence to IPCC recommendations to mitigate climate change is imperative and the South African government is to be encouraged to support such action in international fora. South Africa itself needs to reduce its CO_2 output.

Data Requirements

- The most cost-effective **coral cover data** can be derived from random photo-quadrats. These provide a permanent record for percentage cover of the reef benthos.
- **OCPs** are extracted from field-collected samples and subjected to sophisticated gas chromatography and mass spectrometry to measure pesticide residues in the samples relative to recognised standards; the process is thus costly.
- Numbers of **indicator species** can be quantified per unit area from quadrats according to the size and density of the target organisms. In the case of giant clams and COTS, long transects or timed swims are appropriate. Point counts are used to assess fish abundance and community structure.

6.2 ROCKY REEFS

Prof Michael Schleyer and Dr Sean Porter (ORI)

INTRODUCTION

Rocky reefs are found in patches along the entire KZN coast, extending from the intertidal region to greater depth, in places even to the edge of the continental shelf. While intertidal and near subtidal reefs are dealt with in Section 6.1, the focus here is on reefs at greater depth than 5 m. Conspicuous reef formations are found just south of Durban, comprising Aliwal Shoal, Landers Reef, and Protea Banks. Similar formations are located to the north in Maputaland, where they are encrusted by coral communities and are dealt with as Coral Reefs (Section 6.1). The rocky reefs are inhabited by a wide diversity of algal and invertebrate life (Jackson 1976, Sink *et al.* 2005, Porter *et al.* 2013) as well as an estimated 500 reef-associated fish species. This highlights the high value of the biodiversity on subtidal rocky reefs along the KZN coast.

It is difficult to isolate suitable indicators of the condition or state of rocky reefs as their morphology and biodiversity are variable; one must thus determine commonalities between them. These are best sought amongst the well-studied resources extracted from this environment. Potential indicators are found amongst the most extracted benthic invertebrates: the oyster, *Striostrea margaritacea*, redbait, *Pyura stolonifera*, and panulirid rock lobsters, principally *Panulirus homarus*. The first two are patchy in distribution, cryptic and difficult to find (Berry 1982) while the last is nearly ubiquitous, is the most sought of KZN's subtidal rocky reef resources (Berry 1971a, b) and has excellent indicator value. While oysters are exploited in a limited commercial fishery (Schleyer 1991, De Bruyn *et al.* 2008) the other two are only harvested recreationally as they are sensitive to overexploitation (Robertson 2002). Limited brown mussels (*Perna perna*) also occur on the rocky reefs in question, but they primarily inhabit the intertidal zone (Berry 1978).

Redbait, *Pyura stolonifera*
Photo: Sean Porter

P. homarus is the prevalent spiny rock lobster on KZN rocky reefs, being found wherever suitable habitat and adequate food are available (Berry 1971a, b). As far as habitat is concerned, it takes refuge in crevices and small caves that are not subject to excessive sand movement or sedimentation during the day. It ventures forth at night to feed, and while it is considered a generalist feeder, it favours molluscs and small crustaceans, particularly barnacles and the mussel, *P. perna*. Both are suspension feeders and *P. homarus* thus feeds at the upper levels of the reef invertebrate food web. This gives the condition of its stock potential indicator value within protected and managed populations, both in terms of the population status of *P. homarus* itself and of reef biodiversity. Furthermore, *P. homarus* can live for approximately eight years, and being a 'top' predator, it probably bioconcentrates pollutants; longevity imparts animals with this attribute. *P. homarus* thus may also have indicator value for this parameter. Little is known of the longevity of redbait, but mussels can live for up to three years, while oysters live for up to 12 years (with few probably doing so). These suspension feeders probably have similar indicator potential for pollution (Section 2.3).

DRIVERS

HABITAT DEGRADATION

The habitat of *P. homarus* comprises crevices and small caves that may be rendered uninhabitable by sedimentation. While the KZN coastline is subjected to considerable natural sediment movement, this can be exacerbated by anthropogenic perturbation (e.g., sand pumping, the construction of berms and piers). The principal habitat of *P. perna* and *P. stolonifera* is accessible at low tides and vulnerable to trampling by anglers and tourists.

REEF DEGRADATION

Episodic storms, which are expected to increase in frequency and intensity with climate change, affect the biodiversity and productivity of reefs through direct damage and increased turbidity. This is exacerbated by degradation of reefs through anthropogenic pressures. These factors, in turn, affect the food supply of *P. homarus*, a top predator dependent on molluscs and small crustaceans.

PRESSURES

EXPLOITATION

The resources in this habitat are vulnerable to exploitation, but apart from *Striostrea margaritacea*, can only be fished recreationally. *P. homarus* and *S. margaritacea* are in demand and are heavily fished; *P. perna* and *P. stolonifera* are most prolific in the intertidal and near-subtidal and are thus also subjected to harvesting.

P. homarus is possibly the most ubiquitous of the larger invertebrates on KZN rocky reefs. It is also the most valuable and studied of the reef resources, and population assessments of its KZN stock have, at various times, been undertaken. This is accomplished by diver surveys, the results of which will have indicator value. A considerable wealth of literature is thus available to evaluate and interpret the results of such surveys which, due to their complexity, must be undertaken by experienced scientists.

POLLUTION

The effects of pollution on the environment are well-established, ranging for example from impaired reproduction, to stunted growth, increased vulnerability to disease and outright mortality. Preliminary research has shown that OCPs are found in high concentrations in benthic reef organisms collected on South Africa's coral reefs (Porter *et al.* 2018b) and an ORI proposal is under consideration to expand this research to KZN's rocky reefs where these substances also constitute a problem (Greyling 2018). *P. homarus* will be a good candidate for this research, as well as *P. perna*, *P. stolonifera* and *S. margaritacea* within their patchy distribution.

STATE

As stated, *P. homarus* is one of the most intensely studied marine invertebrates in KZN; this research has been ongoing since the late 60s in the last century and has covered the taxonomy, biology, behaviour and genetics of this species (Berry 1970, 1971a, b, 1974, Smale 1978, Steyn and Schleyer 2011, Reddy *et al.* 2014). Much of this information was summarised by Steyn and Schleyer (2009) in a document that focused on management of the resource.

Ongoing invertebrate catch statistics monitoring (Steyn and Schleyer 2014) provides background information on trends in the harvest of this valuable resource, thereby revealing levels of exploitation (Steyn *et al.* 2008, Steyn and Schleyer 2009). This shows where the harvest is sustainable, and where *P. homarus* retains indicator value, or where regulation of fishing is needed to prevent over-exploitation of the stock. An indication of the extent of the harvest of this resource, mostly by divers (Figure 6.3), and the other target species in KZN is presented in Table 6.1.

Perna perna, *P. stolonifera* and *S. margaritacea* have been subjects of both harvest monitoring (Table 6.1; Steyn and Schleyer 2014) and research in KZN, and this includes a limited amount of information on their bioconcentration of pollutants and metals.

Table 6.1: Representative data on the annual *P. homarus*, *P. perna*, *P. stolonifera* and *S. margaritacea* harvest (tonnes) in KZN. All are for landed weight except for *S. margaritacea*, which is for shelled weight (flesh only).

Year	*Panulirus homarus*	*Perna perna*	*Pyura stolonifera*	*Striostrea margaritacea*
2003	51.2	44.2	2.45	0.015
2005	52.6	43.9	1.47	0.42
2006	53.9	34.9	2.87	0.67
2007	25.9	20.8	1.54	0.19
2008	47.0	32.8	2.47	0.05
2009	31.7	37.6	3.05	0.17
2010	24.7	19.11	0.94	0.20
2011	49.3	48.6	2.60	0.12
2012	40.3	24.8	9.42	0.88

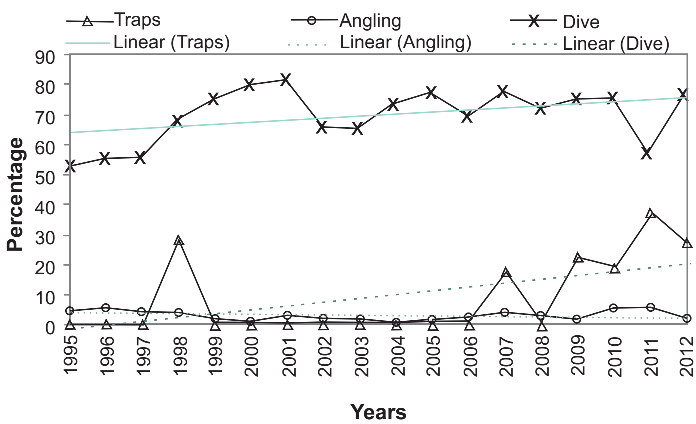
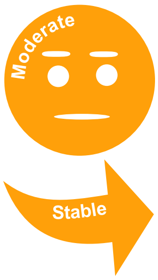


Figure 6.3: Comparative percentage of rock lobster harvesters employing the various collecting methods: snorkel diving, traps and angling (Steyn and Schleyer 2014).

IMPACT

Reef habitats are biologically productive and provide multiple resources and ecosystem services of benefit to humankind. Impacts of reduced reef biodiversity and productivity affect reef community structure, and in consequence, their economic value. In all these respects, the rocky reefs of KZN provide benefits to its coastal communities and support ecotourism, diving and angling.

RESPONSE



Ongoing invertebrate catch statistics monitoring will provide background information on trends in the harvest of these valuable resources, thereby revealing the levels of exploitation. This will provide management recommendations for refinement of management protocols to ensure their sustainable harvest. Additional funding is required for long-term monitoring of the marine invertebrate resources on the KZN coast for this purpose.

Data Requirements

Diver surveys are conducted by experienced rock lobster fishers in timed dives. The fishers bag their catch for on-shore measurement that yields size and catch-per-unit-effort data. Thereafter, the catch is released back into the environment. These data provide a measure of the 'health' and abundance of the lobster stock, providing an indirect measure, or indicator of reef health (in localities that are not over-harvested).

Extracts from field-collected samples are subjected to sophisticated gas chromatography and mass spectrometry to measure pesticide residues in the samples relative to recognised standards; the process is thus costly. The results are subjected to statistical analysis to establish their significance.

Toxicological tests on living material in aquaria will be needed to establish cause and effect of the consequences of any high levels detected. Ongoing monitoring of their levels is essential to determine their upward or downward trend, and to predict the consequences and possible avenues for mitigation of their effects.

Close-up of a bed of *Perna perna*
Photo: Sean Porter

Panulirus homarus clustered in a reef crevice
Photo: SAAMBR

6.3 SOFT SEDIMENTS

Fiona MacKay (ORI)

INTRODUCTION

Soft sediments create the largest of marine habitats as they cover >70% of the seafloor. Sediments are vital in the remineralisation and exchanges of organic matter and nutrients with continental shelf sediments, remineralising 52% of global organic matter (Thrush and Dayton 2002). Soft sediment environments are abiotic substrates of terrigenous origin derived mainly from erosion of the continents (Green and MacKay 2016), that are influenced by the interactions of hydrodynamic and nutrient regimes and physical and biological processes (Ellingsen 2002). These unconsolidated ecosystems provide a variety of habitats for a diversity of benthic (bottom-dwelling) vertebrate, invertebrate and plant species (Lohrer and Hancock 2004) with species traits that select for living on (epifauna), living in (infauna), or being associated with (demersal fauna) specific sediment types. Coastal marine soft sediments are generally inshore of -30 m and this zone differs markedly in size across KZN. On the KZN shelf, vast areas of shallow soft sediment habitats are found between Durban and Richards Bay, known as the KZN Bight. There, dense sediments are mainly fluvially derived (Green 2009) from outflowing estuaries delivering freshwater, nutrients and terrestrial

The uThukela Estuary delivering inputs to fluvially dependent ecosystems on the KZN Bight
Photo: ORI

sediments. Other oceanographic features influencing the KZN shelf are the Agulhas Current, wind-driven hydrodynamics, an upwelling area at Richards Bay, a semi-persistent Eddy off Durban (Lutjeharms 2006, Robert *et al.* 2016) and a passive shelf margin (Scrutton 1982). These combined influences make for unique benthic habitats (Green and MacKay 2016) and are key to the ecology of the region. The types of sediments present depend on fluvial inputs, currents, waves, bathymetry and local climate. Coarse, well-sorted sediments are found on high energy parts of the shelf and more stable areas are characterised by muddy, organically rich sediments (Gray and Elliott 2009). Soft sediment ecosystems are significant contributors to marine ecosystem function (Snelgrove 1999) as they support dominant marine biota.

The geological aspects of KZN's soft sediments have been well studied (e.g., Green and MacKay 2016, Engelbrecht *et al.* 2020) but the biotic attributes less so. Largely due to the costs involved, expertise required, difficulty in sampling and many sediment species still require taxonomic assignment (Griffiths *et al*. 2010). Early biotic studies were for the purposes of outfalls monitoring (McClurg 1988) and more recently on the community distribution across the Bight relative to the environmental drivers (MacKay et *al.* 2016). The shallow, central KZN Bight supported a commercial trawl fishery (but is now mostly closed) targeting several prawn species (Section 8.6; Fennessy and Groeneveld 1997); all these which have a coastal connection, requiring estuaries to complete lifecycles.

DRIVERS

The KZN shallow marine soft sediment environment is influenced by global change drivers that together influence ecosystem state. The drivers are separated according to those arising from human development or climate change (see UNEP 2015). The demographic profile of KZN, including population growth, highly influences development levels. The KZN coastal population has a wide-ranging economic profile, including elevated grant dependency and poverty at the lower end, and both are increasing (see KZN Provincial Government 2019/2020). The lack of education and awareness of environmental, development and climate issues affecting the marine environment, particularly those arising from individual behaviours (e.g., littering and habitat destruction) on land are also drivers of change. With increasing coastal development, the number and reach of land-based activities increases into the marine environment. Changes due to climate-induced drivers are pertinent for the sediment biophysical system (see Birchenough *et al.* 2015), as habitats, species and communities that may already be compromised due to anthropogenic activities are less able to ameliorate or buffer against climate change effects. Climate change and variation could affect the habitats, benthos, plankton, fish, mammals, seabirds, and the presence of non-native species of marine and coastal ecosystems. Ecosystem drivers are primarily sediment grain size attributes (MacKay *et al.* 2016), characteristics such as texture, grain size and composition influence benthic species composition (Snelgrove and Butman 1994). Other factors such as sediment organic content, water depth and temperature also play a role (Reiss *et al.* 2010). All factors are affected by the physical oceanographic attributes from the local to regional scale.

PRESSURES

The direct pressures on KZN marine soft sediments and their species are all from human activities. Land-use change and development up to the foreshore can influence beach and inshore soft sediment ecology, particularly by influencing processes that are land/ocean dependent such as nutrient and sediment dynamics. The soft sediment fauna of KZN estuaries are highly correlated with particular land-use types and activities (Sheppard and MacKay 2018). Broadly, this could be extended to the corresponding inshore marine benthic environment to coarsely delineate high pressure areas e.g., urban developed, rural transformed (agricultural) and natural (coast forest) dominated etc. Building sand for development, is mined from KZN coastal rivers and estuaries (Section 8.8), and has placed enormous pressure on coastal ecosystems including marine soft sediments. The KZN nearshore is therefore ever more sediment-starved (see de Lange *et al.* 2008), denoted by extensive erosion across the coast, especially in hotspots from Durban to Zinkwazi and uMkomaas to Pennington (Breetzke *et al.* 2008).

Increasingly, the KZN coast (particularly off Durban) has received excessive raw sewage, polluted stormwater and litter (mostly plastics), due to failing infrastructure, flooding after storm events and electricity outages. Other serious pollution incidences are increasing such as oil and chemical spills, the most disastrous being the UPL spill of agrochemicals in July 2021 (Section 2.3). Pollution enters the KZN shelf via estuaries, subterranean freshwater flow (e.g., Porter *et al.* 2018) and marine outfalls.

No significant trawling occurs over inner shelf sediments, the previously trawled area is now within the restricted uThukela Banks MPA (declared in 2019). However, trawling was already on the decline since 2013 (Sink *et al.* 2019a). It still sporadically takes place inshore off Richards Bay and St Lucia (Section 8.6) over sandy and muddy sediments. Activities associated with the petroleum industry pose less risk to inshore sediment ecotypes, due to MPAs (Section 9.2). However, pressure remains due to speculative surveys for oil and gas (Section 8.10). The estuarine-marine connectivity linkages are now also recognised not only for biota movement but also for freshwater delivery to marine habitats (see Sink *et al.* 2012, 2019, Van Niekerk *et al.* 2019). Marine river-dependent ecosystems are important, particularly in KZN where there are many estuaries, and the marine environment is oligotrophic. Freshwater inputs via estuaries transport sediments and nutrients that maintain ecological processes but also sustain unconsolidated sediment habitats (see Green and MacKay 2016).

Changes to ocean circulation and sediment dynamics, temperature rises, pH decreases causing carbonate dissolution (ocean acidification), sea-level rise and increased storminess are among the climate changes that could affect marine sediment environments. However, the individual pressures are problematic to disaggregate because of the complex linkages between the various environmental and biotic effects (benthic and pelagic systems) (Birchenough *et al.* 2015).

STATE

There are no specific assessment methods for ecosystem condition or valuation protocols for goods and services targeting South African marine soft sediment environments. Thus, soft sediment state assessments follow more general marine environment protocols (that also include shallow-, deep- and reef ecosystems). Main ecosystem services (Atkins *et al.* 2011) of food provision (direct extraction of organisms for consumption), regulation (climate, flood and storm protection, waste bioremediation through remediation and storage) leisure and recreation, and support services (life support, nutrient cycling) are assessed during each cycle of the marine component of the NBA.

Historic perspective

Prior to 2004, there was no mapping of marine habitats. The first marine National Spatial Biodiversity Assessment (NSBA) derived nine bioregions (Driver *et al*. 2004). At that time KZN marine systems (including soft sediments) were mostly influenced by extractive uses of marine living resources, coastal development and mining. The shallow photic environment (shelf sediments) was considered Vulnerable and poorly protected except in the far north where it was Least Threatened and well protected with no-take restrictions. In 2011, the first marine habitat classification and national habitat maps were developed underpinning ecosystem threat status and protection levels for 136 habitat types (Sink *et al.* 2012). A higher proportion of coastal than offshore habitat types were threatened, and benthic habitats were more threatened offshore, with 40% of flow from South Africa's 20 largest catchments, no longer reaching the coast. The crustacean trawl fishery was a significant impact inshore at uThukela and offshore at Durban. Coastal development was high from eThekwini to the south coast. Based on cumulative impact scores the KZN benthic environment was Poor to Good, with an ecosystem threat status of mostly Vulnerable (Sink *et al*. 2012).

Current state

The Marine Ecosystem Pressure Matrix (used for evaluating ecosystem threat status) and the National Marine Ecosystem Map (see Sink *et al.* 2019) was used to see which pressures induced high scores for KZN coastal soft sediment ecosystem types: 'Soft Inner Shelf', 'Muddy Shelf' and 'Shelf Mosaic' environments. Very High impacts were attributed to crustacean trawling, commercial line fishing (Section 8.6), recreational line fishing (Section 7.3) and shark control. High impacts were due to mining and reduction of freshwater flows. Petroleum activities, wastewater disposal and dredged material dumping was scored as Medium. Overall, the KZN shelf ecosystem was Moderately to Very Severely degraded and much of the KZN shelf is Vulnerable to impacts from human induced pressures. The threat status of the shallow, soft sediment ecosystem types such as the KZN Bight Muddy Inner Shelf and the KZN Bight Sandy Inner Shelf are Vulnerable and Endangered, respectively (Sink *et al*. 2019).

Considering the restrictions to the human-caused damages to KZN marine ecosystems, KZN has expanded its MPA network to significantly increase the area under protection. Since 2019, four MPAs in KZN have restricted and controlled uses and protect sizable areas of the shelf (Section 9.2). The increased protection for soft sediments will contribute to biodiversity conservation, and socioeconomic benefits. The soft sediments have been coarsely mapped (Green and MacKay 2016) and show the vast mudbanks off uThukela, a mid-shelf coarse sand and gravel field between uMvoti and uThukela and the increase in grain size from the coast to offshore Richards Bay (Figure 6.5).

There are few KZN soft sediment community studies, but two focused exclusively on the macrobenthos component (infauna size > 0.5 mm) (MacKay *et al.* 2016, Untiedt and MacKay 2016). Over 1000 taxa were sampled across the KZN shelf from Durban to Richards Bay and were diverse types mainly from six Phyla (Annelida, Arthropoda, Mollusca, Echinodermata, Sipuncula and Cnidaria). Two unique and distinctive assemblages were found, one in the muddy sediments off the uThukela Estuary and another on the mid shelf between Thukela and Durban. The latter is influenced by poorly sorted, coarse sand and likely influenced by the Durban Eddy (MacKay *et al.* 2016). Some taxa have adapted to specific sediment habitats on the KZN shelf, particularly those influenced by freshwater out welling by switching from deposit to suspension feeding during periods of increased riverine flow or from carnivorous to deposit

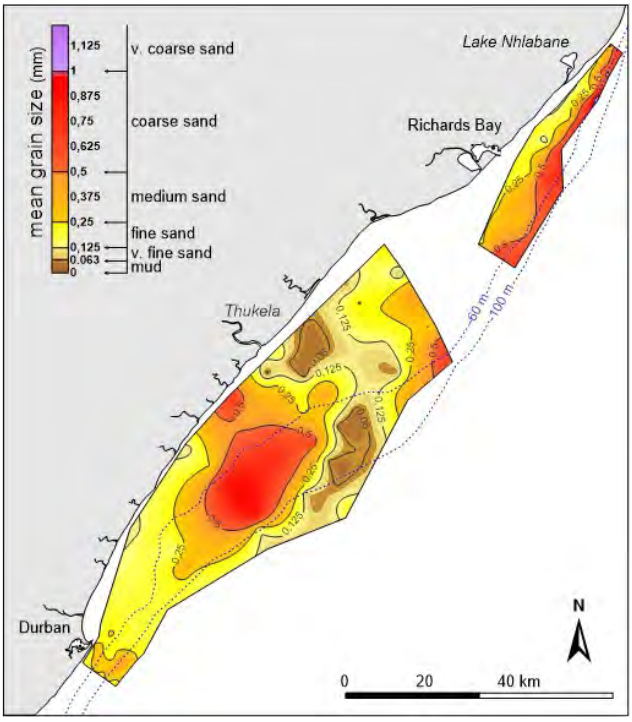


Figure 6.5: Soft sediment grain size distribution across the KZN Bight (from Green and MacKay 2016)

feeding modes (Untiedt and MacKay 2016). These studies found sediment grain size to be an important driver of community composition and abundance distribution. The macrobenthos are an important link in soft sediment food webs to higher levels like demersal fauna, they also dominate the KZN shelf benthic food web, which relies on detritus delivery through KZN estuaries (Scharler *et al*. 2016). The sediment epifauna are a large information gap, but several studies are addressing this. The Sciaenidae and Cynoglossidae fishes are prominent among the mud banks of the KZN shelf, the former possibly indicate the presence of prawns. The very fine sand and mud habitats off uThukela supported a prawn fishery (Section 8.6; UNEP 2015).

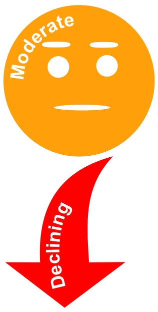
IMPACTS

Multiple stressor studies superimposing spatial and temporal components of marine benthos show complex synergistic or antagonistic responses which must be understood to inform management actions (Carrier-Belleau *et al*. 2021). The effects manifest at the ecosystem, population and organism level and may be non-linear. Alteration of natural communities through loss of diversity leading to possible local species extinctions and changes to abundance, and habitat degradation leading to functional ecosystem change. Overall, it is estimated that the KZN soft sediment impacts are moderate and ecosystem health is declining. Coastal development, beach nourishment, sand mining and other land use changes can alter sediment movements between the coast and marine environment (Dugan *et al.* 2011). The most severe responses will result from a complete loss of sediment supply and restructure marine sediment habitats, the communities that reside in or on them, and the associated fish assemblages. Thus, sediment habitat and biodiversity losses may suppress the provision of important coastal ecosystem services (Sink *et al*. 2019) and disrupt cross-realm connectivity and ecological processes including nutrient supply. The visible extent of river plumes on the KZN shelf is testament to the amounts of freshwater and suspended sediments that are transported and eventually settle to the seafloor. There is also evidential support for the dependencies of some coastal marine systems on fluvial inputs. It is stated that the larger river systems have experienced the greatest alterations to flow and that these have caused the most changes to South African marine ecosystems (Sink *et al.* 2019). Freshwater alterations disrupt environmental cues and therefore reproductive movements, food web processes (Scharler *et al.* 2016), and potentially reducing bottom fish catches causing economic impacts (Lamberth *et al.* 2009). Freshwater transports habitat creating sediments such as important muds to the uThukela Banks. The uThukela supports a unique sediment community that is dependent on these muds (MacKay *et al.* 2016) and has adapted specific feeding modes to accommodate freshwater pulses as they arrive from the coast. Consistent flow reductions will lead to the loss of muds and the unique communities they support.

The impacts of crustacean trawling on physical habitats and the communities that reside there have not been studied in KZN. Trawling impacts nursery habitats and there is a substantial bycatch of the fishery of other invertebrates (e.g., crabs, molluscs), fishes (impacts on sensitive species e.g., sharks, rays) and occasionally turtles (Fennessy and Groeneveld 1997). From trawling disturbance studies done elsewhere, resident biota determines the response intensity; even low disturbances can have large effects on sensitive species. The direct habitat effects of trawling include removal of physical habitat and decreases in sediment texture (Thrush and Dayton 2002). The effects to sediment organisms, communities, biodiversity and functional diversity are variable depending on trawl depth, sediment habitat and location. Many impacts are negative and moderate to high effect. Pollution takes many forms and impacts on marine sediments have wide-ranging effects from killing off species to causing diseases and algal blooms (Section 2.3). The direct effects cause contamination of sediments and then sediment organisms show physiological responses. Indirect effects are population, community and ecosystem responses such as reduced numbers of sensitive species richness and biomass, and eventual loss of ecosystem goods and services (Borja *et al.* 2011). Pollution is considered a large pressure on marine biodiversity (Sink *et al.* 2019).

Climate change effects to sediments are primarily to sediment communities. For instance, changes in seawater temperature causes distribution shifts in species and benthic species phenology may be altered through shifts in, e.g., spawning timing (Birchenough *et al.* 2015). The most important effects of altered hydrodynamics are related to water column food pathways to the benthic system. Lower calcification rates because of lower pH affects organism physiology, in turn affecting biodiversity and trophic interactions. Soft sediment calcareous organisms such as molluscs, echinoderms and foraminifera may experience calcification issues of shells and skeletons (Birchenough *et al.* 2015).

RESPONSE



Despite marine sediments making up most of the coastal seafloor, knowledge is relatively poor. Supporting points in the NBA 2018, Marine Realm (Sink *et al.* 2019), responses should focus on:

- *Improving foundational biodiversity knowledge*. Smaller invertebrates in, and on the seabed, are still poorly inventoried.
- *New generations of marine taxonomists* need to be supported; incentives and funding directed towards the discipline are needed. Primary focus should be on invertebrates.
- *Shelf-wide physical surveys*. Data are critically deficient on fine scale bathymetry. No sediment work has been conducted in the iSimangaliso and Aliwal Shoal MPAs.
- *Detailed mapping* of physical features, sediment distribution and soft-sediment habitats are needed to inform Critical Biodiversity Area maps.
- *Cumulative pressures on coastal marine sediment habitats* need to be considered in environmental assessments for urban areas where there are pressure hotspots.
- *Fluvially-dependent marine sediment ecosystems must receive vital quantities and quality of freshwater.* Coastal marine ecosystems are dependent on land-derived sediment and flows.
- *Cross-sector and cross-realm plans* need to be developed and must consider the coast-marine connectivity of ecosystem processes, species movements and environmental flows.
- *Implement fisheries management plans* that focus on fishing in soft-sediment habitats, to reduce biodiversity and physical impacts.
- *Climate change impacts on soft sediment biodiversity* require a strategy for detecting and monitoring change.
- *Awareness campaigns* on KZN's soft sediment biological assets and biodiversity value.

Data requirements
Monitoring and long-term studies that gather data for climate change and ecosystem shifts are required. For instance, continuous temperature, conductivity and pH should be measured at strategic shelf locations. Local wave climate data is needed to inform local coastal models for sea-level rise. Updated sediment data exported from the coast will inform sediment budget studies and assist in rationalising sand mining activities.

6 .4 PELAGIC ENVIRONMENT

Prof. Sean Fennessey (ORI)

INTRODUCTION

The pelagic environment is considered here as the sea's water column, the organisms it contains and the processes occurring there, from the surface to just above the seabed. Pelagic water depths are shallow in areas close to the coast and range from shallow to very deep with increasing distance from the coast as seabed depth increases. The Agulhas Current, one of the world's strongest continental boundary currents, is the prevailing offshore pelagic feature, transporting billions of litres of warm, salty water southwards every second. The inshore edge of the current is normally close to the coast (10-15 km offshore) off southern and northern KZN, but up to 50 km offshore off central KZN, and can extend down to depths of >2 km. The wide current core varies from 50-100 km offshore, but meanders can bring warm, clear, nutrient-poor, current water onto the shelf and close to the coast, and this is consistently so in the northern parts of the province. Large Mozambique channel eddies also regularly influence KZN shelf waters as they progress southwards. Pelagic waters on the shelf are cooler than in the current, and off central KZN, are more turbid owing to terrestrial runoff and the characteristically rough seas caused by an unprotected coast and regular winds. Marine life in the pelagic habitat ranges from minute (plankton) to massive (whales) and is much less prolific than off the Western Cape, although there is higher diversity. Many larger pelagic organisms make use of the wider Agulhas Current or its inshore processes for regional or local migration.

DRIVERS

The pelagic environment of KZN is very closely influenced by the Agulhas Current. Seasonal differences in Agulhas Current flow and the recent broadening and warming of the current are being driven respectively by spatial and temporal disparities between, and an increase in, wind speeds in the southern Indian Ocean. The latter is partly mediated by changes in frequencies of Mozambique channel eddies and meanders. These are proximate oceanic-scale drivers, with the broadening and warming of the current linked to anthropogenic climate change (Beal and Elipot 2016, Sections 3.1, and 3.2). A local, proximate driver is that of reduced terrestrial outflow of nutrients to the marine environment because of river abstraction via, amongst other interventions, dams.

PRESSURES

Volumetrically and spatially, the pelagic environment is the largest of the marine habitats. It is a strong driver of climate and weather on the KZN coast and on the southern African region and is globally influential too. Most marine organisms spend part of their life history in pelagic habitats; some are permanently pelagic. Currents in the water column distribute nutrients, eggs and larvae locally and more widely, assisting organisms to maintain their distributions and to widen recruitment, if settlement conditions permit. The habitat supports some pelagic fishing: a small, seasonal, commercial beach-seine fishery, recreational fishing and industrial longlining (Sections 7.3 and 8.6). Coastal pelagic habitats receive run-off and effluent from the land (Section 2.3), and when these contaminants settle out of the water column, they affect other habitats. Finally, the sea provides a medium for most of the global trade undertaken by shipping.

STATE

Historic perspective

The dominance of the southward-flowing Agulhas Current has been long established, with indications that its temperature and mean position of the flow have been stable for around 150 000 years (Winter and Martin 1990), although Prell *et al*. (1980) suggest that during the Last Glacial Maximum (which peaked ca. 21 000 years ago), the current was cooler, probably shallower, and with considerable seasonal variation. If so, the upper pelagic environment off KZN would have been considerably cooler than currently, and the pelagic ecology would have differed too. For example, the sardine run would have extended much further north (Freon *et al*. 2010). Heydorn *et al*. (1978), Schumann (1988) and Lutjeharms (2006), and references therein, give overviews of the more recent historical physical oceanography that characterizes much of KZN's pelagic environment. The Agulhas Current was known to at least partially account for the subtropical nature of the pelagic habitat; the current itself being warmer, particularly in the upper layers, than the adjacent shelf waters. Water temperature at great depths could be as low as 4°C though. Meanders in the current were known to cause inshore current reversals, and the core of the current could move by as much as 30 km in one day. In the absence of continuous monitoring, seasonal patterns could not be determined. The turbulent nature of KZN's seas was recognised as being a consequence of the narrow continental shelf and exposed coast, which lacks barrier reefs or offshore islands; the lack of embayments meant limited retention of coastal waters. This turbulence and the relatively high rainfall meant that inshore water clarity was known to be low off central KZN, and not uncommonly so off the south coast. Primary productivity (phytoplankton) was concentrated in the upper pelagic layers and was known to be low compared to that on the South African west coast. There was unanimous acceptance that, at least in the central region, productivity was mainly driven by the Agulhas Current causing prevailing shelf-edge upwelling in the region off Richards Bay, supplemented at times by inputs from the uThukela River. Peaks in secondary (zooplankton) productivity were known to be associated with phytoplankton blooms in these areas; zooplankton diversity was high in the Agulhas Current, but low on the shelf and beyond the Current. Ecological knowledge of higher pelagic organisms focused on the winter run of sardines and their associated predators to KZN, the spring nesting and summer hatching of turtles, and the natal seasonal migration and dispersal of these and other animals using the regional and/or local currents associated with the Agulhas Current. Seasonal spawning to disperse pelagic eggs and larvae of even non-pelagic fisheries species such as lobsters and fishes was initially thought to occur via the Agulhas Current itself, but inshore shelf currents were later demonstrated, instead, to be the main vector.

Current state

The characterisation of the oceanography of the pelagic environment provided in the overviews by Heydorn *et al.* (1978), Schumann (1988) and

Lutjeharms (2006) is still largely relevant today. The review and bibliography by Fennessy *et al.* (2016), based on more recent (2010) synoptic surveys of much of the pelagic environment off KZN, provides updates and refinements of this knowledge. Subsequent overviews and findings from episodic surveys have been drawn on here as well. There has finally been formal measurement of Agulhas Current seasonality, showing a 25% increase in strength in summer relative to winter (Beal *et al*. 2015, Hutchinson *et al.* 2018), and that the current has warmed (Rouault *et al.* 2009) and broadened (not strengthened) in the last 30 years (Beal and Elipot 2016). Shelf current directions alternate between southward (predominantly) and northward, influenced by prevailing north-easterly and south-westerly winds and the proximity of the Agulhas Current to the coast; a semi-permanent cyclonic eddy south of Durban is responsible for an inshore north-flowing current "swirl" north of Durban. Pelagic waters off central KZN can be displaced into the Agulhas Current and propagated downstream, or can be retained centrally for some time, or can be pushed northwards on the inner shelf. While the Agulhas Current is still recognised as a major driver of upwelling off Richards Bay, shelf-edge upwelling of cool water is also now known to be driven by north-easterly winds. Sea surface temperatures close to the coast range from 16-28°C, lowest in August and highest in February, with an annual average of around 24°C (Figure 6.6); offshore surface temperatures are up to 5°C higher. In winter, shelf water salinity may be slightly lower than in the current, but in summer it can be much less due to riverine outflows, with associated increased turbidity.

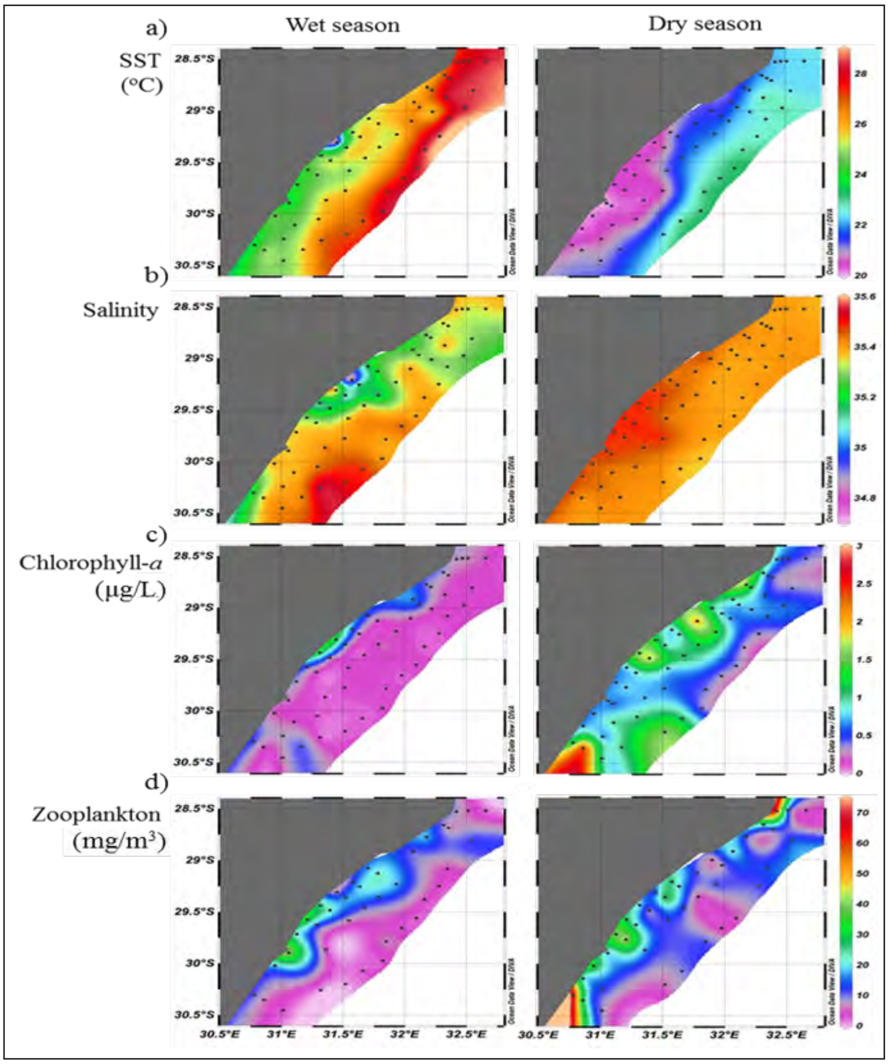


Figure 6.6: Surface environmental variables during Wet (January) and Dry (August) seasons recorded in the most recent (2010) comprehensive synoptic surveys of the KZN pelagic environment. Adapted from Pretorius *et al.* (2016)

Average seawater nutrient levels and planktonic primary productivity are low (Figure 6.6), as upwelling features are not extensive. The upwelling off Richards Bay is still believed to be the main source of nutrients off central KZN, although their retention in the system is very variable owing to the dynamic oceanography. Riverine organic inputs are important in the central inshore pelagic ecosystem during the summer, while organic matter of marine (upwelled) origin is a pelagic driver offshore, and during winter. In the phytoplankton of upper water layers, where light penetration is greatest (< 200 m depth), diatom-flagellate communities predominate in cooler shelf waters, while prokaryotic phytoplankton are prominent offshore in the warmer Agulhas Current. Bacterial prokaryotes in contrast are more abundant close to the coast, particularly around river mouths. Zooplankton biomass is dominated by copepods, and is very variable, but is concentrated in the upper 100 m and is much higher on the shelf than in the Agulhas Current; concentrations are higher in winter, particularly north of Richards Bay. Generally, variability in zooplankton biomass is associated with varied short-term oceanographic features, rather than seasonal effects.

Fish larvae are patchily distributed but are more concentrated on the shelf, with greater diversity further offshore, reflecting the role of the Agulhas Current in transport of more tropical species; composition also varies seasonally (ORI, *unpubl. data*). Pelagic fish abundance is dominated by sardines and anchovies, the former migrating to KZN during winter, although there are fewer observations of the phenomenon in recent years (Fitchett *et al.* 2019). Medium-sized pelagic fishes occur seasonally on the shelf and, although there are no recent population assessments, there are concerns about the status of several species (Mann 2013, Section 7.3). Larger pelagic fishes such as tunas and billfishes mainly occur offshore and are also seasonally abundant; the population status of the majority of these in KZN is even less well known, as they form part of regional stocks (Section 8.6). It is probable that the abundance of all exploited pelagic fishes off KZN, except for Cape anchovies which have recently expanded their distribution into KZN (Horton and van der Lingen 2019), has declined substantially since the mid-20th century. Pelagic marine mammals, particularly whales and common dolphins, become increasingly common off KZN during their winter migration from

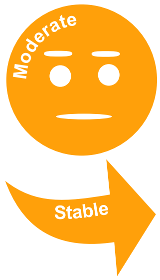
Sharks break up a mass of sardines
Photo: Ryan Daly

southern waters and there has been a substantial increase in the numbers of humpback whales migrating to KZN in recent years (Findlay *et al*. 2011).

IMPACT

Cross-shelf, alongshore and depth-related variability in the characteristics of pelagic waters off KZN are driven by changes (meanders and pulses) in the position of the inshore edge of the Agulhas Current, as well as by the occurrence, persistence and dynamics of passing offshore cyclonic eddies emanating from the Mozambique Channel and southern Madagascar (Lamont *et al.* 2016). Spatial and temporal changes in the Agulhas Current directly impacts coastal upwelling (and hence pelagic ecosystem productivity) and the exchange of water (and its constituents, such as larvae and pollutants) between the coast and the open ocean. Longshore shelf currents and their role in larval recruitment, retention and dispersal, as well as migration of harvested fishes (Beckley 1993, Roberts *et al.* 2010, Hutchings *et al.* 2002) will also be affected. Instabilities and changes in the Agulhas Current can potentially exacerbate warming and extreme weather events (Beal and Elipot 2016). Reduced riverine outflows will result in reduced nutrient availability for the KZN shelf pelagic ecosystem in summer (de Lecea *et al.* 2016), with potential reduced productivity and availability of organisms in higher trophic levels, such as fishes. Although not yet demonstrated, turbidity on the central shelf will also probably be reduced, with concomitant changes in pelagic fish species composition, prejudicing species favouring high turbidity.

RESPONSE



Notwithstanding recent advances in understanding of the dynamics and impact of the Agulhas Current on the KZN coast, much remains to be learnt. The oceanography driving the pelagic ecosystem changes rapidly in time and space, which makes for difficulties in observing and predicting, further aggravated by operational and financial challenges to deployment of instrumentation. However, long-term in situ monitoring, remote sensing and improved ocean models will improve fundamental understanding of the role of the Agulhas Current and how the changes it is undergoing will affect the pelagic ecosystem.

Data Requirements

There is very limited regular in situ monitoring of the pelagic environment off KZN. Knowledge is based on episodic oceanographic surveys, or monitoring of disposal outfalls, or inferred from indirect surveys such as for fisheries, or from remote sensing by satellite. Ideally long-term monitoring transects are needed, sampled throughout the water column, at shallow and deep depths, from the coast to far offshore, at regular intervals, for a suite of parameters, including temperature, salinity, turbidity, oxygen, pH and nutrients; samples to be collected of phytoplankton, zooplankton, pollutants and contaminants. Fisheries monitoring and compliance is required.

7 HUMAN ENVIRONMENT

People enjoying the Golden Mile, Durban
Photo: Kierran Allen

CHAPTER 7:
HUMAN ENVIRONMENT

7.1 COASTAL ACCESS

Marinel Willemse (formerly ORI)

INTRODUCTION

The cultural, historic, economic, and spiritual value of the coast to the people of KZN, and indeed the whole of South Africa, make it imperative that access to the coast is provided, maintained and where necessary, improved. Coastal access provides opportunities for economic development, extracting resources, recreation, education, and overall improvement of both mental and physical health (KZN EDTEA 2017).

Coastal access land is defined in the ICM Act as *"land designated in order to secure public access to coastal public property"*. This includes the provision of public amenities and associated facilities such as parking areas, public toilets, boardwalks and boat launch sites. The ICM Act emphasises the need for equitable access to and utilisation of the coast and its resources.

The composition of access routes along the coast is an important indicator of the state of access and the effect on the coastal environment, that too many informal access networks crossing the dune systems indicates deterioration of sensitive coastal environments while well-distributed formal public access routes indicate an equitable well balanced coastal environment accessible by all.

The KZN coastline varies from a highly pristine northern coast to a highly developed southern coast. Due to this variability the type, occurrence and density of coastal access routes along the coast will differ and will therefore need to be accommodated for differently.

DRIVERS

Different environmental, socioeconomic and cultural drivers are evident along coastal areas, often leading to conflicts in land use and a need to either improve and increase access in light of increasing development, population growth and tourism or restrict access to aid in conserving the environment.

Three out of four visitors to KZN will visit the coast and undertake activities related to the coast, highlighting the expectation of being able to access the coast with ease. Increasing environmental awareness and consequent conservation actions are driving rehabilitation of damaged, sensitive coastal areas such as dunes and sensitive vegetation. Controlling, diverting and limiting access routes falling within these areas, are attempts to balance out the pressures placed on them.

Another driver is that of coastal development, which continues to expand along large sections of the KZN coast. Public access becomes increasingly restricted, as gated estate development can result in unequal access to the coast and its resources.

PRESSURES

The most significant pressures are those placed on the environment and social equality. The former is due to the removal or damage of vegetation where access routes are created and maintained. The latter is a result of access not equally distributed along the coast or not available to all where private routes predominate, leading to increased pressure on social expectations and inequality.

STATE

Historic perspective

Historically, public access to the South African coast took the form of street ends, boat ramps, parks, and public piers. Waterfronts, view corridors and designated rights-of-way have been developed in recent years as an attempt to improve public access to the much-desired coast. However, many cases still exist where industrial, commercial and residential developments reduce and at times eliminate public access to some areas.

From 2006 to 2018, as observed from aerial imagery (excluding iSimangaliso Wetland Park), access routes to the coast increased from 2006 to 2128. Formal public routes increased from 480 to 543 displaying a significant improvement in the provision of maintained routes by local municipalities. Informal public routes remained static, only increasing from 599 to 608 routes. Private routes increased from 927 to 977. Parking facilities along the coast increased from 405 to 434 while recreational facilities such as open parks and amenities increased from 124 to 137 (EDTEA 2019).

For many years, the use of off-road vehicles such as 4x4s and quad bikes in the South African coastal zone was subject to little or no regulation. While this assured access to the coast for some users, it resulted in some cases, in

Durban's promenade ensures coastal access for all coastal users
Photo: Kierran Allen

damage to unique coastal ecosystems and habitats. Accordingly, the control of vehicles in the Coastal Zone Regulations (1399 of 2001) was enacted in January 2002 under NEMA. These regulations, since updated and promulgated in terms of the ICM Act, prohibit the driving of motorised vehicles within the coastal zone except for reasons including emergency, health and safety (EDTEA 2017).

Current state

The current coastal access status in KZN reflects the socioeconomic and environmental state along the coast. The south and central coast are popular tourist destinations with a high demand for recreational activities. They are also characterised by ribbon developments with medium to high density establishments directly adjacent to the coastline. As a result, an extremely high density of routes is evident (Figure 7.1, Table 7.1). While this provides easy access to the coast, many of these routes are private and thus limit public access. Furthermore, public access is often informal and damaging to natural coastal dunes.

Along the north coast substantially fewer access routes exist. The sparse distribution of rural settlements was influenced to some degree by historical Apartheid planning and the presence of protected areas. Nonetheless, this region provides many opportunities to subsistence fishermen while more public routes are required to ensure sufficient access to these areas.

At the provincial level, the coast is highly accessible. On average, the province has three public access points per one kilometre of coastline, with density increasing from north to south (Figure 7.1; Table 7.1). Almost half of all the routes are private with an average route density of 2.5 private routes per km. Public access routes are well connected to transport networks, with 71% of public routes connected to paved roads and only 2% not connected to public transport infrastructure (KZN EDTEA 2019).

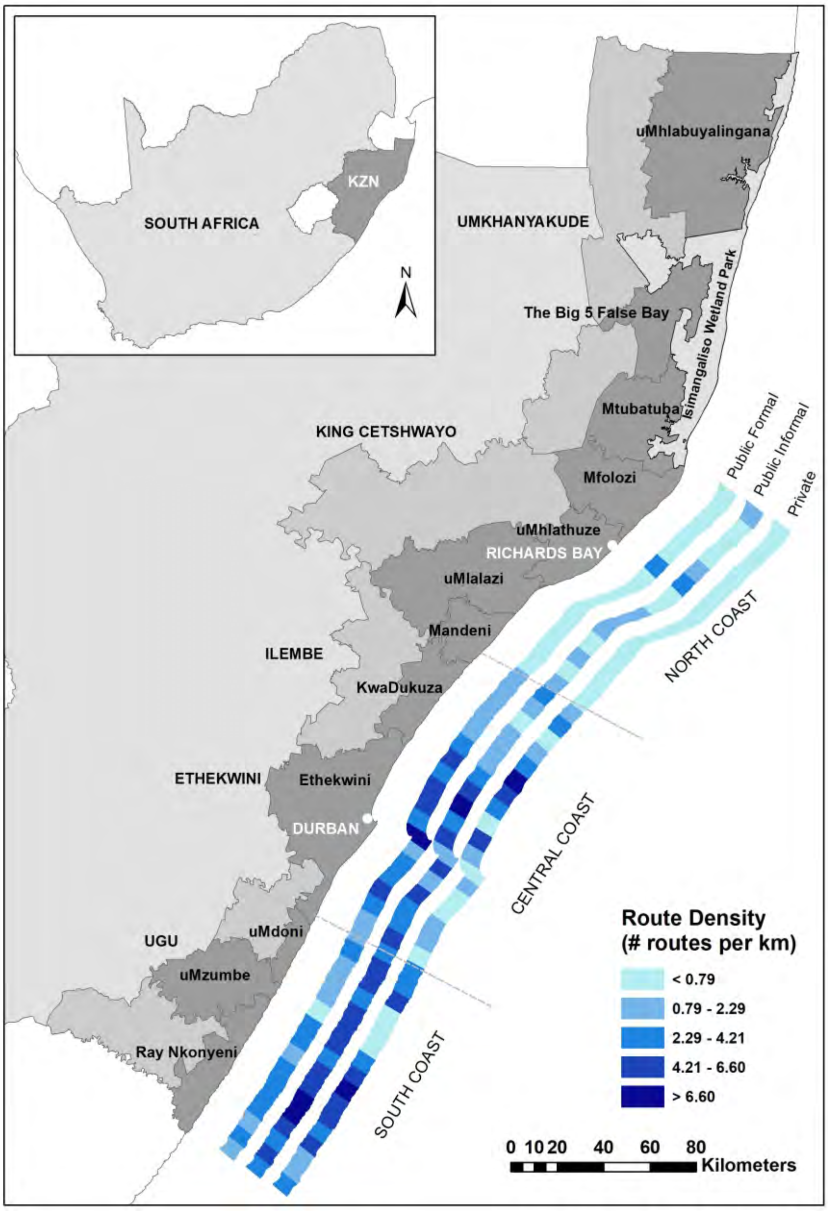


Figure 7.1: A summary of the coastal access results per Local Municipality (excluding iSimangaliso Wetland Park). Access route density results, as captured from 2018 aerial imagery, are displayed as number of routes per km per grid along the coast.

The dominant route types on the north coast are informal public routes (47%) whereas private routes dominated the central and south coast (46% and 47%, respectively). The central coast had the greatest occurrence of surfaced pedestrian routes (46%), formal parking lots (255) and recreational open areas (46) which indicate highly utilised areas. While the north and south coasts have the greatest occurrence of unsurfaced pedestrian routes (67% and 82%, respectively) and substantially less amenities and recreational areas (KZN EDTEA 2019).

In addition to pedestrian access, there are many boat launch sites along the KZN coast. Collaboration between the various stakeholders in KZN has resulted in the development of a Boat Launch Site Monitoring System (BLSMS) that generates unique and comprehensive launch statistics and information about associated activities. This innovative system is a province-wide monitoring initiative for launch sites and is an example of unique, mutually beneficial cooperation between different stakeholders towards the common goal of improved management of small craft launch sites and fisheries in KZN (Mann *et al*. 2018). There are currently 41 boat launch sites which participate in the BLSMS, 24 of which are licensed by the Province. In addition, nineteen other public launch sites fall within the jurisdiction of Transnet National Ports Authority (Durban and Richards Bay harbours), Ezemvelo as well as iSimangaliso Wetland Park Authority also participate in the BLSMS providing comprehensive coverage of all small vessel launching activities in the province. In 2017, a total of 50 215 individual marine launches was recorded (Mann *et al*. 2018)

Table 7.1: Distribution of the type of access routes along the coast as captured from 2018 aerial imagery, comparing between north, central and south as indicated on the map.

Total number current routes	South Coast	Central Coast	North Coast
	1066	**989**	**76**
Current formal public routes (% of total routes)	19%	33%	21%
Current informal public routes (% of total routes)	35%	21%	47%
Current private routes (% of total routes)	47%	46%	22%
Surfaced pedestrian (% of public routes)	12%	46%	4%
Unsurfaced pedestrian (% of public routes)	82%	45%	67%
Unsurfaced vehicle (% of public routes)	4%	5%	23%
Gravel vehicle (% of public routes)	1%	2%	4%
Tarred vehicle (% of public routes)	1%	2%	2%
Public route density	4.94	3.87	0.40
Formal public route density	1.73	2.38	0.12
Informal public route density	3.20	1.49	0.28
Private route density	4.37	3.28	0.18
Formal parking lots	97	255	11
Informal parking spaces	36	30	4
Tidal pools	34	24	0
Recreational open grass areas	24	46	1

IMPACT

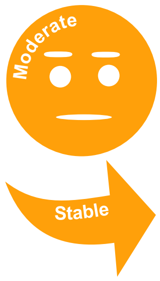
At the provincial level equitable and sufficient access to the coast exists. Three main challenges are however evident: (i) limited public access in less developed, previously disadvantaged regions; (ii) restricted access to an elite few due to private developments and costly nature reserves; and (iii) the detrimental impact on the environment, specifically the sensitive dune systems, from inappropriate access routes.

Well distributed public access routes are imperative to those relying on the coast for household support through subsistence fisheries and harvesting. The impact of development and tourism on the coastal environment is, however immense and despite the need to access the coast, a balance is required between providing sufficient public access without compromising on environmental conservation.

The current state of coastal access indicates that the north coast requires more formal public access routes through strategic placement of additional routes or formalising existing informal routes. The central and south coast however has sufficient formal public access, but too many informal and private access routes which pose a potential threat to the coastal environment, thereby requiring closing or consolidation of routes. The necessary stakeholders are expected to communicate and discuss the true needs of each region, as well as what is reasonable and feasible access to each.

Coastal access at Amanzimtoti beach
Photo: ORI

RESPONSE



Municipalities have various responsibilities with regards to coastal access land, including: sign-posting at entry points; controlling the usage of land; protecting and enforcing the rights of the public to use this land; maintaining land where appropriate and possibly providing facilities that encourage access, such as parking areas, toilets and boardwalks. They must ensure that infrastructure does not cause any adverse environmental impacts. Provincial government should assist local municipalities with monitoring and regulating coastal access and propose coastal access by-laws.

Coastal access has received attention from some municipalities and with the assistance of coastal conservancies they have tried to preserve, improve and restore public access and natural resources along the KZN coast. This has been done mainly through building trails and walkways, rehabilitating dune systems, providing appropriate signage and closing off access routes that are not required, inappropriate or detrimental to the coastal environment.

The rapid development of beachfront properties along KZN's coastline and its impact on limiting public access to the coast is increasingly recognised as a priority concern. Local, provincial and national government are beginning to react to such situations with the issuing of notices regarding illegal structures on CPP and the need to close and / or consolidate illegal private access routes.

Local knowledge and further groundtruthing of access routes would assist in completing this picture and advise on improving access within each municipality. Stakeholders involved could communicate and discuss the true needs of each region, what is considered reasonable and feasible access. Groundtruthing would specifically be useful in areas where dense vegetation is present and identifying paths from aerial photography is challenging. It would also greatly assist in confirming which routes provide vehicle access as well as wheelchair access.

Data Requirements
Routes can be classified according to the following characteristics, based on the National Coastal Access Guide (DEA 2014): private or public routes (depending on the location of the entry point of access); formal or informal routes (depending on the construction and maintenance of the route); route surface; connection to public transport and the presence or absence of amenities (parking lots, tidal pools, wheelchair access and recreational open areas). All these properties combined provide an indicator of the quality of access to the coast.

7.2 SMALL-SCALE FISHERIES

Dr Bruce Mann (ORI) and Dr Stephen Lamberth (DFFE)

INTRODUCTION

Previously described as subsistence and/or artisanal fishing (Mann *et al.* 2014), the small-scale fishery (SSF) has only been formally recognised in South Africa since the promulgation of the SSF Policy in June 2012 (Government Gazette No. 35455). As part of the transformation of the fishing sector, this policy aimed to redress and recognise the rights of SSF communities living around the coast of South Africa, that had been previously marginalised or discriminated against in terms of racially exclusionary laws and policies. SSF refers to the use of marine living resources on a full-time, part-time, or seasonal basis, to ensure food and livelihood security. To be recognised as a small-scale fisher, an individual needs to prove historic dependence on fishing, live near the resource, fish close to the shore using low technology gear and derive a major part of his/ her income from fishing to meet food and basic livelihood needs. This fishery is therefore primarily concerned with harvesting finfish/ linefish and invertebrates/ shellfish found in the near-shore zone. Unfortunately, a large amount of illegal fishing is conducted along the KZN coast; particularly estuarine gill and seine-netting. It is estimated that > 1 200 t (65 %) of the KZN estuarine catch is illegal.

Woman harvesting intertidal invertebrates in northern KZN
Photo: Judy Mann

DRIVERS

There are several factors which can drive change in the SSF. The first is human population growth and the increasing levels of unemployment and poverty in the province. Unlike the Cape provinces, KZN does not have a long history of SSF with a few exceptions such as the traditional artisanal Trap Fishery at Kosi Bay and the Durban Seine-net Fishery (Beckley and Fennessy 1996, Kyle 2013). The past 50 years has seen a gradual increase in the number of people being forced to subsist on harvesting marine organisms, in effect employment of last resort. Whether legal or illegal, such harvesting, in combination with

[2] *This is a conservative estimate as the recent catch data are almost exclusively gillnet confiscations form within protected areas.*

harvesting conducted by both commercial and recreational fisheries, has increased the pressure on marine resources with the result that many target species are now over-exploited. Other drivers of change in this fishery overlap with those described for the commercial and recreational fisheries.

PRESSURES

Given that increased harvesting by the different groups within the small-scale sector continues to increase, it follows that the pressure exerted on the fish stocks may not be sustainable. So too, will pressure increase on non-target species including vulnerable and protected species, considering that adherence to fisheries regulations may decline at such times. Examples include sharks and stingrays.

As with commercial and recreational fisheries, the scale of SSF can serve as an indicator of the pressure being exerted on the resource. Because it involves many people living in poor coastal communities who harvest living marine organisms for food security and as a means of basic livelihood, this can also serve as a social indicator. Clearly, there is potential for overexploitation of the resources being harvested, as well as competition with other sectors (such as the commercial and recreational fisheries) for the same resources. This exerts even more pressure on the resource, although quantifying poaching/illegal fishing along the KZN coast can be difficult, especially in the absence of a robust compliance system.

STATE

Historic perspective

A detailed description of the history of the SSF in KZN is provided by Mann *et al*. (2014). Following the promulgation of the SSF Policy in June 2012, the Marine Living Resources Act (18 of 1998) needed to be amended to accommodate the SSF Policy. The Marine Living Resources Amendment Act (5 of 2014) was thus promulgated in 2014. The SSF Regulations were promulgated in 2016 (Government Gazette No. 39790). To implement the SSF Policy, the responsible government department at the time (DAFF) has undertaken the following process over the past four years (2016-2020): identification, registration and verification of SSF communities and fishers; a formal appeal process; finalisation of successful applicants; fishing cooperative training; registration of applicants; and long-term rights allocation (15 years) to the identified fishing communities. However, the current lack of capacity in the directorate responsible for the implementation of the SSF (i.e., only seven dedicated personnel), means that the roll-out of this complicated process has not been ideal and there is still much uncertainty surrounding the implementation of this fishery. This uncertainty, coupled with the lack of effective enforcement of fishing regulations, is currently being exploited and there has been a dramatic increase in the amount of illegal fishing along the KZN coast (Harris *et al*. 2018 & 2019, Mann and Mann-Lang 2020).

Current state

By February 2018, 2 184 small-scale fishers had been identified in KZN during the roll-out of the SSF policy initiative. However, in May 2020, only 1 014 fishers from 35 identified SSF communities were publicised during the Covid-19 lockdown as being allowed to fish. The exact locality of these 35 SSF communities and the areas in which they can fish is not publicly known, nor are the details of the additional "basket of species" that fishers within each community may harvest. The draft SSF Regulations, circulated for public comment in 2015, drew much criticism about the inclusion of

A small-scale line fisherman in northern KZN
Photo: Bruce Mann

East Coast rock lobster (ECRL) and shad/elf in the basket of species for the SSF in KZN. Both these widely popular species have been managed as no-sale species in the province. Allowing their sale by the SSF will place unsustainable pressure on their stocks, especially as it will be impossible to control illegal sales by the other fishing sectors which compete for these resources.

Stock assessments of the main inshore linefish and invertebrate species have revealed that most already exist in a depressed state (Mann 2013, Steyn 2019), hence allocation of commercial rights to the SSF sector will result in additional pressure on these stocks. Equally disconcerting are the expectations of small-scale fishers which were raised during the roll-out of the SSF themselves. However, it is highly unlikely that the resource base allocated to them can sustain their livelihoods in the long-term. Moreover, the further decline in popular linefish stocks is likely to harm the recreational tourist fishery, one of this province's important sources of revenue (McGrath *et al.* 1997).

IMPACT

Without careful management and regulation, the major impacts of the SSF will likely be localised over-fishing of inshore resources and the associated negative impacts on the fishing communities directly dependent on them. This will lead to the increased use of illegal methods of harvesting (such as gillnetting) with further damage to the coastal environment (particularly estuaries in the case of illegal gillnetting). There is already a substantial amount of illegal gill and seine-netting taking place in KZN estuaries with annual catches estimated to be over 1200 t of fish and invertebrates per annum (Van Niekerk *et al.* 2018). Depending on where SSF communities can fish and what resources they are permitted to harvest, it is also possible that there will be increasing levels of conflict with other fishery sectors targeting the same resources. Other impacts of the SSF will be like those described for the commercial and recreational fisheries.

RESPONSE

Firstly, it is essential that the responsible government department (now DFFE) provides sufficient management capacity on the ground to effectively support and manage the SSF (and other fishery sectors) along the KZN coast. This function could be delegated to the provincial management agency (i.e., Ezemvelo) as it was prior to August 2016 (Kramer *et al*. 2017). Without effective law enforcement and a staff of well-trained Fishery Control Officers (FCOs), the implementation and effective functioning of the SSF (as envisaged in the SSF Policy) is likely to be severely compromised.

Secondly, it is critical that an effective monitoring programme is initiated immediately to monitor the impact of harvesting by SSF communities along the KZN coast on targeted resources. Although a long-term subsistence fishery monitoring programme was previously established by Ezemvelo (Mann *et al.* 2014), this programme has ceased to function. Without effective monitoring there is no way to determine the sustainability and socioeconomic viability of the SSF and any attempts to manage this fishery or provide support for fishers will be further compromised. Under the likely scenario playing out along the KZN coast (i.e., designated SSF communities struggling to harvest sufficient resources to achieve a reasonable standard of living), it is considered essential that the responsible government department facilitate the identification of alternative livelihoods for these communities to help alleviate further poverty.

Data Requirements

Basic data required to monitor the SSF in KZN includes: the number and location of each SSF community and where they are allowed to fish/harvest, the number of individual fishers within each recognized SSF community and clarification on the "basket of species" that are allowed to be harvested within each community. In addition to this, monitoring of catch (by number and weight), fishing effort, and size structure and sex ratios of harvested organisms is also required. This will enable stock assessments to be conducted to determine whether harvesting is sustainable. Furthermore, information on the proportion of catch that is kept for home consumption and that which is sold, will be useful in determining the viability of each SSF community, and its contribution to the local economy. Information on the degree of processing, product beneficiation (including ice facilities) that is currently happening is needed. In terms of national compliance information on illegal fishing is required relating to estimated catch and effort, number of reported transgressions, arrests, amount of confiscated fishing gear, etc.

7.3 RECREATIONAL FISHING

Dr Bruce Mann and Erika Steyn (ORI)

INTRODUCTION

Recreational fishing involves the catching or harvesting of marine resources for a variety of reasons: leisure sport and as a supplementary source of high-protein food. This activity is known to have psychological and societal benefits in terms of relaxation and de-stressing (Arlinghaus *et al*. 2015). It is also an important economic activity through the associated activities such as bait, tackle, boats and accommodation (Saayman *et al*. 2017). While coastal communities draw benefit from harvesting, it is the recreational fisheries that appeal to visiting tourists. Management of recreational fisheries dictates that catches are for personal use only and may thus not be sold. There are also an increasing number of recreational anglers who practice catch-and-release angling and do not keep the fish they catch (Cooke and Suski 2005). In KZN, there are a wide range of different facets of recreational fishing including linefishing (i.e., shore angling, kayak fishing, skiboat angling, charter-boat angling), spearfishing, shellfish/ invertebrate collecting, etc. Marine recreational fisheries are managed in terms of the Marine Living Resources Act (18 of 1998) implemented nationally by the DFFE. Anglers must purchase a permit through a South African Post Office for each type of fishing and/or resource-type being harvested. Specific output management controls limit the catches, such as size limits, daily bag limits, closed seasons and areas closed to fishing (e.g., no-take marine protected areas (MPAs)). Historically, enforcement and monitoring of marine recreational resource use in KZN was delegated to the provincial nature conservation authority, Ezemvelo; however this was inexplicably terminated by DFFE in August 2016. DFFE appointed Fisheries Control Officers (FCOs) to undertake this oversight role (Kramer *et al*. 2017), however, there are insufficient officers to effectively enforce fisheries regulations along the entire KZN coast. As a result, monitoring of catch and effort has decreased substantially.

DRIVERS

There are several drivers that can cause change in a recreational fishery. The main biological driver is the impact of over-fishing/harvesting on the biomass of the targeted fish stocks or populations. Basically, too many people are catching too many fish. This affects both the number of fish available to be caught and future stock recruitment. The biomass of a target species theoretically determines the allowable catch (or amount of fishing effort) that can be taken/used to ensure that the maximum sustainable yield (MSY) is not exceeded. This should be regularly assessed and carefully managed using appropriate fishing regulations. Fishing can also result in changes in fish communities and trophic cascades because of removal of top predators (Pauly *et al*. 1998). In addition to fishing, other drivers such as pollution, sedimentation, habitat destruction and climate change can affect the availability of target fish species.

In recreational fisheries the demand or desire to go fishing can be affected by both the availability and quality of fish, as well as other environmental and socioeconomic factors. For example, a healthy outdoor environment, perceived safety, and level of human well-being can all be considered as potential drivers of the desire to go fishing. Economic factors such as the cost of transport, accommodation, bait, tackle, etc. can also affect the demand for recreational fishing.

PRESSURES

Recreational fishing has high socioeconomic importance to the province of KZN. However, unlike commercial fishing, recreational fishing is not dependent on the economic yield from catches and can therefore effectively fish species down to levels well below their optimum. This, and the large number of participants in recreational fisheries, makes it difficult to manage (Arlinghaus *et al*. 2010).

Recreational fishing can selectively target and remove larger individuals (e.g., trophy fish) and/or species, which can cause changes to a species' population structure, and can also affect ecology via altered predator-prey relationships and changes in community composition (Pauly *et al*. 1998, Maggs *et al*. 2013). Some species are particularly vulnerable to fishing because they may have one or more of the following life-history characteristics: highly resident, aggregate to spawn, long-lived, slow-growing, late-maturing, low fecundity and/or change sex. Long-term monitoring of recreational catches can provide an indicator of the status of targeted fish stocks. It can also provide an indication of ecosystem health over time, as catch composition provides an index of the degree of change in marine communities impacted by fishing. Such changes can be compared using a benchmark such as unfished communities in no-take MPAs.

STATE

Historic perspective

Everett (2014) and references therein provide a detailed overview of marine recreational fisheries in KZN. Recreational fishing in KZN commenced in the 1800's and has gradually increased in terms of the number of participants and has diversified into different facets of fishing with increasingly diverse fishing gear (van der Elst 1989). With the increase in effort, so too has the quality of fishing gear and associated technology improved (effort creep), thus making fishing far more effective than it was historically (e.g., better hooks, line, rods, reels, boats, motors, echo-sounders, GPS, etc.). In addition to recreational fisheries, commercial and small-scale fisheries have also increased in number and diversity and often target the same resources. As a result of increasing fishing pressure being placed on the province's fish and invertebrate/shellfish resources (in addition to other anthropogenic impacts such as pollution, increased sedimentation, habitat destruction, climate change, etc.), several changes and environmental responses have taken place. For example, large predatory reef fish species such as seventy-four, red steenbras, black musselcracker, etc. that dominated catches in the early 20th century have been fished down to critically low levels and have been replaced by other smaller, less desirable species in lower trophic levels such as slinger, santer and Natal emperor (Sauer *et al*. 1997, Penney *et al*. 1999, Dunlop and Mann 2013). Similarly, once abundant shore angling species such as garrick and dusky kob have also been depleted to critically low levels and largely

Table 7.2: The stock status of some of the recreationally important fish and invertebrate species caught along the KZN coast. Stock status is based on the levels suggested by Griffiths *et al.* (1999).

Species	Stock status	Assessment method	Year	References
Shad/elf	Over-exploited	Per-recruit	2015	Winker *et al.*, 2015
Karanteen/strepie	Optimally exploited	Per-recruit	1996	van der Walt and Govender 1996
Blacktail	unknown	-		
Yellowfin tuna	Over-exploited	Surplus production	2019	IOTC
Slinger	Optimally exploited	Surplus production	2017	Parker and Winker 2016
Dorado	Unknown	-		
Englishman	Collapsed	Per-recruit	2005	Mann *et al.*, 2005
King mackerel/cuda	Optimally exploited	Per-recruit	2013	Lee 2013
Garrick/leervis	Collapsed	Per-recruit	2008	Smith 2008
Queen mackerel	Optimally exploited	Per-recruit	1999	Chale-Matsau *et al.*, 1999
Brown mussels	Over-exploited	CPUE	2019	Steyn 2019
Burrowing prawns	Over-exploited	CPUE	2019	Steyn 2019
ECRL	Optimally exploited	Per-recruit	2011	Steyn and Schleyer 2011

replaced by smaller species such as shad, karanteen and blacktail (Brouwer *et al.* 1997, Griffiths 1997, Dunlop and Mann 2012, Maggs *et al.* 2016). Shellfish resources have shared a similar fate and many of the province's popular intertidal resources such as brown mussels have been greatly reduced (Tomalin and Kyle 1998). Fortunately, primarily through careful past management, East Coast rock lobster (ECRL) stocks are currently still considered to be optimally harvested (Steyn and Schleyer 2011).

Current state

Most recent estimates suggest that there are at least 1.3 million recreational anglers in South Africa (i.e., anglers that fish by means of rod and line but excluding shellfish collectors), and of these about 730 000 are marine anglers (Saayman *et al.* 2017). In KZN, there are approximately 70 000 shore anglers (Dunlop and Mann 2012), 20 000 boat anglers (Dunlop and Mann 2013), 4 000 spearfishermen (Mann *et al.* 1997) and about 18 000 shellfish collectors (Steyn 2019). Estimates of the annual total catch of these facets of recreational angling suggest that shore anglers catch approximately 270 t (700 000 fish), skiboat anglers catch approximately 460 t (260 000 fish), charter-boat anglers catch about 245 t (160 000 fish) (Dunlop and Mann 2012, Dunlop and Mann 2013) and spearfishermen shoot about 150 t (35 000 fish) (Mann *et al.* 1997). Interestingly, the combined catch of the recreational linefishing sector is greater than that taken by the commercial linefishery in the province (i.e., approximately 800 t per year (Dunlop and Mann 2013)). The

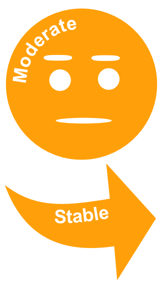
Recreational skiboats beaching during fishing competition at Sodwana
Photo: Bruce Mann

overall annual catch taken by shellfish collectors is approximately 49 t of mussels, 37 t of ECRL, 8 t of redbait, 6 t of octopus and 5 t of burrowing prawns (Steyn 2019). In terms of catch composition, shore anglers' catches by mass are dominated by species such as shad (20%), karranteen (14%) and blacktail (11%) (Dunlop and Mann 2012). Recreational skiboat angler's catches comprise species such as yellowfin tuna (22%), slinger (14%) and dorado (10%), while charter-boat anglers catch mainly yellowfin tuna (43%), slinger (11%) and englishman (8%) (Dunlop and Mann 2013). Spearfishermen mainly shoot species such as king mackerel, garrick and queen mackerel (Mann *et al.* 1997). Without regular monitoring, the status of these fish resources is difficult to assess. While fish species caught in well monitored fisheries with accurate catch and effort data can be assessed using standardised catch per unit effort (CPUE) and surplus production models (Winker *et al.* 2014), species in data poor fisheries need to be assessed using other simpler techniques (often with more assumptions) such as per-recruit models. While some species of fish are resident, others are migratory and only visit KZN waters for part of the year. Stock assessments of migratory species therefore need to take the full distribution of the stock into consideration. Estimates of stock status of some of the most important species harvested by recreational fisheries in KZN are shown in Table 7.2. Where a fish species is also harvested in commercial fisheries (e.g., yellowfin tuna and slinger), their stocks may have been assessed using data provided by those fisheries. It is also important to note that many of these stock assessments are old and need to be updated.

IMPACT

The impact of overfishing is the decline of fish stocks and the resultant impact on both the biological systems and the recreational fishing industry. For example, several important fish species such as seventy-four, red steenbras, dusky kob, garrick, etc. have been overfished to the point of population collapse. This has in turn affected the trophic dynamics and composition of fish communities and has greatly decreased the “potential reward” to recreational anglers. Selective removal of larger fish (from a variety of different species) has resulted in reduced reproductive success and, in the case of sex changing species such as slinger and englishman, greatly distorted the natural sex ratios (Garratt 1993). The socioeconomic implications of overfishing will include reduced demand to go fishing. This impacts on all the industries that support recreational fishing such as accommodation, tackle, bait, boats, fuel, etc. (Saayman *et al.* 2017). Other factors such as political changes in the country have also impacted on recreational fishing in KZN. For example, the increased levels of crime and lack of security along the KZN coast has resulted in a 23% decline in the number of shore anglers between the mid-1990s and 2018 (Mann and Mann-Lang 2020). The recent roll-out of the small-scale fishery and the issuing of long-term (15 years) fishing rights also has the potential for increased user conflict by placing greater demand by one sector on limited resources.

RESPONSE



Multi-species, multi-user fisheries such as the KZN marine recreational fishery are extremely difficult and complex to manage. However, due to their high socioeconomic value to the province, it is essential that they are well managed. In this regard, primary goals of management should include:

1. Maintain fish populations at target levels of

biomass through implementation of appropriate fisheries regulations (e.g., reduce or limit fishing mortality to a level where biomass of targeted fish populations is not reduced below 40% of their theoretical pristine level).

2. Ensure the health of fish and invertebrate populations by protecting at least 30% of key habitats (including spawning aggregation sites, nursery areas, foraging areas, etc.) in no-take MPAs.
3. Optimise levels of carrying capacity (e.g. number of angler access points, boat launch sites, etc.) and ensure a safe, clean environment.
4. Improve angler awareness and compliance. To achieve these goals, a well-trained, well-organised team of FCOs with sufficient manpower is required to effectively enforce fisheries regulations along the KZN coast. Secondly, an independent observer programme is required to conduct roving creel surveys (shore), access point surveys (boat launch sites) and remote questionnaire surveys (online) to enable random collection at least 10% of the catch and effort and size frequency data for each facet of recreational fishing and shellfish collecting. This would provide the information necessary to monitor the fishery and to ascertain whether it is achieving the goal of sustainable use. Existing monitoring programmes such as invertebrate catch monitoring, boat launch site monitoring and periodic snapshot surveys to assess total effort should be continued. Stock assessments of targeted fish species need to be undertaken or updated at a recommended frequency of the half-life of the fish species concerned (e.g., every 10 years for a species that lives for 20 years). Collection of species-specific biological data (e.g., size-at-maturity, age-length key, spawning season, population size structure, etc.) may be required to undertake such stock assessments and provide sound management recommendations. MPAs established in KZN (including; iSimangaliso, uThukela, Aliwal Shoal and Protea) need to have effective management plans implemented and monitoring of fish populations within these MPAs should be carried out using suitable methods. Lastly, a well-designed angler awareness programme is required to ensure that anglers understand the rationale behind the fishing regulations and to ensure improved compliance by self-policing.

Data Requirements

In the long-term, a well-managed observer program is needed to collect suitable fisheries data for improved management of the recreational fishery. In the short to medium-term, stock assessments on the main target species are required to assess sustainability of the fishery.

7.4 BOAT-BASED ACTIVITIES

Dr Bruce Mann (ORI)

INTRODUCTION

The KZN coast is host to a wide variety of recreational boating activities which range from the use of small vessels such as paddle-skis and surf-skis through to large, harbour-based yachts. Non-consumptive recreational activities undertaken on/with these vessels include paddling, sailing, scuba-diving (including shark-diving), whale/ dolphin watching and pleasure trips. The motivation for undertaking such activities includes fun, exercise/ fitness, sport/competition, curiosity, and natural history. These activities are extremely popular with many thousands of people participating in such boating activities along the KZN coast every year. Consequently, several support industries have been established including boat building, boat and motor servicing, diving equipment suppliers, diving companies, charter-boat companies, etc. Safety, a major concern for boating activities in small vessels at sea, is governed under the National Small Vessel Safety Regulations (2007) in terms of the Merchant Shipping Act (57 of 1951) implemented by the South African Marine Safety Association (SAMSA). The National Sea Rescue Institute (NSRI) is a voluntary NGO that provides help to injured people or stricken vessels at sea.

DRIVERS

The greatest driver of change for this activity is the state of the economy, linked to the availability of disposable income and levels of tourism in KZN. The state of the marine environment (especially the biodiversity associated with diving reefs), the presence and abundance of sharks (e.g., tiger, blacktip, ragged-tooth, hammerhead, etc.) and whales (e.g., humpbacks) are essential to draw tourists and for the ultimate viability of these industries. Factors such as weather and sea state (i.e., wind and swell height) influence when small boats can launch and factors such as underwater visibility affect scuba diving.

PRESSURES

The many thousands of participants in non-consumptive recreational boating activities and the industries that support them are important contributors to tourism and the economic stability of coastal towns and their communities. However, these activities can result in pressures on the natural environment. Like many such activities with growing human demand, they need to be carefully managed to ensure that they are safe, that they do not exceed the available carrying capacity and that associated damage to the environment is minimised. Monitoring use levels can therefore provide coastal zone managers with valuable information to ensure informed management.

STATE

Historic perspective

Excited divers before a dive on Two-mile Reef at Sodwana Bay
Photo: Bruce Mann

Since the development of the ski-boat in the late 1940s, the number of such vessels launching along the KZN coast has increased rapidly (Penney *et al*. 1999). Ski-boats require sheltered bays or beaches for safe launching, which lead to the development of several suitable beach launch sites along the KZN coast (Town and Regional Planning Commission 1988). As a 4x4 vehicle or tractor is required to launch these vessels, the implementation of the ban on beach driving in 2002 necessitated the formal recognition and registration of these launch sites (Mann *et al*. 2015). In addition to the two large industrial ports in KZN (i.e., Durban and Richards Bay harbours), there are currently 30 registered launch sites along the KZN coast (including 7 sites within protected areas managed by Ezemvelo and the iSimangaliso Wetland Park Authority) (Mann *et al*. 2019). The launching of other motorized craft such as jet-skis is also largely limited to registered launch sites (except for one additional jet-ski launch site near Blue Lagoon on the Durban beachfront). Smaller paddle-craft such as paddle-skis, surf-skis and small sailing vessels are not restricted to launching from registered launch sites (Mann *et al*. 2012).

To monitor launch activity, the KZN Boat Launch Site Monitoring System (BLSMS), consisting of boat launch registers placed at each of the registered launch sites, was established in 2004 (Mann *et al*. 2015). This provides information on the number of launches and activities undertaken.

Permitting of scuba diving in MPAs, shark diving and boat-based whale watching along the KZN coast was implemented in the mid-2000s by the departments preceding the DFFE.

Current state

There are currently over 45 000 launches of small vessels < 10 m recorded along the KZN coast each year (Mann *et al*. 2019). While a large percentage of these launches take place in Durban and Richards Bay Harbours (30%), the remainder are undertaken at the 30 registered launch sites between Mabibi and Port Edward (Figure 7.2).

Based on 2018 launch statistics collected (Mann *et al*. 2019), for those launches where outing purpose was stipulated, approximately 66% were undertaken for consumptive purposes (i.e., recreational, charter and commercial fishing) and

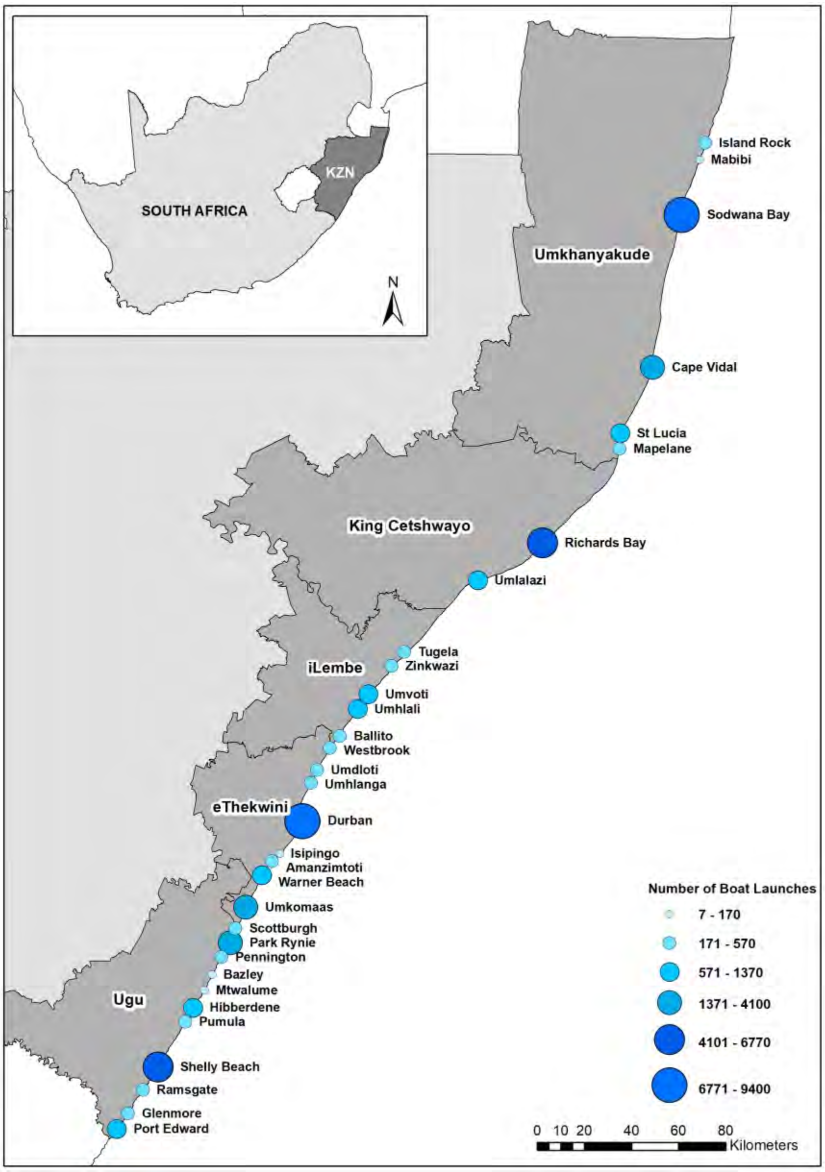


Figure 7.2: Location of registered boat launch sites and harbours along the KZN coast indicating the relative number of boat launches at each site.

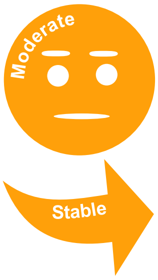
the remaining 34% were undertaken for non-consumptive purposes. These include scuba diving (84%), pleasure trips (7%), shark diving (2.4%), whale/dolphin watching (2.3%), other (4.3%).

Scuba diving mainly takes place at Sodwana Bay (iSimangaliso MPA), Umkomaas and Rocky Bay (Aliwal Shoal MPA) and Shelly Beach (Protea Banks MPA) (Figure 7.2) and because all these sites fall within MPAs, scuba diving operator and individual scuba diving permits are required. There are currently 33 companies permitted to operate scuba diving companies in MPAs along the KZN coast but the number of MPA scuba diving permits sold annually through the National Post Office is not known. There are currently 13 shark diving permits (11 in Aliwal Shoal and 2 in Protea Banks) and 8 whale-watching permits (1 in Shelly Beach, 3 in Durban, 1 in Richards Bay, 2 in St Lucia and 1 in Sodwana) issued by DFFE in operation along the KZN coast. However, the number of people that undertake these activities each year is not known.

IMPACT

When the economy is depressed, recreational activities such as scuba diving (which is a relatively expensive activity) and its associated support industries quickly become less viable economically. If diving reefs in the MPAs become degraded or over-used, the attraction for scuba diving will decrease with associated negative impact on the diving industry. Similarly, if the presence of sharks or whales were to decrease (as has recently happened to the white shark cage diving industry in the Western Cape), the associated industries suffer. It is therefore essential that sound environmental management principles are applied and adhered to.

RESPONSE



The KZN BLSMS was an innovative response to the growing number and diversity of small craft launches along the KZN coast. This should be maintained to ensure ongoing monitoring of non-consumptive (and consumptive) boat launching activities along the KZN coast. This will provide coastal managers with the ability to detect trends in the various boat-based activities and to respond with appropriate management actions. Small vessel launch sites located within the jurisdiction of the National Ports Authority (i.e., within Durban and Richards Bay harbours) should be encouraged to complete boat launch registers to ensure complete coverage of all launching activities. The number of scuba diving operators permitted within MPAs should be managed based on the capacity of the main diving reefs. Permit fees from both the diving operators as well as from the scuba divers themselves should be internalised and used to assist with operational management of the respective MPAs. DFFE should continue to permit shark-diving and whale watching operations in close consultation with the industry to ensure equitable access to permits and adherence to sound environmental principles.

Data Requirements

To monitor non-consumptive boat-based activities along the KZN coast, a launch register is required to document the number of launches and the types of activities undertaken at sea (Mann *et al.* 2015). Similarly, in the case of scuba diving in marine protected areas (MPAs), shark diving and boat-based whale watching, a permitting system is required to limit the number of operators, minimise environmental impact, and prevent excessive competition/user-conflict.

A dive charter boat launching at Umkomaas
Photo: Judy Mann

8 ECONOMIC ENVIRONMENT

Port of Durban, one of the busiest economic hubs in Africa
Photo: Kierran Allen

CHAPTER 8:
ECONOMIC ENVIRONMENT

8.1 PORTS AND SHIPPING

Dr Bronwyn Goble (ORI)

INTRODUCTION

Maritime trade has been a feature of human development for eons, not least in South Africa, with its Trade Route around the Cape. Globalization has served to accentuate the dependence on shipping as a key element of economic and industrial development (UN 2019), with developing countries accounting for the largest share of global seaborne trade. They account for 58% loaded and 65% unloaded goods of the world total (UNCTAD 2020).

For Africa, maritime transport remains the main gateway to the global marketplace (UNCTAD 2020), with South Africa, particularly KZN, playing an important role. KwaZulu-Natal has two of South Africa's three major commercial ports, at Durban and at Richards Bay. The former is Africa's busiest port, primarily serving as a regional container hub, while the latter is specially designated for bulk cargo, including coal, timber and non-ferrous metals. The combined performance of the two ports is of national importance, accounting for 63% of cargo, 62% of containers and 51% of ships (Jones 2014).

Ports represent an asset to economic development and attract many industries, generally through the establishment of Industrial Development Zones (IDZs) and they serve to increase employment and economic activity.

However, ports are often centres for environmental disturbance, firstly, through the establishment of industries, but over the long-term industries may dispose of waste via stormwater systems, which requires dedicated management. In addition, the management of port infrastructure often calls for dredging and removal of fragile ecosystems such as mangroves and seagrass beds to make space for shipping activities. Shipping itself creates potential environmental problems by their frequent lack of proper on-board waste and sewage management facilities.

DRIVERS

Maritime transport is considered one of the priority economic sectors towards unlocking the country's economy, through a focus on the 'Blue Economy'. Maritime activities will stimulate trade, increasing its contribution to the Gross Domestic Product (GDP), at the same time creating employment opportunities for South Africans (DoT 2017). Since 1994, there have been various national growth and development strategies. The most recent of these is called Operation Phakisa which focuses on unlocking the ocean economic potential of South Africa (Section 2.1).

PRESSURES

South Africa is set to grow its economy, with the 'Blue Economy' (under Operation Phakisa) being identified as one avenue to facilitate this. This growth will see an increase in trade and a likely need to expand port operations which, in addition to daily port actives, is likely to result in significant pressures for the receiving environment. Thus, a GDP growth strategy is likely to add increasing pressure on the environment, unless this can be ameliorated through good management and planning towards a steady state.

STATE

The origin of ports is variable. Given that some are created out of bays, estuaries, lagoons or river mouths, it follows that the smaller systems are likely to be more vulnerable to environmental perturbations. The two KZN ports were both created out of originally quite shallow estuaries: Durban Bay and the Mzingazi Estuary.

The port of Durban has been progressively developed over 200 years, during which time different phases removed important sections of the estuarine biota. Historical development of the port was limited because of the semi-permanent siltation of the port entrance, due to littoral drift of beach sand up the coast. The port of Durban is now the largest container port in Sub-Saharan Africa and the leading port for the SADC region, serving KZN and the Gauteng region as well as the Southern African hinterland (Humphreys *et al.* 2019). Its geographic location further enhances its appeal for relay transportation and hub-and-spoke, providing a strategic position for the transportation of goods from North and South America to Africa (Humphreys *et al*. 2019).

The Port of Richards Bay was opened on 1 April 1976; however, development was ongoing for well over a century. The Richards Bay site was considered favorable for several reasons, including the ease of dredging, the availability of land for back-of-port developments and port-related industries, and the proximity of the site to the Mpumalanga coalfields and the industrial and market-heartland of Gauteng (Jones 2014). It is essentially a dry bulk and neo-bulk port, albeit with a wide cargo base. Cargo shipped exceeds cargo landed by 18:1, with the key imports being metallurgical or coking coal and alumina. Exports are dominated by coal, followed by a broad range of products including ferro-alloys and chrome ore; woodchips; titanium slag and mineral sand products from the Richards Bay Minerals' Dune mining operations, pig iron, steel

The Port of Richards Bay, KZN north coast.
Photo: ORI

and base metals; and liquid-bulk acids and chemicals (Jones 2014). Potential future expansion of the Port of Richards Bay is unlikely to affect the KZN coastline directly, aside from the potential deepening of port approaches and access channels (Jones 2014).

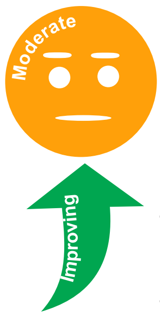
The ocean economy is considered a priority area for South Africa, with maritime transport being a key sector in fostering trade and thus heightening its contribution to the Gross Domestic Product (GDP) through employment opportunities. It also offers a means to achieve the objectives outlined in the 2030 National Development Plan and the New Growth Path (NGP) (DoT 2017). While maritime transport is relatively flourishing, the same cannot be said for ancillary activities such as ship repair, ship building and dry docking, all activities that have declined following the Covid 19 pandemic.

The two ports on the KZN coast offer complementary services, with Durban strengthening its role as a general cargo (mainly containerised), liquid bulk and automotive port; while Richards Bay will continue to serve the needs of the bulk trades, through increased coal volumes. Together, the two ports are also almost certain to continue to dominate South African seaborne commerce into the future (Jones 2014).

IMPACT

Shipping activities bring a range of environmental impacts, such as air, water and noise pollution. Ships, cargo handling equipment, transport trucks concentrating in port areas often result in poor air quality and polluted waters (Braathen 2011). The greatest concern remains the pollution caused by non-native species following the discharge of untreated ballast water from ships. Ships use ballast water for draught control and gravity: these tanks are filled and emptied with sea water, thus ballast water accrued in one region may be released elsewhere and introduce alien species into a new environment (Braathen 2011). These introduced species may not naturally occur in the 'new' environment, resulting in significant environmental harm which threatens biodiversity (UN 2019). In 2017, the International Convention for the Control and Management of Ships' Ballast Water (ICCMSBW) and Sediments (2004) entered into force. The Convention aims to prevent the introduction and proliferation of non-native species because of the discharge of untreated ballast water from ships. One way to reduce this risk is to install ballast water treatment systems (UN 2019). South Africa drafted a Ballast Water Management Bill (2013) which provides for the prevention of the introduction of invasive species via ships ballast water and sediment while ensuring the implementation of the ICCMSBW and matter related thereto.

RESPONSE



Issues related to pollution are ongoing but being addressed through the ICCMSBW and the South African drafted Ballast Water Management Bill (2013). Additionally, the National Transport Master Plan 2050 provides guidance for some of the challenges facing maritime transport infrastructure. The proposed critical interventions identified for maritime transport infrastructure should receive high priority if 2030 targets are to be met (DoT 2017).

While KZN port development may appear to have reached a maximum capacity, several innovative concepts are being explored. For example, the establishment of industrial development zones (IDZ) adjacent to ports created an opportunity for enterprise dependent on sea imports or exports. Such proposed zones need to be strategically located to derive maximum economic benefits while minimising environmental impact (DoT 2011).

The Port of Durban is a mature port with increasingly congested operations. However, innovation, reconfiguration and rationalization of the current operations can lead to extensive improvement and greater capacity, while also improving sustainability (Humphreys *et al.* 2019).

Data requirements
Information pertaining to port operations is largely obtained from the Department of Transport, and is valuable in understanding changes in operations, which can result in increased environmental pressures. Ports are important for the economy of South Africa and KZN; and the ocean economy is a priority going forward (under Operation Phakisa).

8.2 TOURISM

Dr Bronwyn Goble and Rudy van der Elst (ORI)

INTRODUCTION

While domestic tourism has always been a popular activity, it is international tourism that generates a more valuable return on investment. However, globally, international tourism developed late as two world wars delayed opportunities and it was only once profitability improved that tourism took off, around the mid-1950s (UNCTAD 2021). The growth since then has been spectacular allowing tourism to develop into a sector of global economic, social and environmental significance. In South Africa and KZN, tourism has also become a key economic activity, in terms of generating income, creating jobs and playing an important role in infrastructure development for different regions. Importantly, tourism also has significant links to and implications for the natural environment and improvement of livelihoods. As such, tourism is identified in the National Development Plan (NDP) 2030 as a factor that can improve rural economies (KZN Tourism Authority 2019).

While tourism remains a key focus area for economic development in South Africa, the Covid-19 pandemic has brought the world to a standstill, and tourism is one of the worst affected economic sectors, with at least an 80% unprecedented decline in international tourism (KZN Tourism Authority 2019). This has resulted not only in a crisis in tourism but has contributed to South Africa's total GDP dropping by 51% in six months (KZN Tourism Authority 2019). Although tourism in KZN should continue a path of expansion and profitability, in reality; containment of this and future pandemics is a priority and requires a recovery programme in view of tremendous implications for the economy. Such a review should focus on domestic tourism, which should continue to be the backbone of the KZN tourism sector in the

The provision of tourist facilities is important for tourism
Photo: Kierran Allen

short term. Foreign tourists are a highly desirable component and can be attracted by unique features in KZN, mostly environmental and cultural.

DRIVERS

Tourism is identified as one of the fastest growing sectors globally. It is therefore not surprising that for KZN, the tourism sector is regarded as an important economic driver, largely due to its ability to generate employment opportunities without significant capital investment (KZN Tourism Authority 2019). Fluctuations in tourism activity are evident and are the result of different drivers; the three main concerns as identified by international tourists relate to safety and security, the appeal of other destinations and the cost of getting to South Africa (time and financial). This includes the time and cost for visa applications, resulting in competition from destinations that offer easier visa processes or visa waivers (KZN Tourism Authority 2019).

Other variable factors such as economics (exchange rates), major health issues such as pandemics (Covid-19), malaria, and civil unrest play an important role. Although these drivers affect domestic and international tourism differently, they invariably influence consumer spending and employment levels which equates to a drop in investment in the tourism sector (DoT 2017). Measurables which reflect the state of these drivers include international arrivals, domestic visitor numbers, length of stay and spend during a stay. These affect the contribution to the provincial GDP, as well as job creation (KwaZulu-Natal Tourism Authority 2019). The duality of the drivers reveals their complexity. For example, weaker exchange rates have a pronounced positive effect on international travel, yet a weak rand can also result in greater domestic tourism, as South Africans who might have travelled internationally now invest in local holidays, thus supporting the local GDP.

PRESSURES

Coastal and marine-related tourism is complex and can lead to both negative and positive environmental impacts (Marafa 2008). Poorly planned tourism results in pressure on the coastal environment through land-use change with the conversion of natural or agriculture lands to build areas that can offer accommodation and services. This in turn leads to modification and fragmentation of habitats. Tourism that exceeds its carrying capacity for a specific situation (such as overfishing or littering) will impact long-term sustainability of the tourism sector. Of considerable consequence is the finding that, notwithstanding the complexity of calculating, global tourism contributes 4% towards global CO_2 emissions and that this is growing rapidly (UNCTAD 2021). However, the pressure from tourism may also result in protection of such habitats where such environments are left unmodified as the pristine nature of the environments attract visitors (Marafa 2008).

STATE

Historically, KZN had been a prime domestic tourist destination given its year-round warm climate, rich natural environment and, significantly, its beaches. The unique biodiversity of the KZN coast provides tourists with exceptional opportunities such as recreational angling, coral reef diving, tiger shark encounters and joining nocturnal nesting tours of endangered loggerhead and leatherback turtles on beaches in the northern section the iSimangaliso Wetland Park. A highlight is the annual sardine run which attracts people to the coast to witness the phenomenon, which sees millions of sardines chased out onto beaches by feeding-frenzied gamefish, sharks and dolphins. This event ranks with one of the greatest natural migrations on earth, with approximately 21% of all tourist visits to the south coast occurring in the months of June and July coinciding with this migration (Seymour 2006).

An estimated eight million international tourists visit KZN annually, 80% of whose visits include KZN beaches, and contribute to the employment of 180 000 people (KZN Tourism Authority 2019). KwaZulu-Natal domestic tourism is important for maintaining this economy, with 22% of local tourists choosing KZN as a destination. While these numbers decreased from 2016 to 2018, 2019 showed an increase in visitor numbers to KZN. Income generated for the same period increased by 77.7% to R8,0 billion (KZN Tourism Authority 2019).

KZN coastal tourism has flourished over time, highlighting the value to the province. Foreign visitor surveys in 2018 indicated that 68% of them visit Durban, 13.6% the North Coast, 9.4% the Elephant Coast, with only 0.9% visiting the South Coast; however, the latter is favoured by the domestic market. Importantly, 50% of international visitors will visit one or more of KZN's beaches (KZN Tourism Authority 2018). This shows the significant value of these coastal areas, particularly the eThekwini beaches and surrounds. It has been calculated that the Total Market Value of foreign visitors reached R5.7 billion in 2018, contributing 4.2% to the Province's GDP (DoT 2019). The domestic tourist market is seen as an equally valuable sector for KZN, especially as it can sustain or recover markets during global threats such as pandemics. Records show that there are almost 3 million trips made to KZN per year by local tourists. Again, beaches are a significant attraction, with 40% of domestic tourists visiting the KZN beaches. This equates to a spend of R5.04 billion (KZN Tourism Authority 2018).

While records indicate a thriving KZN coastal tourism sector, there are several opportunities for development of the sector. Rural and township areas within KZN offer potential for transformation into tourism destinations, offering different tourism products to address the changing requirements of the market (KZN Tourism Authority 2019).

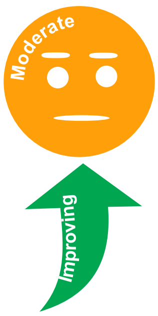
Of concern is that poor management and the lack of maintenance of cultural and heritage attractions detract from visitors' experience, in turn adversely affecting the image of KZN. Therefore, there needs to be a focus on developing products and experiences which improve and expand the current offerings. However, given the current health climate, funding for tourism projects is lacking in both the public and private sectors (KZN Tourism Authority 2019).

IMPACT

Balancing the positive economic benefits derived from tourism with the potential environmental costs presents a challenge. Growth of the sector, while leading to job creation and supporting GDP, may also require increased demand for tourist space and access to the natural resources that makes these areas popular tourist destinations. This, in turn, can negatively impact these coastal habitats through the loss of natural vegetation and land resources, soil degradation, strain on water supply and increased pollution levels of marine and freshwater resources, increased levels of air pollution, increased risk of exposure to natural hazards and the effects of climate change. Indeed, there is growing evidence that adverse weather such as created through climate change is already changing tourism behaviour and development patterns (Forland *et al*. 2012).

While many positive impacts can be argued, an increase in tourist-related activities and the associated land-use changes can result in a loss of public access to the coast and its resources; a loss of cultural resources and ultimately social disruption can occur. Tourism has tremendous capacity to rapidly transform into a much-needed source of income for public and private stakeholders alike and lead in areas ranging from consumer confidence, entrepreneurship, women and youth employment to technological innovation.

RESPONSE



The greatest risk to tourism is to take it for granted and to do nothing to ensure its sustainability. Clear targets need to be set, for example, a key sustainability target for KZN tourism is increasing the number of KZN's Blue Flag beaches. Presently there are nine full status Blue Flag beaches (17,6% of the South African total) and 21 pilot beaches (63,6% of SA's total) (WESSA 2021). As a prime beach tourism region, KZN should aim for more than 50% of the country's full blue flag beaches. The standards that these require can have a positive effect on the natural coastal environment, in terms of ensuring water quality and natural vegetation are maintained. What requires careful management is the provision of additional services such as ablution and parking facilities.

Ultimately for marine and coastal tourism to continue to develop in a sustainable manner, an integrated, strategic approach is needed. This needs to consider both the social and environmental benefits or impacts of the sector, particularly considering climate change impacts that will render the coast more vulnerable. While projected growth in global tourism will continue to benefit KZN, the scale of this will be reduced with lower employment and reduced GDP (World Tourism Organization 2011). Clearly KZN needs to develop a realistic approach and strategy to minimise the expectations in the event of future pandemics and other global upheavals. Social, technical, economic, environmental, and political dimensions all influence tourism; a synthesis of available data is important for planning the future of tourism.

Data requirements

Tourism activities are critical for the GDP of the Province. Thus, important data is collated by the KZN Tourism Authority. This provides information as to the number of visitors, the reasons for visits, from where they have traveled and what has attracted them to KZN. However, strict environmental parameters should be maintained to ensure long-term sustainability. Data such as Blue Flag provides important quality standards for tourism.

People enjoying the safe Blue Flag Beach at Trafalger
Photo: BlueFlag

8.3 AQUACULTURE

Dr Neil Stallard (Previous Director: Zini Fish Farms) and Dr Larry Oellermann (SAAMBR)

INTRODUCTION

Aquaculture is the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants, requiring some form of intervention in the rearing process to enhance production, such as regular stocking, feeding and protection from predators (FAO 1988). Aquaculture usually involves some form of private or communal ownership of the stock being cultivated, as opposed to wild fisheries, where aquatic organisms are harvested by the public as an open common property resource, or as a managed resource with appropriate licenses. Aquaculture has been recognised globally as a major solution for feeding the world's increasing population, filling the fish supply deficit from wild fisheries, and achieving this in a sustainable manner (FAO 2016, FAO 2018, Hara *et al.* 2017). Under the United Nations' 2030 Agenda for Sustainable Development Goals (SDGs), aquaculture is aligned to play a leading role in the FAO's responsibility to achieve SDGs 2 and 14 (FAO 2016, UN 2015). World aquaculture production reached 111,946,623 tonnes in 2017, of which Africa contributed a meagre 2%, at 2,214,143 tonnes (FAO 2020). South Africa's production in 2015 reached 5,418 tonnes, with only 7.6% (413 tonnes) being produced in KZN (DAFF 2017).

DRIVERS

Drivers for the development of aquaculture in KZN are both socioeconomic and environmental in nature. The World's growing human population has led to an increase in the demand for quality animal protein such as fish. The harvest from wild fisheries peaked in 1994 (FAO 2019) and no matter how much fishing effort has increased since, the output from this natural resource has remained relatively constant (Section 8.6).

The increasing demand for fish is not just a result of the increasing size of the World's population, but also the general increase in affluence, which has led to an increase in per capita consumption of seafood from 9.0 kg in 1961 to 20 kg in 2014 (FAO 2016, FAO 2018). In addition, rural coastal communities are generally poor and to some extent rely on the constrained resources of the coastal environment to make a living. Here, environmental drivers such as the overfished resources of commercially important species play a role. As wild fisheries decline and human populations increase, the widening gap between supply and demand will be a substantial driver for aquaculture development along the KZN coast. In addition, the industrialised nature of aquaculture operations provides relatively secure and well-paid employment.

PRESSURES

As a potential source of food security and employment, it is evident that pressure for aquaculture development is likely to increase in KZN. This should not be viewed in a negative light, provided that the principles of ecosystem-based management are applied (Bricker *et al.* 2016, Froehlich *et al.* 2017). KwaZulu-Natal, as a coastal province with a wide range of climate conditions, has the potential to considerably improve its aquaculture contribution for both the marine and freshwater environments, as identified by the Operation Phakisa initiative (DPME 2014).

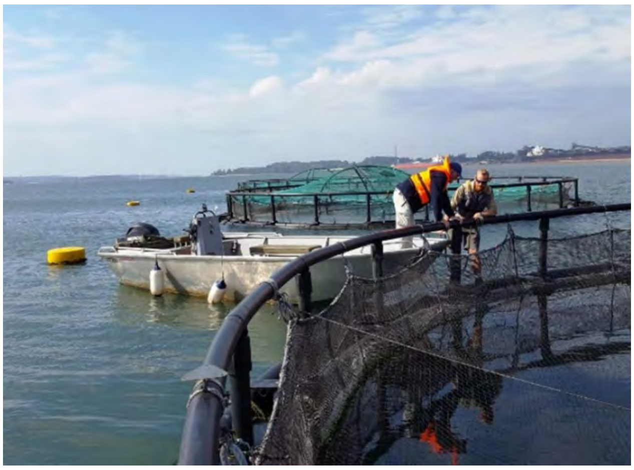
STATE

Historic perspective

Aquaculture began in 1890 in KZN with the introduction of the imported brown trout (*Salmo trutta*) to some rivers in the Midlands (Crass 1986). This introduction sparked the provincial government's interest in aquaculture, leading to the development of three government-run trout hatcheries in the Midlands and a warm water hatchery at Nagel Dam, near Cato Ridge. All of these were phased out by 2003, due to the cessation of stocking alien fish into natural water bodies, which conflicted with the conservation ethos. Several private trout hatcheries have also started over the years, which still exist today, but these are now only for recreational fly fishing.

In the 1970s a prawn research station was established on the edge of the Amatigulu estuary, on the KZN north coast by the Fisheries Development Corporation (Evans, 2009). After unsuccessful attempts to commercialise both the marine white prawn (*Fenneropenaeus indicus*) and the brackish/freshwater prawn (*Macrobrachium rosenbergii*), the grow-out ponds were converted to culture freshwater ornamental fish and plants. This became a thriving business (the Amatikulu Hatchery), exporting to Europe and the USA, while also supplying the local market. Post 1996, the ornamental farm dwindled from mismanagement and loss of the export market due to increasing freight rates.

In addition to ornamental fish, prawn farming was reintroduced at the Amatikulu Hatchery site in 1989, focusing on the white prawn and tiger prawn (*Penaeus monodon*). This led to the development of grow-out ponds at the Amatikulu site and a new site at Mtunzini, covering an area of 10 and 26 hectares respectively (Evans 2009). After ten years of



Stellenbosch University's floating cages at Richards Bay, containing dusky kob (2017)
Photo: Larry Oellermann

production these ventures became unviable in 2004, due to competition from cheap imports from India and Southeast Asia. In 2012, the culture of two marine finfish, dusky kob (*Argyrosomus japonicus*) and spotted grunter (*Pomadassys commersonnii*), commenced at the Mtunzini site. This ceased in 2017, after the salinity of the water pumped from the operation's beach well-point dropped too low for spawning to be viable.

In 2015 an experimental cage culture project was set in Richards Bay by the University of Stellenbosch and partners. The operation consisted of three circular cages stocked with dusky kob (Viljoen 2019). The project proved that dusky kob could be successfully reared in cages in sheltered waters along the KZN coast but various issues, not least of which included harbour operations within Richards Bay, resulted in the project being mothballed in 2017.

In 2018, the Mtunzini site now known as Zini Fish Farms, started experimenting with stocking and rearing Mozambique tilapia (*Oreochromis mossambicus*) in their large open ponds. This operation was put on hold in May 2020, due to the National lockdown response to the COVID-19 virus epidemic.

Several freshwater aquaculture farms have been set up in KZN over the years, with various levels of success. Some are still currently (as of 2020) in operation, but these are located inland and have not been included in this report.

Current state

In South Africa, one must be in possession of a Right to engage in aquaculture, granted by the Minister of the DFFE, which is valid for 15 years. There are several permits attached to this Right, depending on the species and nature of the farming operations involved. The permits are renewed annually and contain various conditions that must be met before they are re-issued. These include the monthly and annual reporting of various information. The DFFE's Directorate: Sustainable Aquaculture Management (SAM) is responsible for the collection of this information, such as quantity and value of production, and environmental and aquatic animal health statistics. The most recent aquaculture production data available from SAM is for 2015, which indicates the level of aquaculture activity in the province for that year (Table 8.1).

Table 8.1. Production data for KZN aquaculture for the year 2015 (DAFF 2017). Ornamental fish and Koi carp are sold per unit and not by weight, hence production in tonnes is not applicable.

Environment	Species	No. of farms	Production (tonnes)
Marine	Finfish	2	24
Freshwater	Trout	5	378
	Tilapia	5	10
	Koi carp	2	N/A
	Ornamentals	3	N/A

Extrapolating to 2020, we know that the two marine finfish farms have ceased operation, but the freshwater farms are still operating. In addition, Zini Fish Farm had 484,000 Mozambique tilapia stocked out in its ponds as of May 2020.

In March 2019, a Strategic Environmental Assessment (SEA) was conducted on behalf of the then Department of Agriculture, Forestry and Fisheries (DAFF) for the development of an Aquaculture Development Zone (ADZ) at the old Amatikulu site; where two of the freshwater ornamental farms still currently operate (Table 8.2; NuLeaf Planning and Environmental 2019). The previous Department of Environmental Affairs (DEA) declined the application and subsequently the DAFF have appealed. The result that the amalgamation of DEA and DAFF into the Department of Forestry, Fisheries and the

Table 8.2. Information and data collected by Zini Fish Farms as required by their aquaculture permit conditions

Item	Data collected and information provided to SAM
Stock	Number, average weight & total mass of organisms: in stock, mortalities, sales, moved (origin & destination), restocked (origin & destination)
Spawning	Number of events, induced (hormone used) or naturally spawned
Food	Manufacturer, mass of onsite stock, food fed, food procured, food sold, spoilage/waste
Medicines	Type (antibiotics/vaccines), stock, amount used, expiry, prescribed, manufacturer, prescriber
Chemicals & pesticides	Type, stock, amount used, manufacturer
Site inspections	Date, veterinary / health inspection, name of official
Environmental monitoring	Approved Environmental Management Plan (EMP) in place and implemented
Water quality samples	Temperature, salinity, electrical conductivity, pH, total suspended solids, ammonia, chloride, orthophosphate, biological oxygen demand, chemical oxygen demand, faecal coliforms; including information on laboratories used and number of samples
Aquatic animal health management	Biosecurity programme in place, measures in place to prevent the escape of farmed animals, disease surveillance and inspection by DFFE, notifiable diseases to be reported within 24 hours
Diseases	Location of disease outbreak (i.e., tank/pond/cage number), species, disease, treatment, any additional information
Notifiable events	Examples: algal bloom, extreme weather, power failure, environmental parameter anomalies
Chemicals	Records of use and proof of responsible disposal
Movement of live aquatic animals	SAM notification, species transported, and vehicles used, quarantine, veterinary inspection of high disease risk animals
Traceability & food safety	requirements of the South African Aquacultured Marine Fish Monitoring and Control Programme are met

Environment (DFFE) will have on this issue has yet to be determined. This Amatikulu site might not be suitable for the culture of marine species, but it would make an ideal location for freshwater aquaculture. In March 2020, Trade & Investment KZN (TIKZN), issued a tender document for conducting a feasibility and a business plan for the development of a catalytic aquaculture project for TIKZN (TIKZN 2020).

IMPACT

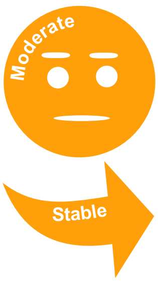
The aquaculture sector in KZN is currently severely depressed, despite past development and recent political will. This has resulted in the province falling far behind the global trend of aquaculture development as the fastest growing food production sector (FAO 2018). The current impact of aquaculture on the KZN coastal zone is negligible compared to other commercial and industrial users. The positive impacts of aquaculture include economic development, job creation, food production and food security.

The negative impacts of aquaculture can largely be mitigated against through careful, responsible management and adoption of proven better management practices. Negative environmental impacts for coastal land-based aquaculture would include site clearing and construction, water extraction, water quality modification (including soil and ground water modification if they leak), and the subsequent discharge of the water back to the environment with a potentially higher nutrient, sediment, chemical and pathogen load. Biological impacts include

Large open ponds containing dusky kob at Zini Fish Farms, Mtunzini
Photo: Larry Oellermann

cultured organisms escaping from the aquaculture operation and influencing the local biodiversity, ecosystems, population genetics, species distribution (e.g., alien and invasive species) and acting as a vector for disease. For offshore aquaculture (e.g., cages or pens), modification of the benthos and eutrophication of the sea floor below the cages can be added to the list, as well as modification of the local environment and population structure by acting as fish aggregation devices (FADs) and by attracting predators.

RESPONSE



From a regulatory point of view, South Africa's current environmental legislation is sufficient to manage the aquaculture sector, without the need to create further laws and regulations. However, because aquaculture has the potential to impact negatively on the environment in which it operates, provision must be made to incorporate the better management practices already in place in other countries as the pressure increases to develop the sector in KZN. Effective monitoring of operations by well trained and resourced compliance officials will be key to growing the KZN aquaculture sector in an environmentally sustainable manner.

DATA GAPS

Sufficient operational, production and environmental quality data is collected by compliant aquaculture facilities in South Africa for their activities and impact on the coast to be suitably managed.

Data Requirements

Besides the data that needs to be collected, recorded and submitted to the DFFE's SAM Directorate, each aquaculture operation must collect environmental data as outlined in their Environmental Management Plan (EMP). The type of information that fish farmers collect to meet the conditions of their EMPs and permits is summarized in Table 8.2, using Zini Fish Farm as an example. Zini Fish Farms is a land-based marine aquaculture operation growing finfish in large open ponds near the uMlalazi estuary on the KZN north coast.

8.4 AGRICULTURE

Dr Bronwyn Goble and Marilyn Bodasing (ORI)

INTRODUCTION

Agriculture is a primary contributor to food security and the economy of South Africa. Some 46 million hectares (equal to 38% of the land area in South Africa) is in use by commercial farming and related agricultural activities (Statistics South Africa 2020). In addition, there is a significant and growing sector of informal agriculture, which in 2019, involved almost half a million small-scale farmers, generating R49 billion and contributing significantly to food security. It has been estimated that almost 8.5 million people are directly and indirectly dependent on agriculture for their livelihoods, with close on 1 million people formally employed in the agricultural sector (Brand South Africa 2016, Statistics South Africa 2020). Although KZN agriculture is comparatively modest in size compared to national commercial agriculture, it produces products of higher value than much of South Africa and contributes almost 13% to agriculture employment (Table 8.3). Included are sugar cane, nuts, tropical fruits (bananas, pineapples, litchis, mangos and paw-paws) (Sugden 2014), livestock and forest products (Ngcobo and Dladla 2002). Many of these activities occur within the coastal zone as the climate offers exceptionally favorable conditions for cultivation of sugar cane, forestry and sub-tropical fruits (Sugden 2014). The KZN coastal region has recently developed into one of the best regions for macadamia nuts, with production figures amongst the highest in the world (DAFF 2017).

Table 8.3. Contribution of KZN to the agricultural sector

Agriculture in South Africa	RSA	KZN
Employed	757 628	96206 (12.7%)
Income generated	R332 Billion	R34 Billion (10.2%)
Total land area	122.5 Million ha	
Arable	7.6 Million ha	5.4 Million ha (12%)
Grazing	38.4 Million ha	
Commercial farming	46 Million ha	1.8 Million ha (4%)

(Statistics South Africa 2020)

DRIVERS

Agriculture represents an important factor in the National and Provincial development strategies. There are multiple drivers that promote agriculture: food security, population growth, economic benefits and employment.

Feeding the nation is a prime responsibility and in KZN there are communities where food security is uncertain, including in the coastal zone. This is aggravated by demographic shifts and population growth. KwaZulu-Natal has a flourishing youth sector which can be a provincial asset if quality jobs can be created in the agriculture sector to cater for growing job demand. As the agricultural sector is a key economic asset, this too presents a potentially important driver for KZN, serving as a catalyst creating downstream business and employment opportunities. There are several manufacturing sectors dependent on agriculture such as food processing, beverages and paper industries that

add further value to the provincial economy through employment and export activities (KwaZulu-Natal Top Business 2016).
Global economics will influence the export markets. The type and distribution of agricultural lands are affected by climate and climate variability, particularly in terms of drought and flooding. Following recent droughts many farmers diversified their crops and some included additional geographical areas and crops into their portfolios to mitigate future risks (Maree 2019).

PRESSURES

South Africa's population is growing at almost 2% per year and is projected to reach 82 million by the year 2035 (Goldblatt 2010). The coastal zone experiences a high growth rate because of this natural population growth and through in-migration (Section 2.2), as such, food production needs to keep pace with this growth forecast. Arable land (hectares per person) is a useful indicator of potential, but this has varied widely over the past 55 years, from a maximum value of 0.685 in 1961 to a minimum of 0.222 in 2016.

Production will need to become more efficient and targeted, using the same or fewer natural resources (Goldblatt 2010). Research also suggests that demand for certain food types will shift as people's disposable income is increasing. Evidence suggests that food consumption patterns have changed post 1970s because of increased overall wealth post-apartheid, with the middle-income groups increasing by 30% between 2001 and 2004. This has led to a shift in consumption from staple grains to a more diverse diet (Goldblatt 2010), a factor that will put pressure on agriculture as it caters for alternative food production or importation. Agricultural activities are sensitive to changes in the external environment such as oil price, exchange rate, low market predictability and non-tariff trade barriers in importing countries (Goldblatt 2010). Climate change is already imposing pressures on the agricultural sector, while the full implication is yet to be understood.

The sector is subjected to many pressures and is easily affected by changes in the natural environment, being affected by water scarcity and loss of soil. Historically South African agricultural production has suffered drought cycles since the seventeenth century (Byrnes 1996).

STATE

Historic perspective

Sugar has for many years been the mainstay of the KZN agriculture industry, providing an important contributor to the economy and high levels of employment (SASA 2020). Sugarcane was first cultivated in the mid-nineteenth century in the former Natal region; many of these farm areas were established with indigent labour and allocated under the apartheid planning era; a legacy that exists even today. Hence resulting in the need for agrarian reform, broadening land ownership and increasing overall productivity (Byrnes 1996).

Despite a modern primary health care system being accessible to the wider community, many, people remain reliant on traditional healers and medicinal plants. Studies show there is one traditional healer for every 700 to 1200 patients. The trade in traditional medicines in South Africa is estimated to be worth R2.9 billion per year, with 27 million consumers and at least 133 000 people employed in the trade (Mander *et al.* 2007). This trade in plants is a key rural industry, although many of the 770 species used are highly vulnerable. This provides opportunity for the development of appropriate technology in wild plant harvesting, farming, storage, packaging,

Agricultural activity in the KZN coastal zone
Photo: Kierran Allen

Sugarcane production remains one of the main agricultural activities in KZN with Tongaat Hulett and Illovo Sugar being the two major sugar producers (KwaZulu-Natal Top Business 2020). As the monoculture of sugar carries risks, the province is seeing a shift towards a wider range of high value crops, such as the production of macadamia nuts and avocados, mainly for export markets, with 'marginal sugar land' being diversified into macadamia nuts. Ninety percent of macadamia production is being exported, mainly to China (Maree 2019).

dosage and treatment. KZN is home to one of the largest medicinal markets in Africa; most of these are harvested from wild species, some species now facing extinction (Agribook Digital 2020). As a result, there have been several cultivation trials and pilot projects conducted to date, which show that medicinal plant cultivation has good economic potential for supplying commercial-scale volumes of medicinal plants. Fast-growing species can be supplied in sufficient quantities to meet market demand within a few years (Agribook Digital 2020, Mander *et al*. 2007).

Current state

The primary agricultural industry has shown a growth of 7.5% annually since 1994, during which time, the total economy grew by 10.7% per annum (DAFF 2019). Agricultural production invariably fluctuates from year to year reflecting its vulnerability to environmental conditions. Indeed, the agricultural sector saw a 13. 2% decline in 2019, while figures for 2020 are on the rise again (DAFF 2019). While agricultural potential in KZN is good, much land is degraded due to inappropriate and uncontrolled land use.

SUGARCANE

Although sugarcane is widely grown elsewhere in South Africa, extending from northern Pondoland in the Eastern Cape through the coastal belt and midlands of KZN, to the Mpumalanga Lowveld, producing an estimated 2.5 million tons (mt) of sugar per season (Farming Portal 2020), it remains a key agricultural activity for KZN. Within KZN it is estimated that there are 22 500 registered sugarcane growers, producing an average of 2.2 mt of sugar per season (SASA 2020). It also offers high levels of employment, particularly in rural areas; generating an annual estimated average direct income of R8 billion, which constitutes R5,1 billion in value of sugarcane production in KZN (SASA 2020). South Africa is the thirteenth largest producer of sugar in the world, with 50% being marketed in the Southern African Customs Union and the rest exported to Africa, the Middle East, North America and Asia (Farming Portal 2020).

An emerging risk for the sugar industry, is the import of subsidised sugar, so that Government has introduced a tariff barrier to mitigate the risks of cheap imports. Additionally, the new sugar tax on beverages has seen a decline in the demand for sugar from this industry.

MACADAMIA NUTS

While macadamia is a relatively young crop in South Africa, it has quickly become the largest producer in the world with 19,500 hectares under cultivation, producing over 50,000 tonnes per year (van Wyk 2018). Of this, more than 95% is exported to Asia and Southeast Asia, North America and Europe (Agribook Digital 2020). In 2017, the South African Revenue Service, estimated the value of this export to be over three billion Rand (SAMAC 2018). Importantly the industry has created several permanent jobs and a significant number of seasonal opportunities for harvesting and processing (DAFF 2017). KZN has the second highest number of hectares under cultivation of macadamias in South Africa.

SUB-TROPICAL FRUIT

The cultivation of subtropical fruits is only possible in certain parts of the country, given their climatic requirements (Statistics South Africa 2020). As such, these are found in small pockets limited to certain regions within KZN, forming a minor proportion of South Africa's current total production (Sugden 2014).

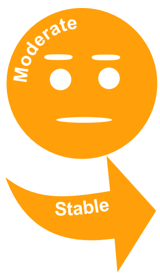
Importantly, for those with market gardens (vegetables, madumbies, herbs, etc.), pineapples, mangos, litchis and bananas are a source of valuable subsistence income for rural communities located in these KZN coastal regions (Sugden 2014).

IMPACT

Some agricultural practices result in sources of pollution that affect the coastal environment, affecting biochemical cycles and ecosystem functioning (Bruinsma 2003). Notable inputs are insecticides and other pesticides affecting species, oil pollution, animal hormones, increased nutrient run-off from silage and slurry-manure and the use of fertilisers. If overused, both organic and synthetic fertilisers can cause major damage, because of run-off into rivers leading to eutrophication (Bruinsma 2003, Goldblatt 2010).

Significantly, the production of food takes an enormous amount of water. If today's food production, consumption and environmental trends continue, we face a critical water crisis, which may be exacerbated given projects around climate change and its implications for water availability and scarcity, the demand for biofuels, and growing competition for water. It is important that agricultural practices promote more sustainable water use if it is to survive and flourish into the 21st century (Goldblatt 2010).

RESPONSE



Agri-business, such as mechanisation, milling, and oil extraction etc., offer high commercial potential. Some of South Africa's largest agri-business firms are in KZN, such as sugar milling, packaging and sugar products, and shelled macadamia nuts for export. The industry contributes 3. 6% toward the provincial economy and employs 3. 8% of the KZN population (Deloitte 2016). However future growth of the sector needs to be managed to ensure long-term sustainability and reduced impacts on the natural environment.

Given South Africa's historical spatial planning, land reform is a key factor to be addressed when it comes to agricultural lands. It is an urgent and sensitive task to reconcile differences in future agricultural land use, but failure to settle the farmers aspiration risks more than food production.

Diversification in farming is becoming ever more critical; focus on a single crop renders farmers vulnerable to rapid price fluctuations and natural disasters such as a drought (Deloitte 2016). However, innovation in agriculture often happens at a high level and this does not filter down to small-scale farmers. While innovation is an ongoing, dynamic process that contributes hugely to the development of the agricultural sector; there needs to be a dialogue and mutual accountability between higher and lower levels (Deloitte 2016). In particular, the South African situation requires a broader approach to agriculture by fostering the small-scale farming sector through strengthened technical support. Agriculture is one of the oldest professions, and arguably the most important in terms of sustaining humans. There is little point in protecting the coastal zone in an environment of food insecurity. A flourishing agriculture sector is an essential ingredient for a stable and prospering society with enormous potential to generate food and jobs, both essential in meeting the future demands of a growing human population.

There are at least 30 excellent agricultural training institutions in South Africa. In KZN there are two universities, two agricultural colleges and one Technikon providing formal agricultural education. However, only 912 students enrolled in agricultural colleges in South Africa in 2020, 60 in KZN (Matsimela 2020). To some extent this is a relic from apartheid, when jobs in agriculture were only those involving poorly paid manual labour. Add to this the lingering uncertainty over land ownership, while even today those that have qualified are often disenchanted with the lack of opportunities and innovation made available by government. Considering the prevailing poverty and future needs in South Africa, this is a challenge that is fundamental to all our endeavours in development, including challenges brought about by climate change and coastal zone management.

Agriculture is a major but semi-dormant economic and social force in the province. It touches on the livelihoods and households of millions in the province. Sugar, cattle, forestry and staple grains are the dominant crops in the province. By adding diversity in the form of pineapples, banana, vegetables and nuts, it will be important to raise current low production on the eve of climate change.

Data Requirements
Agricultural activity is a significant contributor to GDP and employment creation. Agri stats are important to understand the breakdown of how the range of agricultural activities contribute to the overall economy. Data presented in this section was sourced from the sectors, sugar, macadamia nuts, tropical fruit. Provincial GDP information is important to understand the trend of these sectors and should continue to be monitored.

This Section is compiled with special thanks to Kathy Hurly from South African Sugar Association (SASA) and Liesel Pretorius from Macadamias South Africa (SAMAC).

8.5 MANUFACTURING & INDUSTRY

Dr Bronwyn Goble (ORI)

INTRODUCTION

Manufacturing and industrial development are key sectors in many successful economies around the world. In addition to economic benefits, they also have the potential to ameliorate many societal problems - in particular, employment and poverty alleviation, and attraction of foreign investment. Government plays a major role in this sector, largely through the Industrial Development Corporation (IDC), which facilitates infrastructure development and partnerships in mega projects.

South African industrial development historically centred around the gold mining industries, far inland and distant from the coast. This is unlike many maritime nations where industrial development mostly arose near port facilities on the coast. However, the competitive advantage of being located at the coast for many industries has been recognised and the trend has changed. Access to excellent port facilities and maritime waste assimilation are two key factors driving industrial development along the coast, and particularly for KZN (Goble and van der Elst 2014). Indeed, the KZN coastal zone is one of the most active industrial development regions in South Africa (IDC 2020) with particular emphasis on five sectors: agro-processing, textiles, metals, chemicals, and health care. As a result, several large, globally competitive industries have located in KZN, involved in manufacturing diverse products such as motor vehicles and vehicle parts, specialised metals, textiles, chemicals, forestry products, food and beverages - many of which are located within the KZN coastal districts (Goble and van der Elst 2014).

KwaZulu-Natal is second only to Gauteng in terms of percentage contribution to South Africa's GDP (KZNs 16% to Gauteng's 34%) (TIKZN 2016). Additionally, KZN's manufacturing sector contributes 20% of the province's employment and 29% to the provinces GDP (TIKZN 2016) and remains an important activity for sustainable growth and for meaningful employment, as emphasised by the national industrial policy action plan (Department of Trade and Industry 2011). Labour-absorbing production and services sectors, increasing access to the economy of historically disadvantaged people and regions, and building South Africa's contribution to industrial development beyond its borders are key objectives. Moreover, the KZN action plan aims to promote long-term industrialisation, expanding production in value-added sectors. Ultimately, one must gauge the success of industrial development on its economic value, the impact on jobs and societal improvement in the surrounding areas should be quantified.

Industrial development along the banks of the Umkomaas, KZN south coast
Photo: ORI

DRIVERS

The prevailing socioeconomic climate in South Africa urgently calls for an improved economy with moderate growth, employment, and poverty alleviation. Over the past few years there have been mega-government initiatives to create such a climate. However, successive government interventions have largely been thwarted by the global economy, domestic fraud and corruption, HIV, and more recently, the Covid-19 pandemic. A common feature of each of these plans has been the manufacture and industrial theme, thereby serving as a major driver, often via the IDC. For example: RDP, Gear, NDP, Phakisa, etc. (Gomersall 2004). Simultaneously, there have been investment conferences that also drive industrial development, especially mining and agriculture. As a coastal province, it is notable that there have been few marine drivers, (other than offshore oil and gas) a feature that may be worth pursuing as part of the blue economy.

Notwithstanding the important historic role of manufacturing and industrialisation in coastal KZN, there can be no complacency about the future. The population of KZN is largely poorly educated and as we venture into a new industrial revolution, so the education and training towards a digital economy is essential. Similarly, manpower-intense industries carry a huge risk and burden during pandemics (such as the Covid-19 pandemic), a fact that requires planning (StatsSA 2020). During the height of the HIV crisis in 2005, labour was reduced by 21%, disrupting many enterprises (Vass 2005). The likely increase in the use of robotics, for example in the auto industry, raises additional concern about employment. Finally, labour and work conditions must be part of planning the future, lest disputes harm entire industries.

PRESSURES

While promoting manufacturing and industrialisation as a significant potential towards solving South Africa's socioeconomic challenges, the environmental sustainability should feature as an equally important objective. Kraft and sugar mills, coastal mining, vehicle manufacturing, etc., are all potential mega-polluters and while their location in coastal provinces is welcome, this cannot be an opportunity to abuse the access to marine disposal. There is considerable variance in the levels of pressure brought about by the different industries, from aluminium, high-fluoride content gypsum waste in Richards Bay, to lethal mercury leaks into Cato Ridge wetlands, as well as historic Sappi waste on the upper South Coast. Pollution events such as the most recent UPL spill of agrochemicals in July 2021 on the Ohlanga River (Comrie and van Rensburg 2021; Section 2.3). All these industries require surveillance and monitoring, especially if Operation Phakisa is to be the latest and most credible development strategy.

STATE

Manufacturing and industry remain one of the primary anchors of the KZN economy, especially the labour-absorbing companies which are fundamental to creating employment and contributing to inclusive economic growth in the province (Provincial Planning Commission 2019). As such, the KZN province supports a range of manufacturing industries, the largest of which are within the automobile sector (vehicles and parts), pulp and paper, cement, sugar, rubber and plastics, chemicals and petro-chemicals, food and beverages, textiles and clothing. Many of these primary industries have created considerable multiplier effects in secondary suppliers of components and service providers (TIKZN 2016).

Illovo Sugar and the Tongaat Hulett Group are formidable KZN-based companies with substantial sugar-cane holdings in the SADC region. There is a large presence from key manufactories such as Unilever, RCL and Clover (Scholtz 2018).

The production of paper and forest products also makes an important contribution to the provinces GDP (Goble and van der Elst 2014). A range of products are involved, from the manufacture of paper, packaging, and cellulose to wood products such as household and office furniture. Key wood and paper corporations operating in KZN include Mondi, Sappi, Nampak, Merensky, the R&B Timber Group and NCT Forestry Co-op Limited (Goble and van der Elst 2014). Included in these operations is SAFCOL, the State-owned forestry company. As the world's largest single site manufacturing specialised cellulose, the Sappi Saiccor Mill located at Umkomaas (50 km south of Durban), exports up to 800 000 tons of product annually (SAPPI 2021). Employment in the forestry value chain is estimated to be near 750 000 (Pouge 2009). The forest-product export sector in South Africa operates mainly via the port of Richards Bay, made up of paper (45.2%), solid wood (23.3%) and pulp (28.9%).

However, new technologies and the shift away from traditional paper-based communication, the growing use of recycled materials and a focus on environmental concerns make future demand uncertain for the sector. Wood products are seeing a shift to other engineered materials. Nevertheless, one forestry product that remains of note is cellulose, derived from dissolved wood pulp and used in the manufacture of textiles, cellophane wrap, pharmaceuticals, and a suite of other household products.

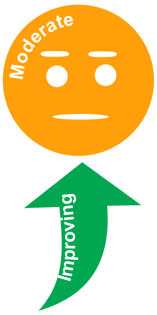
IMPACT

Significantly, the progressive shift of industrial activity to the coast can be attributable to the improved port facilities of Durban and Richards Bay. Similarly, the marine waste disposal benefits for companies in the paper, aluminium and several other industries provides a huge competitive advantage. However, many of these marine outfalls have been controversial and their environmental assimilative capacity seriously questioned. Examples include the Richards Bay mixed product pipeline and Saiccor's outfall close to the Aliwal Shoal MPA. Both outfalls were initially of dubious standard, but public pressure, research and technological advances have improved the management and quality control of these pipelines. However, much improvement is still possible and greater research, monitoring and ongoing vigilance is required. There is concern about non-adherence to permit conditions as well as restricted access to monitoring data. Several industries operate their own pipelines under permit. For example, AECI and SA Tioxide, with its very acidic effluent, are

Industrial development in the coastal zone at Sezela, on the south coast
Photo: ORI

responsible for their own effluent water quality monitoring. Nevertheless, the capacity to validate environmental monitoring must be retained, especially in offshore pipelines, lest they create an 'unseen' pollution disaster.

RESPONSE



The department responsible for Economic Development has over the years endeavored to develop industry-oriented interventions to stimulate the local economy (EDTEA 2020). This has included sector development programmes such as the Richards Bay industrial zone (TIKZN 2016) the purpose of which is to attract local and foreign investors, create production capacity, provide services, and create employment and improve the skills base (KZN Top Business 2016). EDTEA aims to develop Industrial Economic Hubs (IEH) as a way of driving industrial development throughout the province (EDTEA 2020).

To make meaningful progress in eliminating poverty and reducing inequality, South Africa needs to improve the quality of education, skills and make optimum use of its resources. This will spark a cycle of development that expands opportunities, builds capabilities, and raises living standards.

Data requirements
KZN province supports a range of manufacturing industries. The coast is particularly attractive for industry as it provides access to shopping routes and good road networks. Key sectors include the automobile sector (vehicles and parts), pulp and paper, cement, sugar, rubber and plastics, chemicals and petro-chemicals, food and beverages, textiles and clothing, data on these informs understanding of demand and needs for expansion. This knowledge allows us to better plan for the receiving environment and mitigate possible impacts.

8.6 COMMERCIAL FISHING

Prof. Sean Fennessy (ORI)

INTRODUCTION

Commercial fishing entails the harvesting of marine resources (in their widest sense) to legally sell. They are managed differently to other fisheries sectors. They vary in scale from sophisticated industrial operations using large vessels and many crew, to small operations with a few people using simple tools. In KZN, examples include large, harbour-based, crustacean trawlers and longline tuna vessels; small beach-seine net operations for smaller pelagic fishes; small boat-based hook and line fishing for reef fishes; and hand picking of oysters in the intertidal/shallow subtidal zone.

Rights are issued by the DFFE; these rights are valid for varying lengths of time depending on the level of sophistication of the fishery; mostly 15 years. Records of harvested quantities must be reported regularly to DFFE by rights holders, and a small departmental compliance team is seconded to KZN on a rotational basis. Catches are small compared to the Western Cape, since the KZN coast is relatively unproductive (narrow shelf, oligotrophic waters), and resources are mostly fully exploited or over-exploited. Most of the harvest is sold locally or in other provinces, and is insufficient to meet demand, necessitating imports; high value catch such as tuna and some crustaceans are exported.

DRIVERS

There are generic drivers applicable to all commercial fisheries. The main biological driver is the size of the stock or population, this determines the biomass of the target species available to be caught. It also determines recruitment which affects future stock size and catch potential. The biomass theoretically determines the amount of catch or fishing effort (number of permits) applied to the target species.

Oceanography and weather are major drivers, affecting accessibility to fishing grounds, catchability, recruitment, and availability of target species. Climate change as a driver is not well understood, but has the potential to substantially effect species composition and distribution on the east coast (Lloyd *et al.* 2012).

The main economic driver is market demand for target species, a function of socioeconomic factors such as buyers' availability of disposable income, and foreign exchange rates for exported catch. Reduced availability of a species (due to overexploitation, for example) and high demand drive prices up, creating incentive to apply greater fishing effort. External drivers such as the fuel price and fishing crew wages can force commercial fishing to become non-viable and can be artificially compensated by fishing subsidies.

PRESSURES

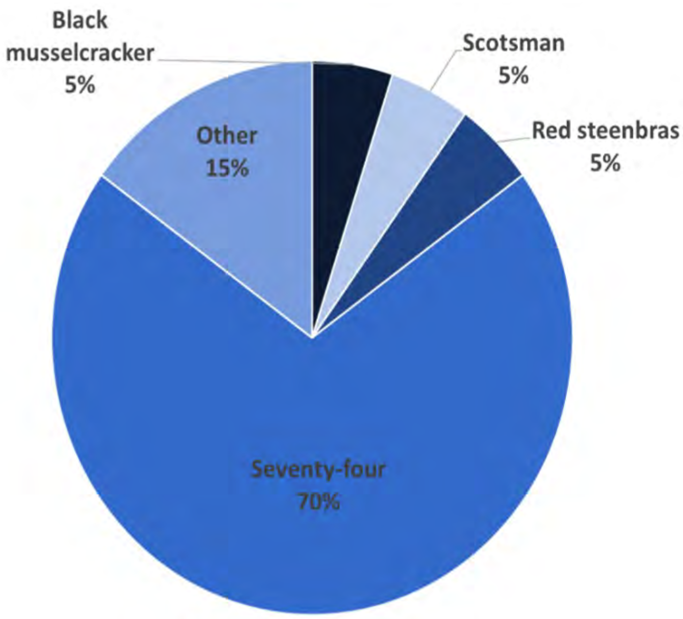
Fishing selectively removes larger, faster-growing individuals, which can cause changes to species' population structures, and can affect the ecology via altered predator-prey relationships. Some species are particularly vulnerable to fishing because they are long-lived, slow-growing, late-maturing, have low fecundity or change sex. Unwanted bycatch organisms, which are caught by fishing gear with low selectivity (e.g., demersal trawls), or which are low value, are frequently killed unnecessarily, and are often wastefully discarded. Fishing gear can also cause physical damage to the seabed. However, commercial catches can provide an indicator of ecosystem health over time, as catch composition provides an index of the level of integrated pressures on marine communities – assuming confounding factors such as changes to fishing methods are accounted for.

STATE

Historic perspective

Industrial trawling for crustaceans off KZN commenced in the 1960s and continues at a low level today; albeit that the initially targeted deep-water rock lobster was gradually replaced with other targets - prawns, langoustine and crabs.

Industrial longline fishing by South African vessels for large pelagic fishes (e.g., tunas) commenced in the 1960s, but was soon replaced by foreign vessels in the 1970s. In 2001, over one hundred foreign vessels were recorded fishing in the South African EEZ. South African vessels commenced commercial fishing in 2005 following an experimental phase from 1997. Several species of tuna and swordfish are targeted, and some pelagic sharks such as makos, and pelagic fishes such as dorado, are also retained. Although a harbour facility to service longliners was developed in Richards Bay (2001), this is no longer used; the longliners still fish off the KZN coast but are restricted to fishing far offshore and fish over very wide areas in the open ocean.



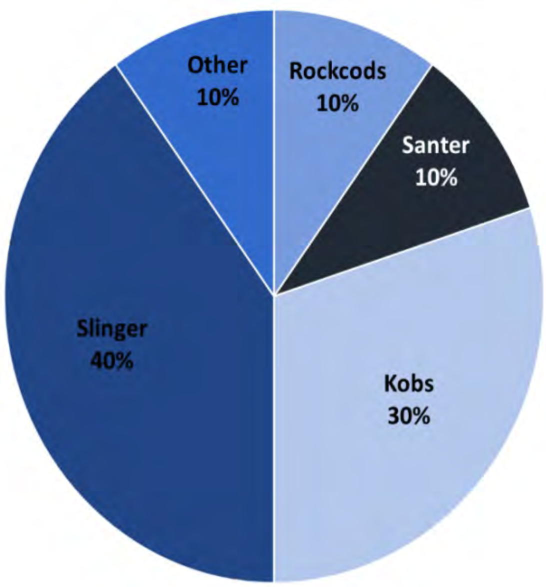


Figure 8.1. Changes in commercial linefish catch composition in KZN: 1910 to 1995 (Penney *et al.* 1999)

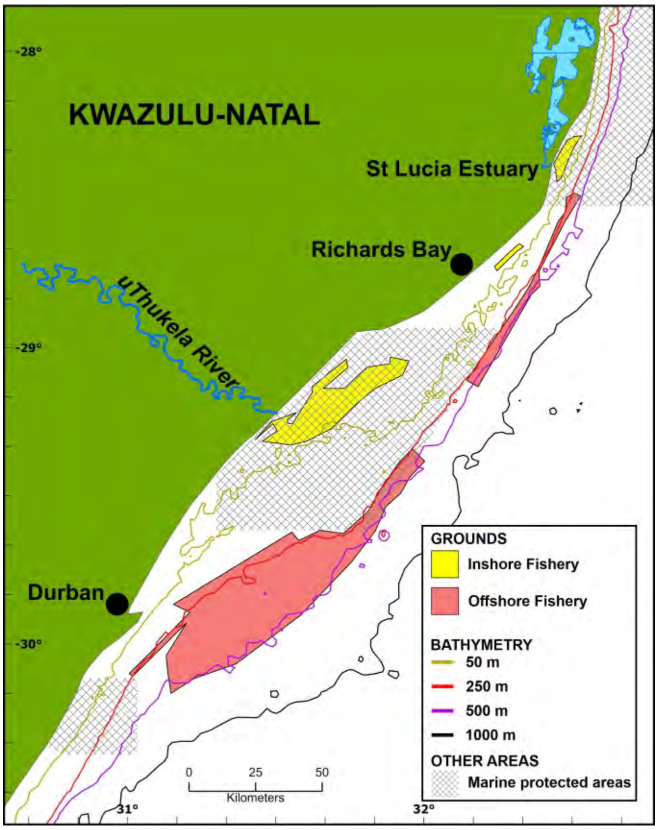


Figure 8.2: Map showing the inshore (shallow-water) and offshore (deep-water) crustacean trawl areas off KZN, and MPAs. (*Bernadine Everett, ORI*).

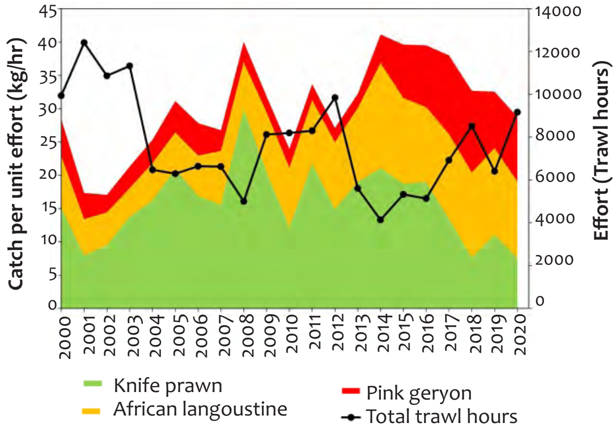


Figure 8.3: Catch per unit effort for deep-water crustaceans targeted by the KZN crustacean trawl fishery. Source: ORI/DFFE (*Bernadine Everett, ORI*).

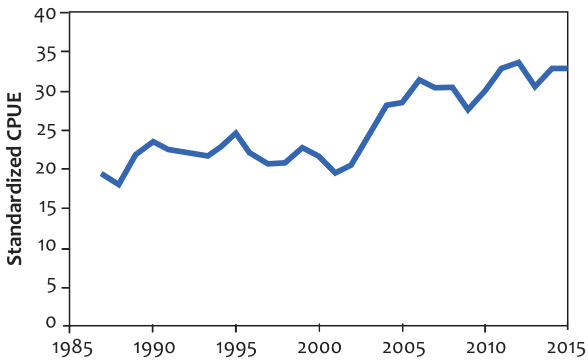


Figure 8.4: Standardized catch-per-unit-effort of slinger in KZN (Maggs *et al.* 2017).

Beach-seine fishing commenced in the 1860s in Durban when Indian labourers with netting skills started catching and selling fish. The fishery increasingly focused on sardines as other species declined, and records of sardine-directed fishing exist from the early 1950s. There is only one seine-net boat which has a permit to catch species other than sardines; it is based in Durban and its catch is mostly sold for bait.

Commercial hook and line fishing commenced in KZN in the early 1900s, from Durban's harbour-based vessels, which were gradually replaced by small beach-launched skiboats which operated along the entire coast, commencing in the late 1940s and formalisation of the commercial skiboat sector occurred in 1976. Remarkable changes in catch composition have occurred since the commencement of the fishery, as stocks of the initially targeted large-sized species declined (Figure 8.1). Oyster harvesting began in KZN in 1888 although it is unclear when the fishery was formally commercialised. Harvesting methods are virtually unchanged, except that wearing masks are now allowed, which permits harvesters to access oysters down to around 1.5 m water depth.

Current state

The KZN crustacean trawl grounds are well-defined (Figure 8.2), a function of the target species' habitat preferences for sand/mud. Trawling on the inshore fishing grounds was excluded from August 2019 when the uThukela MPA and extended iSimangaliso MPA was promulgated. The fishery operates year-round and is marginally economically viable, owing to difficult working conditions, an ageing fleet, high

Commercial trawler, hauling line
Photo: Gareth Jordaan

operating costs and target species that are at the limit of their distribution. Target catches appear sustainable at the current number (3-4) of active fishing vessels (Figure 8.3), which is below the maximum Total Allowable Effort level (7 vessels). Fishing for tunas and swordfish by industrial longline vessels cannot be considered for KZN alone as these fishes are wide-ranging and stocks are shared with several Indian Ocean countries. Fishing operates year-round and can only be undertaken beyond 20 nautical miles of the coast. South African and joint-venture Japanese vessels operate within and beyond the EEZ off KZN, setting lines up to 100 km in length in the upper 200 m of the water column. Fifty permits are available for the whole South African EEZ although only twenty-five were active to the east of Cape Agulhas in 2018; three Japanese vessels take 90% of the catch in South Africa's Indian Ocean waters. Effort off the east coast peaked in 2011 and has been declining since, with a concomitant decline in catch (Parker *et al.* 2019). Numbers of permitted foreign vessels have been much reduced since 2018. Stock status is determined at the regional Indian Ocean level by the Indian Ocean Tuna Commission (FAO 2021). They consider yellowfin tuna to be overfished and subject to overfishing (2018); while swordfish and bigeye tuna are not overfished nor subject to overfishing (2018 and 2017 respectively).

There are around 25 beach-seine permits issued annually for sardines in KZN; fishing mainly occurs on the south coast and this only takes place if the shoals come close inshore. There is very high interannual variation in catches, with none possible in some years. Catches are a tiny fraction of those made on the main stock which occurs off the southern and western Cape coasts. The commercial skiboat fishery mainly targets reef-associated demersal species using rods and reels; many species have life histories that render them vulnerable to overexploitation.

Years of excessive fishing effort culminated in a state of emergency in the linefishery being declared in 2000, and Total Allowable Effort (number of commercial permits) was reduced by 70% by 2006, leaving KZN with a maximum of fifty-two permits, not all of which are operational. This has resulted in a decrease in annual catch to around one third (ca. 400 mt) of the maximum recorded. More than half the catch in recent years comprises a single species (slinger). Stock assessments of this species are used as indicator of the status of the fishery; the latest in 2015 indicates that there is recovery (Figure 8.4).

Around 20-30 commercial oyster permits are issued by DFFE each year; harvesting is permitted between the uThukela River mouth in the north and the Mzimkhulu River mouth in the south, but most occurs north due to higher oyster abundances (de Bruyn 2006, Steyn *et al.* 2010). Gear restrictions and daily catch limits are in place and there is an annual total catch limit of 100 000 oysters. A rotational spatial harvesting system allows stocks to recover before the area is opened to harvesting again. Difficulties with coastal access sometimes makes harvesting difficult, which can create excessive pressure in other areas and may lead to lowered sustainability.

IMPACT

Changes to a species' population structure caused by fishing can impact on a species' ability to withstand fishing pressure by affecting recruitment. Selective removal of Big, Old, Fecund, Female (BOFF) individuals which make a disproportionate contribution to reproductive output (Berkeley *et al.* 2004) can reduce reproductive success. So too, can selective removal of large males in a sex-changing species, by distorting sex ratios (Shapiro 1984). Selective removal of larger, apex species (which are often targeted by fishers because they are financially more valuable or because they are seen as a threat to more preferred species) can affect predator-prey relationships, affecting the ecology and changing community composition. This so-called fishing down the food web results in increasing dominance of smaller, faster-growing, short-lived species (Pauly *et al.* 1998), whose populations are more prone to recruitment failure. This is owing to a reliance on a few year classes, i.e., there are only a few years of recruitment numbers to sustain the population. Consequently, not only is the stock more vulnerable to overexploitation, but the value of the individual fish is reduced so that fishers are worse off. For example, the current dominance of the less desirable slinger in catches compared to the dominance by seventy-four in the early days of the commercial linefishery (Figure 8.1). Size-selectivity (hence age-selectivity) by fishing results in removal of faster-growing individuals, thus genetically selecting for slower-growing individuals, reducing the productivity of the species. Commercial fishing can also have collateral impacts by inflicting mortality or injury of unwanted species or sub-legal sized individuals of target species (bycatch). Demersal trawling is notorious for catching, killing and discarding a wide variety and quantity of bycatch organisms (Fennessy 1994), and also disrupts sediments on the seabed. Tuna longline vessels are responsible for mortality of a variety of non-target organisms, particularly vulnerable sharks (Jordaan *et al*. 2018) and seabirds (Ryan *et al.* 2012). The two remaining commercial fisheries in KZN have limited environmental impacts. Beach-seining for sardines has little bycatch and is confined to a short period of the year if it operates at all. Growth of seaweed and associated fauna on the shells of harvested oysters are removed and discarded during cleaning, but at current harvesting levels, this is relatively minor.

RESPONSE

There are limited opportunities for commercial fishing in KZN. The coastline is short, with naturally low productivity, and frequent rough seas. Additionally, there is high human population density which places resources under considerable pressure, and the more-easily accessible and catchable stocks have been heavily exploited. Deeper resources are limited owing to the narrow continental shelf and are difficult to access due to the strong Agulhas Current. The value of deeper resources and the costs of accessing them are also a deterrent. Mariculture is frequently promoted as a means of reducing pressure on harvested species; however, the KZN coast often has poor water quality and no sheltered embayments, and the low productivity will not sustain unsupplemented farming.

The recent promulgation of MPAs provides reasonable protection for several marine ecosystems, but management plans and implemented compliance measures are still needed. There is inadequate research and compliance monitoring of commercial fisheries. Fisheries being a national responsibility, KZN is not prioritised owing to the relatively low importance of these fisheries here. To an extent, research priorities have been addressed for some fisheries by NGOs, but they have a limited mandate for commercial fisheries. Small-scale fisheries (SSF) were recently (2016) promulgated as a separate sector to the commercial, recreational and subsistence sectors, although SSF encompass elements of all these three sectors in terms of legal sale of catch, catch restrictions and meeting of subsistence needs (Section 7.2).

Data Requirements
Ideally, for a given fishing gear, a time series of daily, independently collected information with as many of the following as possible: catch quantities (landed and discarded), catch composition (landed and discarded), fishing effort, spatial distribution of fishing outings, and length frequencies and sex ratios of the main species caught. Random sampling of 10% of fishing outings (onboard and at landing sites) is an alternative for daily data on discards, catch composition, length frequencies and sex ratios. The current catch records, which are required to be submitted by companies to the Department, must continue, but need to be periodically verified by independent observers.

8.7 COASTAL DUNE MINING

Dr Bronwyn Goble (ORI) and Dr Larry Oellermann (SAAMBR)

INTRODUCTION

South African large-scale mining started in 1867 with the discovery of diamonds, followed by gold in 1886. To some extent these minerals have reduced in commercial significance. However, they are critical to South Africa's economy. More recently there are several other minerals that have grown in importance for the country's GDP. South Africa is the world's biggest producer of chrome, manganese, platinum, vanadium and vermiculite and second largest producer of ilmenite, palladium, rutile, and zirconium (CSIR 2019). These minerals are vital to the economies of the world for manufacturing. Mining and mineral beneficiation currently contributes 5,0% of South Africa's GDP and is the country's single largest private employer (400 000 people) (TIKZN 2016).

Notably, KZN is home to several extractable minerals including coal, lime, slate and titanium. Mining activities account for approximately 1,85% of KZN's GDP and roughly 0.3% of South Africa's GDP in real terms (TIKZN 2016). Significantly, half of the province's mining output comes from Richards Bay Minerals (RMB) on the KZN north coast, with these dunes offering a high concentration of heavy minerals. The main products of RBM are zircon, rutile, titania slag, titanium dioxide feedstock and high-purity iron. More than 75% of South Africa's total titanium production originates from here. Titanium dioxide adds opacity to paints, fibres and plastics and it is also vital to the pigment industry. RMB produces approximately two-million tons of product, of which 95% is exported (Global Africa 2017).

Other mining activities that take place in the KZN coastal zone include:

1. Idwala Industrial Holdings quarries and mills white calcitic and dolomitic limestone near Port Shepstone.
2. Umzimkhulu Industrial Holdings (Pty) Ltd, trading as Rossmin, operates an open cast mining operation to mine high quality limestone deposits near Port Shepstone, known as the Marble Delta. Rossmin has incorporated the local community as shareholders in the business and through this initiative and the Rossmin Social and Labour plan, Rossmin contributes to uplifting previously disadvantaged people in the community (Rossmin Mining 2021).
3. The mining of carbonates occurs in the Simuna area along the banks of the Umzimkulu river, on the south coast, producing some 500,000 tons of clinker lime for the cement industry (Department of Transport 2020).
4. Stone and aggregates are mined for the building and construction industries; these occur at a wide range of sites including Durban and Port Shepstone.
5. Building-sand extractive processes occur throughout the province, mainly located on the major rivers that are the primary source of sand from erosion of the sandstone of the

interior escarpment (Department of Transport 2020). Additionally, there are production facilities for ferro-silicon, ferro-manganese, aluminium, titanium, zircon and rutile (Department of Transport 2020).

DRIVERS

South Africa's mining industry is one of the country's key economic sectors, driving the need to maintain and grow this industry. It is seen as a catalyst to accelerate economic growth and move South Africa's economy forward (Mining Weekly 2022). Significantly, it can be a buffer between low growth and sustainability, as seen in 2020 when the international market for commodities was high, generating greater revenue and thus offsetting the lower tax collected for other sectors. Sand mining operations are of socioeconomic importance to the province, employing at least 2500 people (Oellermann 2014). Despite the value of such operations, they cause a range of environmental impacts, which need to be mitigated.

PRESSURES

Dune mining in KZN utilises a dredge mining approach, whereby a large pond of freshwater is established in the dunes. A dredger and gravity separation plant float on the pond, simultaneously extracting minerals while moving forward along the dune system (DMR 2010). The mineral sand mining operation located 20 km south of Richards Bay uses a hydraulic mining technique: a high-pressure water jet is directed onto the dune face to undermine it, causing it to collapse. Water is used to break up the disaggregated sand into slurry, which is pumped to a wet processing plant at the mine (Oellermann 2014). These activities result in several environmental impacts, most notability the direct removal of coastal flora, fauna and the physical structure of the natural dune fields. The tailings are then reshaped to represent the original contours, they are covered with topsoil and revegetated with a cereal cover crop, together with indigenous seeds of long-lived species (Lubke *et al.* 1996). This progressive rehabilitation has resulted in a chronosequence, representing blocks of vegetation at various stages of succession (CSIR 2019). This rehabilitation programme has received worldwide recognition; however, it cannot replace what has been lost.

The operations also require significant freshwater inputs, which is limited and often competes with a variety of users. Mining activities of this nature compete with other land use options, mainly tourism, exhibited by the fact that it restricts access to the coast for other coastal uses.

It is important to note, an emerging mining pressure is that of offshore sand mining for beach nourishment. The City of Durban has resorted to this to deal with coastal erosion and loss of beach amenity when the existing sediment by-pass scheme has failed to deliver sufficient sediment to beaches north of the port breakwaters. Future port developments are also likely to resort to offshore sources of sediment for backfill.

STATE

The mining sector has historically played an important role in the development of South Africa, making a key contribution to the country's economy, infrastructure, and employment (Swart 2003). RBM accounts for the largest mining output from KZN, making up approximately 3,3 % of the national mining sector by value of output (Global Africa Network 2017).

Dune mining at Richards Bay
Photo: Kierran Allen

RMB is 74% owned by Rio Tinto, an Anglo-Australian multinational. Weak global demand has resulted in overall production of titanium dioxide slag by Rio Tinto going down 25% in 2015; as such, one of the four furnaces at RBM has been idled in response to this reduced demand (Global Africa 2017). Currently, RBM has the capacity to produce approximately 2 Mt of product annually, including approximately 100 000 t/year of rutile and 250 000 t/year of zircon (Williams and Steenkamp 2006). Of this, 95% is exported, yielding a world market share of about 25% of titanium feedstocks (titania slag and rutile), 33% of the zircon and 25% of the world's high purity pig iron (Williams and Steenkamp 2006).

In 2012, the development of Fairbreeze mine and smelter on the KZN north coast, was initiated through a partnership between Canadian company, Tronox, and South African resources company, Exxaro. Following a project investment of $225 million the mine opened in 2015 to replace the closed-down Hillendale mine (Global Africa 2017).

In 2019 it was estimated that mining companies in the province paid almost R3.3 billion in total earnings and payments to employees and employed over 12 000 people (TIKZN 2016). As such, there is opportunity to transform minerals or a combination of minerals into higher-value products for both the domestic and international markets. The potential for beneficiation in the province is an employment driver, which enables the development of new entrepreneurs in the down-stream, mid-stream and side-stream industries and sets a foundation for improved domestic economic activity and product development for KZN (TIKZN 2016).

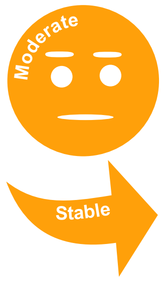
IMPACT

Mining operations have the potential to leave behind irreparable damage to the natural environment, with several potential impacts identified including air pollution, biodiversity loss (wildlife, agro-diversity), soil contamination and erosion, loss of vegetation cover, surface and groundwater pollution or depletion, large-scale disturbance of hydro and geological systems and reduced ecological connectivity. There are also additional impacts should a tailing spill occur (Ott 2017).

These impacts can have adverse consequences for local communities' access to resources and to their health. However, the Mineral and Petroleum Resources Development Act (MPRDA) (28 of 2002) is explicitly designed to compel mining companies to rehabilitate the land after mining operations cease, to offset these impacts (Dlamini and Xulu 2019). The success of rehabilitation remains questionable given the complexity of coastal ecosystems and that climax coastal forests take centuries to develop (Mentis and Ellery 1998). The best that rehabilitation can do is to reduce the impacts of water pollution and ameliorate the aesthetic deterioration of the natural landscape (Gesch 2005).

There is no doubt that mining activities can provide several benefits for surrounding communities. In Richards Bay the local communities have benefited from RBM's social investment programme, which offers health care, water and sanitation, agriculture, business development, education, and several specialised initiatives (Williams and Steenkamp 2006). However, such social and labour plans (SLP) often attract additional people to the area, leading to pressure on these resources and a negative impact on the local communities. A key social concern resulting from these mine developments and their SLPs is that they take over the role of local government regarding the provision of water, health care and education infrastructure. This increases the chance of a social collapse at the end of the life of the mine (Cloete and Marais 2013).

RESPONSE



While the demand for titanium metal is increasing, the high level of technology required to process the metal makes it difficult for KZN and South Africa to exploit these markets fully, given the lack of skills within the whole value chain. This in turn is slowing down future development in South Africa. If we are to see a future unlocking of the titanium metal industry, there needs to be significant investment into research and development facilities for unlocking post-extraction, downstream value (Ott 2017).

The DMRE has identified environmental management as a cornerstone of sustainable mining, as well as the rehabilitation of mining impacted sites through the MPRD Act. However, monitoring and enforcement of this legislation remains key to its successful implementation.

Data Requirements
Coastal dune mining contributes significantly to the GDP. However, these operations potentially have a range of adverse environmental impacts and sound environmental management and monitoring are required. Department of Minerals Resources is the custodian of much of the data pertaining to dune mining operations. In addition, relevant legislation pertaining to mining operations, locations and extents of current and proposed operations, and habitat biodiversity in these areas is required.

8.8 SAND MINING

Fiona MacKay and Bianca McKelvey (ORI)

INTRODUCTION

By volume, the largest global extractive industry is mining of aggregates that constitute sand and gravel sediments (Peduzzi 2014). Sand mining is widespread, where every country mines or imports sand and the rate of sand mining far exceeds natural fluvial sediment supply with an ever-increasing deficit. The United Nations Environmental Programme describes this shortfall as "*one of the major sustainability challenges of the 21st century*" (UNEP 2019), where global aggregate consumption is estimated to increase from 40 to 50 billion tons per year in the next decade (Koehnken and Rintoul 2018). Sand supports the construction industry (aggregates in concrete), is used in industrial applications (industrial abrasives) (Chamber of Mines of South Africa 2017, Peduzzi 2014), for glass and electronics manufacture and is targeted for land and beach reclamation (Torres *et al.* 2017).

At the coast, sand is mined from a variety of environments including riverbeds, estuaries, beaches, dunes or even the seafloor. Geological conditions and steep catchment gradients in KZN result in naturally high terrigenous sediment supply to rivers, estuaries and the downstream marine environment (Cooper *et al.* 1999). Although the practice is controlled in many developed nations, in KZN sand mining is focused on rivers and estuaries. These ecosystems are preferred for industrial applications due to the quality of the resource extracted. Fluvially-derived sands are well-sorted (mix of different sand sizes) by natural sediment transport processes and are of the market-preferred structure and composition (Kondolf 1994, Koehnken *et al.* 2020). The extraction of dune sands for heavy minerals is excluded from the local interpretation of sand mining, falling rather under dune mining (Section 8.7).

The industry is largely mechanised, typically using earth moving equipment in the channel and on river and estuary banks and floodplains, and using floating suction dredgers where water depth allows (Heath *et al.* 2004). These operations appropriate further land for large equipment storage, vehicle maneuvering and

Mining operation at the estuary/interface, iLovu KZN South Coast (2019)
Photo: Kierran Allen

resource stockpiles. They create their own access and haulage networks, collectively resulting in extensive habitat loss at mining sites.
Despite the plethora of knowledge and evidence related to the high environmental and socioeconomic costs of sand mining in these sensitive environments, the pressing need for development has consistently outweighed objective assessment of other benefits, and not recognised the longer-term effects to the greater socio-ecological system. A KZN-specific study showed that effects of sand mining correlate with estuary health and therefore the ability to provide other commercial, recreational and subsistence opportunities (in a healthy estuary). In short, the value of the resource is under-estimated, and the danger is that the resource becomes over-exploited (de Lange *et al.* 2008) against a background of a confused and poor regulatory system (Gondo *et al.* 2019). There has been a significant increase in illegal and uncontrolled activities in rivers and estuaries. Without deterrence and compliance enforcement, unauthorised and poorly managed operations have caused "*irreversible destruction*" to rivers and estuaries and presented diverse challenges related to legislation and the social and ecological environments (Chevalier 2014).

DRIVERS

Development and economic imperatives drive sand mining in KZN. As with elsewhere (e.g., Ahmed *et al.* 2020), the motivation for sand extraction is derived from economic and social development requirements, including infrastructure and housing. In KZN, this is connected to expanding coastal populations and an imperative to address multiple social issues through economic stimulus. The construction industry is the primary consumer of sand and gravel in South Africa, with reported sand mining revenue trending closely with construction revenue, and both have been increasing over the past decade (Mineral Council of South Africa 2010, 2019, PWC 2016). Of concern, in KZN the rapid increase in the sand mining footprint over the same period exceeded the national rate of increase in mined volume, suggesting a high increase in sand demand. It is anticipated that mining extent will continue to increase, given South Africa's need for continued economic development.

PRESURES

The effects and scale of sand mining in South Africa (coastal KZN in particular) has elevated this activity to the level of a distinct pressure, that highly influences the estuarine state (Van Niekerk *et al.* 2019). Nonetheless, there are specific sand mining pressures that originate from the activity itself. Examples are the expansion of illegal operations that limit bona fide future opportunities, the alteration of water courses that limit sand delivery to the coast and the removal of riparian vegetation that causes bank instability and erosion.

The regulation framework intensifies sand mining pressure through lack of monitoring and control systems. Permitting procedures are poor screenings for operators lacking environmental awareness or who do not have the technical know-how to operate in sensitive environments, exacerbated by inaccurate reporting on extraction volumes. This is a demand driven activity and a future change to more sustainable construction materials will influence sand mining.

STATE

There is no active monitoring of sand mining in KZN. Without information on scale and intensity, there is limited opportunity to quantify the impacts on the health status and ecosystem condition of rivers and estuaries. However, the correlation of presence of sand mining (even historical) with compromised estuarine health status is high (Van Niekerk *et al.* 2019).

Historic Perspective

Past mining activities can only be ascertained by gross national figures published annually by the Minerals Council of South Africa (Mineral Council of South Africa 2019). Also, regulatory mechanisms have performed poorly and official records are left incomplete by unlawful mining and a lack of compliance with environmental regulations (Heath *et al.* 2004, Amponsah-Dacosta and Mathada 2017, Bendixen *et al.* 2019). In situ monitoring is impractical given that clandestine operations are often located in remote areas (Chaussard and Kerosky 2016, Duan *et al.* 2019) and that the industry is globally associated with violence and intimidation (UNEP 2019). Three historical sandmining studies have been done in KZN: Demetriades (2007) conducted an aerial survey of 64 KZN estuaries in 2007, which enumerated 18 affected systems; Bredin *et al.* (2019) conducted a situational assessment that revealed that the extent of riverine mining in the study catchment tripled between 2004 and 2019 and a study on sandmining and sediment yields conducted in the eThekwini Metropolitan Area by de Lange *et al.* (2008), found unsustainable over-exploitation of eThekwini sand stocks at the expense of other estuarine ecosystem services. None of these studies reported on the ecosystem condition of the affected environments. Thus, there are no historical baseline conditions or reference points.

Current State

The 2018 National Biodiversity Assessment identified sand mining as an emerging pressure that has resulted in permanent habitat loss in 12% of South Africa's estuaries (the majority of which are in KZN) and is on a trajectory of increase (Van Niekerk *et al.* 2019). The report was based on a survey (ORI, unpublished data) of 68 KZN estuaries using satellite imagery between 2001 and 2018, that found that 54% of surveyed estuaries were subject to direct (72 sites in 19 estuaries with mining within, or partially within the Estuarine Functional Zone (EFZ)) or indirect (35 estuaries with upstream river mining within 10 km of the EFZ) sand mining activities. This doubled the number of estuaries known to be impacted (Demetriades 2007). Mining was associated with all the relatively large Predominantly Open or Large Fluvially Dominated estuaries (Figure 8.5).

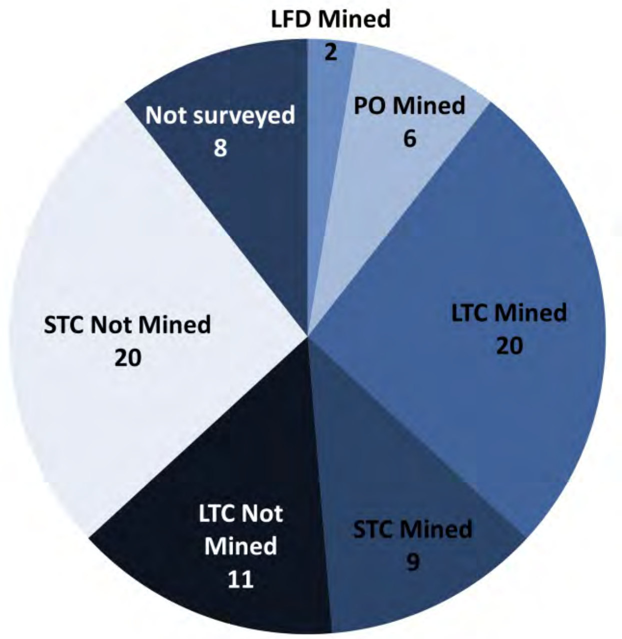


Figure 8.5: Distribution of sandmining sites by estuary type. LFD – Large fluvially dominated, PO – Predominantly Open, LTC, Large Temporarily Closed, STC – Small Temporarily Closed

However, 44% of the sites intersecting the EFZ and 65% of upstream sites affected the smaller temporarily closed estuaries (Figure 8.6), including 20 Large Temporarily Closed estuaries and nine Small Temporarily Closed estuaries (Figure 8.6).

Local land-use strongly influenced mining pressure, regardless of estuary type. Considering

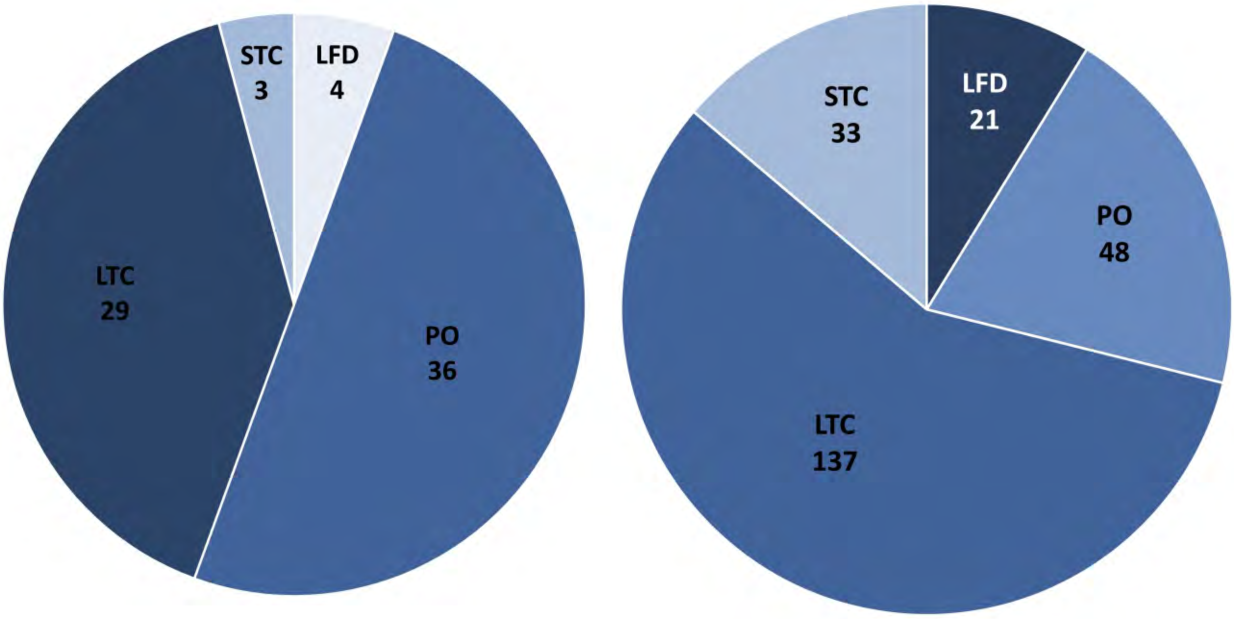


Figure 8.6: Number of mining sites intersecting the EFZ (left) and number of upstream sites within 10 km of the EFZ (right) grouped by estuary type. LFD – Large Fluvially Dominated, PO – Permanently Open, LTC, Large Temporarily Closed, STC – Small Temporarily Closed

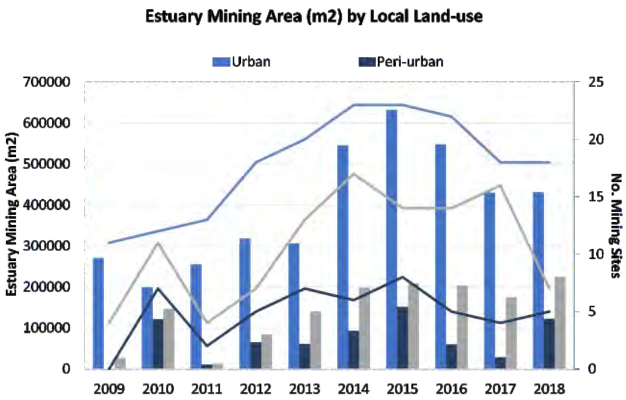


Figure 8.7: Sand mining footprint and number of mining sites intersecting the EFZ between 2001 and 2018, for 68 KZN estuaries

the number and size of sand mining operations intersecting the EFZ, urban estuaries had the highest mining pressure (Figure 8.7), with large, permanent or semi-permanent mines, and a large number of upstream mining sites (within 10 km of the EFZ).

Smaller urban systems are typically in poor to very poor condition (Van Niekerk *et al.* 2019), and may lack the resilience or assimilative capacity to absorb sand mining impacts on estuarine function, resulting in disproportionate declines in estuarine health. Mostly untransformed estuaries in rural landscapes may have higher assimilative capacity, but more than half of these are identified as having high conservation value and impacts on estuary health would impinge on national conservation targets (Van Niekerk and Turpie 2012).

Impact

There is a lack of quantitative data on the impacts of sand mining on rivers and estuaries in the global south (Koehnken and Rintoul 2018) and extrapolation from studies in the developed world can be problematic as effects can be context specific (Koehnken *et al.* 2020). However, universal effects are the loss of habitat complexity and biological diversity, with long term impacts on rivers and estuaries (Le Bot *et al.* 2010, Latapie *et al.* 2014, Kędzior *et al.* 2016). Even operations that are small and contained can cause habitat degradation, as riparian vegetation is removed and land is left unrestored and subject to alien plant invasion. Unsustainable mining rates in large urban estuaries have far reaching consequences, as these are the drivers of sediment supply downstream to coastal and marine environments. The disruption of sediment transport exacerbates coastal erosion across the region (de Lange *et al.* 2008, Corbella and Stretch 2012) and limits the supply of sediment and nutrients to the marine environment.

Instream biota are affected; particularly non-motile burrowers and biological connectivity up- and downstream is interrupted causing fish and crustacean migration blockages. This influences recruitment and even survival (Pitchaiah 2017), causing local extinctions and proliferation of invasive species (Freedman *et al.* 2013). Increased turbidity from instream dredging can influence biota health by limiting light penetration (reducing photosynthesis in plants) and reducing visibility for predators, clogging of gills, and even smothering of small invertebrates, thereby reducing overall food availability. Uncontrolled mining alters system morphology through bed degradation and changing longitudinal gradients and lowering bed elevations, widening channels, and changing flow patterns (Leal Filho *et al.* 2021).

Various methods used to extract sand, including mechanical digging and dredging in the estuary (2019)
Photo: Kierran Allen

There are also economic and social impacts to sand mining. In KZN these have included human health risks (drowning in mined pits), limited access to natural habitats by local communities, damaged infrastructure (e.g., bridges and causeways), and reduced sand deposits. There are indirect impacts such as on tourism (shrinkage of bathing beaches), and although not noted in KZN, changes to recreational and subsistence fishing (Pitchaiah 2017).

It is anticipated that the extent and concomitant impact of sand mining on KZN estuaries will continue to increase given South Africa's need for economic development and the imperative to provide housing and essential services to under-served communities.

Response

KZN rivers and estuaries impacted by sandmining need urgent attention, starting with a critical need to address the governance gaps. The DMRE is responsible for the regulation of mining under the Mineral and Petroleum Resources Development Act. Since 2014, under the *One Environment System* the Minister of Mineral Resources is the competent authority for issuing environmental authorisation. A situation that is far from ideal whereby the Department is 'referee and player' (Chevallier 2014). Several key actions are needed to improve the sand mining impacts:

- Clarity on governance framework for mining, including which spheres are responsible for management, inspection and enforcement.

- In the recent KZN sand mining study, many operations were not permitted. Enforcement to shut down these activities is needed.
- Operators should submit and enforce environmental management plans.
- Whilst in operation, environmental best practice should be adopted. After mining, remediation of the site should be enforced (to date, no active restoration has taken place on KZN coastal rivers or estuaries).
- Consistent environmental monitoring is required. Prior to extraction, ecological baselines for the impacted environment should be ascertained and monitoring targets for restoration should be stipulated. The restoration levy should be commensurate to the ecological sensitivity and complexity of the environment mined.
- Detailed quantitative investigations are required on the biophysical effect of sand mining in the local context to inform impact assessment and region-specific strategic management planning and intervention, including cumulative impacts of multiple mines on a system over long time periods.
- Large estuaries with chronic mining should be prioritised for research and strategic intervention, as sediment delivery from these systems is the most critical to downstream marine and beach habitats. Smaller systems with high mining pressure, particularly those of high conservation value, should be closely monitored given the risk of long-term or permanent impacts on estuary health that impinge on national conservation targets.
- Increased public awareness is necessary around the dangers of illicit mining, the negative effects to the environment and the finite supply of sand as demand increases.
- Detailed mining inventories are required, including closed operations, to inform the scale of mining pressure on aquatic coastal systems and ecosystem recovery times.
- Alternate, sustainable materials for use in industry and construction should be investigated and promoted, including changes to building design.

Data Requirements

The impacts of sand mining arise from habitat loss and sand deficits. Basic data on the location and extent of the mining footprint within coastal rivers and estuaries are required, including active mining pits, lay-down areas, and the haulage road network. Sand mining is also a land use concern. Remote sensing offers near real-time monitoring of mining extent into natural, transformed or developed land influencing other socio-economic aspects. Using historical imagery, a retrospective analysis provides time series data as a reference point for future monitoring. In KZN, <10% of estuaries have had good bathymetry surveys for the last ten years. These are basic data that inform in-channel loss or transformation of subtidal habitats in the downstream receiving environment. Sand budget assessments are needed if not for every estuary, at least for regions of estuaries along the coast, focusing on estuary type. Data on the actual volumes of sand mined from estuaries (including illegal activities) are critical to the estimation of sand budgets and the identification of regional sand deficits. Updated hydraulic and hydrologic data are needed for coastal waterways to the ocean. Even basic information (flow, water levels) is not readily available for most systems.

8.9 OFFSHORE MINING

Prof. Sean Fennessy (ORI)

INTRODUCTION

Offshore mining entails the extraction of non-renewable minerals from the seabed, excluding oil and gas (Section 8.10). The only active offshore mineral mining in South Africa is that for diamonds on the west coast, which is undertaken by divers using suction pumps. Elsewhere, offshore mining entails prospecting by seismic profiling, drilling and/or coring, and large-scale bulk mining with a seabed crawler or a suction hopper-dredge. Minerals such as potassium and glauconite are used in fertilisers, while others of interest such as titanium-based heavy minerals (ilmenite, zircon and rutile) have a multitude of uses, including manufacturing and paints. Deposits of heavy minerals in shelf sediments are known off KZN, particularly in areas adjacent to where coastal dune mining and port-associated offshore dredging is already occurring; locations of phosphate accumulations in shelf sediments are known for the South African west and south coast (Rona 2008). Deep-sea hydrothermal vents are known sources for polymetallic nodules, massive sulphides and cobalt-ferro-manganese crusts (Boetius and Haeckel 2018), while at depths > 350 m, where water temperature is < 4° C, natural methane gas is stabilised and buried as methane hydrate in continental slope sediments. This could potentially be mined; although it is not known if these latter features occur off KZN, they may be discovered as surveys expand. Information is available in the recent overview of marine and coastal mining methods (Biccard *et al*. 2018).

DRIVERS

The economic viability of offshore mining may change as terrestrial reserves are depleted and technology improves. Internationally, offshore exploration for minerals is increasing, so it is likely that exploitation will also increase locally. The DMRE aims to develop seabed mining in the South African Exclusive Economic Zone (EEZ), and applications for offshore prospecting rights have been lodged for phosphate and titanium-based minerals.

Decisions on whether to commence offshore mining off KZN will be driven by cost-benefit, socioeconomic and environmental trade-off analyses. This will need to demonstrate that mining will be economically viable, will meet South Africa's needs, and will not cause substantial, irreversible environmental damage.

PRESSURES

The exploration for and extraction of offshore minerals can be very disruptive to the ecology of offshore ecosystems. Methods for identifying mineral reserves rely on remote sensing to identify promising indicative geological features – such methods frequently involve the use of seismic and sonar equipment. Depending on the frequencies and intensities of the sounds generated, negative impacts are possible, on a wide range of organisms, from benthic infauna to cetaceans, including disrupted communication, hearing and orientation, although there is considerable lack of knowledge of effects for many taxa (Hawkins *et al.* 2015). Mining of minerals generally results in disruption of sediments, leading to increased turbidity and modification, loss and contamination of habitats, and smothering or destruction of biota (Ahnert and Borowski 2000, Levin *et al.* 2016). Deep-sea hydrothermal vent communities are intolerant of disturbance, and minerals released from vents have a critical biogeochemical role in the wider ocean; for example, via mediation of micronutrient productivity associated with phytoplankton blooms (see German *et al.* 2016). Methane hydrate buried in sediments on continental slopes contains far more carbon than released by fossil fuels, and mining of these hydrates from the offshore seabed would accelerate release of methane, a greenhouse gas (Bollmann 2010). Offshore mining was identified as a pressure on the marine environment in the latest South African National Biodiversity Assessment (Majiedt *et al.* 2019).

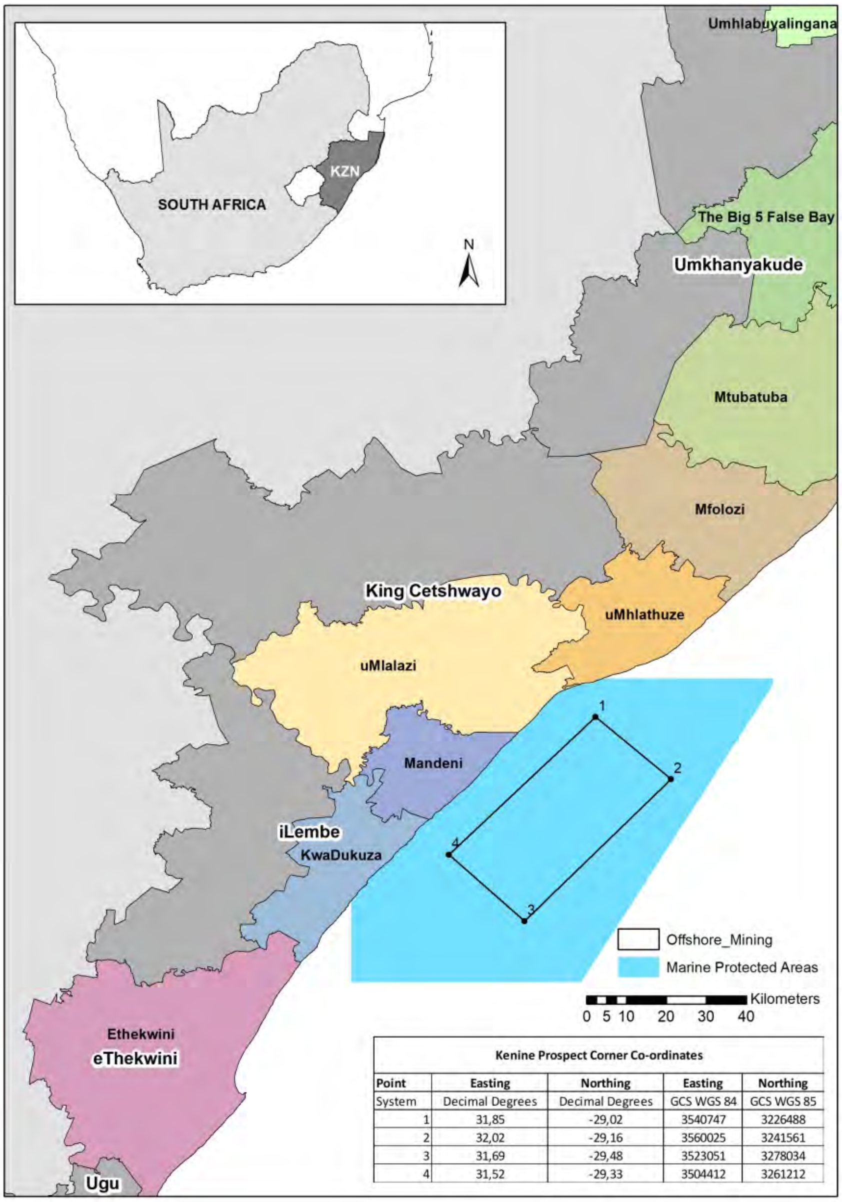
STATE

Historic perspective

To date, offshore mining in South Africa has only been undertaken on the west coast, and only for diamonds. Notwithstanding the identification of substantial reserves of several other minerals, particularly phosphates, off the Western and Eastern Cape, the costs relative to terrestrial/coastal mining (see Section 8.7) appear to currently make offshore mining for less valuable minerals economically non-viable. There has also been considerable resistance to mining offered by NGOs, for example *Safeguard our seas* (Safeguard our seas 2021).

Current state

No offshore mining currently takes place off KZN. The only potential reserves of offshore minerals which have formed the basis of a prospecting permit off KZN, are associated with shelf



Kenine Prospect Corner Co-ordinates				
Point	Easting	Northing	Easting	Northing
System	Decimal Degrees	Decimal Degrees	GCS WGS 84	GCS WGS 85
1	31,85	-29,02	3540747	3226488
2	32,02	-29,16	3560025	3241561
3	31,69	-29,48	3523051	3278034
4	31,52	-29,33	3504412	3261212

Figure 8.8: Demarcation of uThukela MPA and proposed offshore mining area

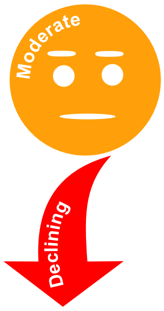
sediments of terrestrial origin off the uThukela River in the central KZN Bight. The magnetic fraction in sediments is linked to the concentration of magnetite, in turn linked to the presence of other heavy minerals, such as ilmenite, rutile, zircon and garnet. The only known potential activity was initiated in 2011, when permission to prospect for heavy minerals off central KZN was lodged with the (then) Department of Mineral Resources, in an area approximately 48 km long and approximately 22 km wide, parallel to the coast between the towns of Zinkwazi Beach and Mtunzini (Figure 8.8).

Although an Environmental Management Plan for the activity was prepared (Department of Mineral Resources, unknown), the status of the application is not known, as no information is available on the Department's website. This area falls within the newly declared (2019) uThukela MPA, so it is possible that prospecting and mining may not be allowed.

IMPACT

No impacts are anticipated in the short term. Seismic noise may cause physical damage to tissues, and disrupts communication, including via damage to hearing apparatus such as cochleas, otoliths and swimbladders, leading to compromised reproduction (e.g., spawning aggregations); and can compromise orientation/balance, which affects feeding and shoaling behaviour (reviewed in Koper and Plon 2012) – which in turn increases vulnerability to predation. Reduced reproductive success and increased mortality can result in modified community composition and functional ecology. Disruption of sediments by mining leads to increased turbidity in the water column, reducing visibility and primary productivity, with loss of productivity higher up the food chain (Parsons *et al*. 1986). Modification or loss of seabed habitats by smothering and contamination caused by mining results in mortality of organisms and altered ecology, which can persist in the long-term, depending on the location of the affected area (Burd 2002, Essink 1999, Hall 1994). The South African National Biodiversity Assessment also provides information on mining impacts (Majiedt *et al.* 2019).

RESPONSE



National protocols and procedures must be put in place to ensure that due process and international best practice is followed should offshore prospecting/ mining be considered in future.

Identification of unique and vulnerable offshore habitats for conservation in KZN has taken place over the years (e.g., Harris *et al*. 2012), and considerable research has been undertaken to support this. The coral reefs off the northern coast (Schleyer and Porter 2018) and much of the central KZN Bight (reviewed in Fennessy *et al.* 2016) have been quite well characterised. However, large gaps remain; while there is some information on commercially important fishes, the life history, taxonomic status, population trends and distribution information are lacking for most marine organisms. There is insufficient data and understanding of the impact and interactions of pressures (e.g., climate change), and knowledge of deep-water habitats is lacking; these and other gaps have been identified in the 2018 National Biodiversity Assessments for marine and coastal habitats (Sink *et al*. 2019). Regarding gaps in knowledge to mitigate environmental impacts of mining, alternatives to seismic surveys, as well as elimination of the use of unnecessary and harmful seismic survey frequencies, should be investigated. Environmental monitoring protocols for pre-, during and post-exploration and mining phases must be established and included in requirements for approval of rights applications.

Data Requirements

1. Proposed and gazetted legislation pertaining to offshore mining (www.dmre.gov.za).
2. Location and extent of concession areas allocated for prospecting and mining (www.dmre.gov.za).
3. Location and extent of areas which could potentially contain reserves of these minerals.
4. Habitat and biodiversity data from indicative areas.
5. Oceanographic data for dispersal modelling of mining-associated plumes and contaminants.
6. Location and extent of areas with habitats/organisms sensitive to prospecting and mining.
7. Location and extent of Marine Protected Areas (www.dffe.gov.za).

8.10 OIL & GAS EXPLORATION

Prof. Sean Fennessy (ORI)

INTRODUCTION

South Africa imports most of its oil, as there have been limited discoveries made locally. Offshore extraction of gas and oil currently occurs off the coast of the Western Cape province. Exploration and license application blocks have been expanded recently into almost the entire EEZ, including KZN, with more than 90% of the ocean territory around South Africa under exploration or production lease or technical co-operation permit (Petroleum Agency SA 2013). Identifying marine hydrocarbon prospects initially relies on remote sensing to identify promising geological features, frequently requiring use of powerful seismic and sonar equipment, as hydrocarbon reservoirs are generally found at depths of 2 000 to 4 000 m below the seabed (Richmond 2016). To confirm the presence of hydrocarbons in prospects, and to understand the geology of the surrounding sedimentary strata, it is standard practice to drill exploratory wells with a drill ship. Over 300 wells for prospecting or extraction have been drilled within the South African EEZ, although very few have been in KZN (Figure 8.9). The success rate for an exploratory well in a newly surveyed region is usually less than 20 per cent. Exploration is extremely expensive, and South Africa does not possess the facilities to survey offshore – international companies carry the risk. Once a viable find is made and extraction commences, the oil or gas needs to be processed, generally requiring its transport to shore-based refineries by ship, as distances from offshore wells can be considerable.

DRIVERS

Notwithstanding its potential for alternative energy sources, South Africa is heavily reliant on oil, particularly for conversion into fuel for transportation (land, sea and air). There is also increasing interest in gas for conversion to liquid fuels, and as an alternative to electricity, which would alleviate demands on the ailing ESKOM. Extraction of local marine oil and gas (hydrocarbons) accounts for only about 7% of South Africa's needs, the rest is imported or generated from coal (Atkinson and Sink 2008).

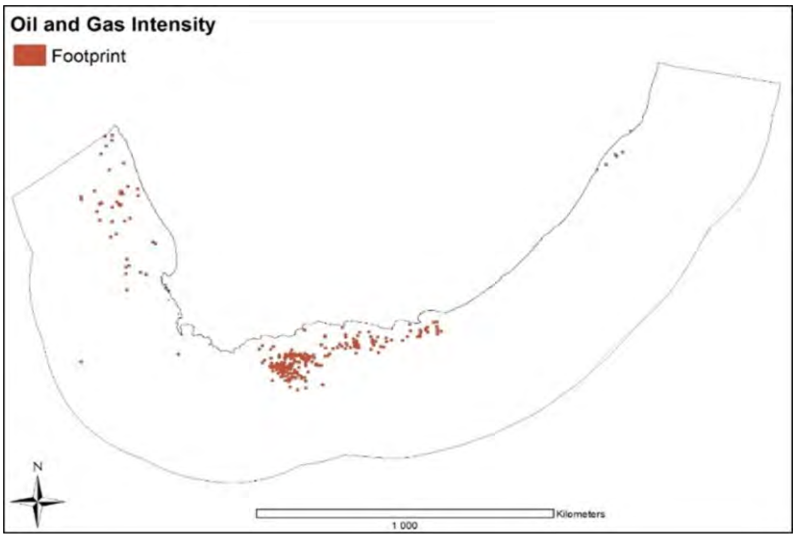


Figure 8.9: Drilling sites in the South African EEZ (Majiedt *et al.* 2019)

The state-owned Petroleum Agency of South Africa (PASA) has the mandate for the promotion and regulation of oil and gas exploration and production in South Africa, as well as for archiving all data. Petroleum Agency SA indicates that, based on existing seismic surveys, there are several promising areas off the east coast: "The area comprises a large under-explored area off the east coast of South Africa which exhibits promising exploration potential. Existing identified leads, play concepts and prospective structures with a total hydrocarbon potential in the multi-billion-barrel range, make further exploration of these blocks imperative" (Petroleum Agency SA 2013). Together with Operation Phakisa plans for development of the marine economy (e.g., an aspiration to drill 30 offshore exploration wells nationally), there is considerable promotion of offshore hydrocarbon activities off the east coast. It is anticipated that this will continue despite initiatives to reduce reliance on hydrocarbons, such as electric vehicles.

PRESSURES

Depending on the frequencies and intensities of the seismic sounds generated during exploration, a wide diversity of organisms, from benthic infauna to cetaceans may be affected, at a wide range of distances, from metres to kilometres. These effects include disrupted communication, hearing and orientation, although there is lack of knowledge of effects on many taxa (Hawkins *et al.* 2015). Drilling activities and associated operations result in air emissions, discharges of contaminants into the sea, waste which requires disposal on land, and noise emissions. Contamination of sediments and the surrounding water, with obliteration or modification of benthic and pelagic communities, can occur. These effects can be localized, or, in the case of catastrophic failure of infrastructure, dispersed over thousands of kilometres (Smith *et al.* 2008), depending on currents and the extent of contamination, and can persist for many years in deep-sea habitats (Cordes *et al.* 2016). In South Africa, 98% of the EEZ has been assigned for hydrocarbon exploration, in the hope of reducing dependency on imports, to encourage foreign direct investment, and to optimize use of marine resources under Operation Phakisa. If extraction commences, greater shipping traffic can be expected, with associated increased pollution, ship strikes on cetaceans, and invasive species from ballast water and fouling of drill rigs.

STATE

Historic perspective

Offshore exploration in South Africa commenced in 1967, and as of 2016, 230 000 km^2 of 2D seismic data and 10 200 km^2 of 3D seismic data had been acquired, and three hundred wells had been drilled (Bhattacharya and Duval 2016). Most wells are in <250 m water depth on the Agulhas Bank off the Western Cape, although some have been drilled off the Northern Cape, and four were drilled in the late 1990s on the continental shelf off Durban in KZN (Majiedt *et al.* 2019). The only extraction that has taken place is for gas and oil off Mossel Bay in the Western Cape, and this is still currently occurring. There does not appear to have been any surveying off KZN after the 1990's well drilling until 2013-2014, when an extensive (ca. 5 000 km^2) seismic survey was undertaken off central KZN at depths commencing at 30 m; this indicated hydrocarbon potential (Bhattacharya and Duval 2016), but no wells were drilled. A deeper seismic survey (commencing at ca. 700 m depth) of around 7 500 km^2 was undertaken off central KZN in 2016. These surveys culminated in a 2018 application for drilling.

Although most of the five identified hydrocarbon prospects off KZN are in deep water >700 m, one commences in 75 m water depth (Petroleum Agency SA 2013). An Environmental Authorisation was granted in late 2019 for proposed drilling of up to six wells, in two broadly defined areas in deep water: one in depths of 1 500 – 2 100 m whose closest point is 62 km off the coast, the other is in depths of 2 600 – 3 000 m with a closest point 65 km off the coast. The depths of seabed to be drilled are ca. 4000 and 5000 m from the sea surface, respectively. Permission was granted despite strenuous and detailed objections to the Environmental Impact Assessment (EIA) from several parties. Notwithstanding recent (1st quarter of 2020) volatility in the oil price, and the postponed planned drilling dates (November 2019 - March 2020), it was assumed the exploration drilling would still go ahead; the latest situation (June 2021) is that a review application has been lodged in the Pretoria High Court challenging the approval decision. If the approval is overturned, this would be a substantial precedent, as there is no evidence to suggest that any application for seismic surveying or drilling exploration has been turned down for environmental reasons in South Africa to date, questioning the likelihood of success of future applications which do not adequately follow protocols.

To compile a current situational analysis, the only information available comprises the above-mentioned two recent seismic surveys, and the recent application for exploration drilling off KZN. The last drilling off KZN took place over 20 years ago, and no hydrocarbon extraction has yet taken place, so there is no current information on drilling off KZN to draw on. Seismic survey EIAs are desktop-based and often rely on a Generic Environmental Management Programme Report compiled for oil and gas exploration in South Africa. There is no during-survey or post-survey requirement for monitoring of impacts, other than the use of ship-board observers and monitors for marine mammals during surveys; presence of mammals requires the survey to cease. Other recommended protocols to reduce impacts include a gradual ramping up of seismic sound volume and avoiding surveys during mammal migrations. Details of mitigation measures often recommended for local seismic surveys are described in United States Department of Interior (2007). Applications for offshore drilling as part of exploration or extraction of hydrocarbons also require EIAs; the development phase (assuming a viable find is made) is separate from the exploration drilling phase and requires a new EIA. Assessments require specialist studies to determine the dispersal of drill cuttings, oil spills and other contaminants, as well as, amongst others, consequences to marine ecology. In South Africa to date, these studies have been desktop-based; as part of authorisation conditions, pre-drilling and during-drilling monitoring and sampling of the water column and sediments are required to be undertaken; recent changes now require monitoring to be undertaken by independent agents.

The oceanography of the exploration/extraction area is a major determinant of contaminant dispersal, and likely trajectories are established by modelling. Pollution from oil spills (attributable to exploration or otherwise) in South Africa has not been mapped (Majiedt *et al.* 2019), so there has not been ground-truthing of the spill dispersal models using a real scenario. The nature of the marine ecology and its vulnerability to hydrocarbon activities vary enormously depending on location. Companies undertaking hydrocarbon exploration and/or extraction activities are required to have equipment, systems and protocols in place for prevention of pollution from oil, gas, drill cuttings, and waste such as sewage and garbage. An Oil Spill Contingency Plan (OSCP) for the drilling site should developed, based on the National Incident Management System for spills and the National OSCP. At the end of the exploration drilling or on decommissioning, once hydrocarbon resources are non-viable, wells are sealed off with cement plugs to prevent unwanted release of hydrocarbon, and the wellheads are left on the seabed, marked on navigational charts.

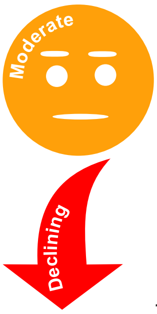
IMPACT

Although there is potential for impact on coastal environments at all stages, no scientific literature could be found with evidence for impacts of marine hydrocarbon exploration activities on the KZN coastal environment. There is a lack of research and consequently few publications on the effect of marine hydrocarbon activities on the environment in South Africa (Atkinson and Sink 2008, Sink *et al.* 2010). The state-owned Petroleum Agency of South Africa (PASA) has not received post-survey complaints (Petroleum Agency SA 2013), although anecdotal reports exist of marine mammal strandings occurring during the 2019 KZN seismic survey (CoastKZN 2020). Seismic impacts on fauna from plankton to large marine mammals are generally assessed as very low, particularly if mitigation measures are implemented. Assessments of impacts in the literature consider short-term responses of individual organisms; understanding of long-term impacts at the population level are limited, and cumulative impacts of successive seismic surveys have not been established (Section 8.9 for seismic impacts).

The report by Sink *et al*. (2010) from the Western Cape hydrocarbon extraction site appears to be the only readily available and independent information on observed local marine drilling impacts from hydrocarbons and provides a useful review of the international literature on impacts, as does Cordes *et al.* (2016). Marine hydrocarbon infrastructure (anchors and pipelines) directly disrupts sediment and in/epifaunal communities within a radius of ~100 m from the infrastructure. Discharges of drilling muds and associated water can extend more than 2 km from the source, with physical disruption of in/epifaunal populations and communities mainly within 300 m of the drill site. These impacts may persist for many years in deep water. Sink *et al.* (2010) reported limited evidence of chemical pollutant impacts on sediment infauna, and the drill rig infrastructure was responsible for introduction, hosting and spreading of alien species. Although small accidental oil spills occurring during routine operations can cause impacts such as fouling of coastal habitats and fauna and flora, major oil spills are seen as the greatest threat posed by the oil and gas industry to marine biodiversity in South Africa (Attwood *et al.* 2000). The most catastrophic situation is when a large spill occurs in a blowout, caused by loss of well control when a drilling rig encounters a pocket of oil under extreme pressure, or when there are technical failures. The probability of this happening is generally considered to be low, although the environmental consequences can be severe (Section 2.3).

At a global impact level, two-thirds of industrial greenhouse gas emissions over the past 200 years can be traced to a few companies, most of which are involved in oil and gas extraction (Grasso 2019); oil and gas are therefore major drivers of climate change, which is responsible for a range of impacts on marine environments, including in KZN (Sections 3.1 and 3.2).

RESPONSE



Ongoing improvements in legislation and regulations pertaining to offshore hydrocarbon prospecting and extraction are required by the Department of Mineral Resources and Energy. There needs to be a rapid phase-out of all fossil fuel usage. This is in keeping with the Paris Agreement, to limit warming to 1.5-2°C, to which South Africa is signatory. Consequently, there should be no new developments aimed at hydrocarbon extraction; in order to negate the knock-on effects of extraction (if companies invest in exploration, they will argue that they be allowed to extract). The EIA processes for exploration and extraction should therefore not be separated, to prevent this.

The global drive to reduce global greenhouse gases potentially conflicts with Operation Phakisa initiatives (although South Africa's climate change commitments as a developing country are less onerous), but the intention of the Integrated Energy Plan is to reduce reliance on South Africa's main culprit - burning coal - partly by increasing use of gas, which opens the door to offshore exploration for gas reserves. Development and roll-out of alternatives to transport fuels would reduce the imperative to explore for oil.

Data requirements

1. Location and extent of concession areas allocated for prospecting and extraction (www.dmre.gov.za).
2. Oceanographic data and data on physicochemical changes undergone by released hydrocarbons, for improved dispersal modelling of oil spills and contaminants, particularly in deep-sea environments.
3. Harmonisation of responsibilities in the event of a catastrophic deep-sea oil spill emanating from an offshore well.
4. Habitat and biodiversity data from areas likely to be affected by hydrocarbon surveys and extraction.
5. Location and extent of areas with habitats and organisms sensitive to prospecting and extraction.
6. Location and extent of Marine Protected Areas (www.dffe.gov.za)

9 GOVERNANCE ENVIRONMENT

Our vibrant KZN coast
Photo: Kierran Allen

CHAPTER 9:
GOVERNANCE ENVIRONMENT

9.1 COASTAL MANAGEMENT

Dr Bronwyn Goble and Rudy van der Elst (ORI)

INTRODUCTION

The coastal zone is a complex and integrated network of dynamic processes which deliver important ecosystem goods and services (van der Elst and Goble 2014). Paradoxically, human activities have left their mark on the coastal environment, placing it under increasing pressure. Effective coastal management and the sustainable use of coastal resources is essential in ensuring a resilient coast for future generations.

The goods and services delivered by KZN coastal ecosystems are a pivotal asset and underpin much of the development potential of the province. Hence, careful management of these resources is critical. Protection of the coastal environment is now entrenched in the National Environmental Management: Integrated Coastal Management Act (28 of 2008), and the ICM Amendment Act (36 of 2017).

In terms of the Constitution, National government is responsible for coastal management and the implementation of the ICM Act, primarily achieved through the development of policies and the promulgation and application of laws. However, much of the implementation responsibility is designated to coastal provinces and accordingly to their next level of local government structures.

DRIVERS

South Africa is signatory to several international agreements which outline requirements and standards to attain. This, coupled with the legislative framework outlined in the ICM Act, drives coastal governance in South Africa. However, coastal governance is complex, not only because it involves many different authorities, but because much of it is a common property resource, it is not 'owned' by the state or any individual. Unfortunately, this often leads to people considering the 'shared' resource for their use, but not taking equal and collective responsibilities in caring for them.

Where resources fall within ocean or international boundaries, rules on the conduct of users can only be implemented through international agreements. Many such agreements exist, for instance MARPOL: the Convention which provides detailed guidance on pollution, waste discharge limits and especially oil pollution. It is important to note that while there is a dedicated legislative framework, coastal management does not take place in a vacuum and there are aspects that need to be considered at a global, regional and national scale (Table 9.1).

Table 9.1: Legislative frameworks at global, regional and domestic scales

Issue	Global	Regional	Domestic
Pollution at sea	International Convention for the Prevention of Pollution from Ships (MARPOL)	The Nairobi Convention	National Environmental Managament Act (NEMA); South African Maritime Safety Authority (SAMSA)
Land-based activities / pollution	Global Programme fo Action (GPA)	The Nairobi Convention	Integrated Coastal Managament Act (ICMA); Integrated Pollution and Waste Management White Paper
Fisheries	FAO; Jakarta Mandate	SWIOFC; IOTC; SADC Protocol	Marine Living Resources Act (MLRA)
Coastal development			Integrated Coastal Managament Act (ICMA)
Protected areas / MPAs		The Nairobi Convention	Protected Areas Act
Species	CITES; TRAFFIC	IUCN; CITES	Biodiversity Act; MLRA
Climate change	The UN Framework Convention on Climate Change (UNFCC)		National climate change response White Paper; ICMA
Wetlands	RAMSAR		
Biodiversity	Convention on Biological Diversity		Biodiversity Act
Sand winning			Mineral Act

PRESSURES

The failure to undertake sound coastal management invariably results in severe pressures on the coastal environment, generally in the form of social pressures, such as in competition for coastal land, or resources such as depleted fish stocks. In response, the implementation of the ICM Act is in fact an attempt to reduce pressures brought about by a range of diverse drivers- local, regional, and global, the application of which aims to reduce these pressures on the overall state of the coastal environment. However, the application of new regulations and legislation can impose different pressures. Some may be short term pain to get long term gain while others may provide instant relief.

STATE

Despite a growing population and an increased human demand for space and resources, and increased economic activities, such as shipping and tourism, the KZN coast remains in a reasonably healthy state. In part, this can be attributed to several structural features of the coast. The powerful (largest in the world by volume) Agulhas Current plays an important role in assimilating land-generated waste. Further, credit must be given to early conservation efforts which, for example, instigated protection of sea turtles and created protected areas (e.g., St Lucia).

Today we can claim to have one of the strongest loggerhead sea-turtle populations; coral reefs protected; coelacanths safe; about 1/3 of our coast fully protected as a World Heritage Site (iSimangaliso Wetland Park) and strong fisheries legislation is helping to recover several stocks. Notwithstanding these positive perceptions of the KZN coast, a deeper investigation reveals that we have collapsed our endemic reef fish stocks, degraded at least 20 out of 76 KZN estuaries with the rest only in marginal condition, and sand winning in vulnerable estuaries remains an issue of great concern. Conflicting mandates such as environmental vs mining, pose major challenges to effective coastal management.

The beautiful KZN coastal zone – sound management is critical for long-term sustainability. *Photo: ORI*

KZN, as with the rest of South Africa, has the legislation to manage these impacts; however, effective implementation is mostly wanting, and in some cases, lacking altogether. Fragmentation of government structures remains a major challenge in effective implementation. This is reflected in poor enforcement and compliance, across the coastal sphere, highlighted in a recent assessment on the status of this legal landscape governing South Africa's coastal marine environment (Taljaard *et al.* 2019).

Numerous examples of failed implementation are an almost daily threat (e.g., Sowman and Malan 2018). This is largely the result of what appears to be a lack of basic understanding of the overall implications, which points to a lack of training, both in the higher provincial structures and the coastal municipalities. This is exacerbated under the current political framework where coastal and environmental governance are unfortunately a lower political priority, than for example, health and the provision of services.

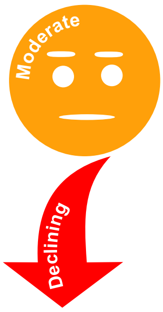
The ICM Act outlines the framework for the establishment of a 'National Coastal Committee' (Working Group 8) which coordinates oceans and coastal management in South Africa. Below this, the Act required the establishment of a Provincial Coastal Committees (PCC), with Municipal Coastal Committees (MCC) being optional, should the local municipality require the oversight role it can provide. The current challenge is that the KZN PCC has been non-operational for several years, with the procedures for its re-establishment turning slowly. Coupled with this, the once established sub-committees, such as the estuaries sub-committee, have fallen away all together. These served a critical gap between science and management.

Coastal Management Programmes and local development planning ensure wise use and biodiversity protection. Estuary zonation plans (considering the EFZ) should also be incorporated into spatial planning by local or district municipalities under the Local Government: Municipal Systems Act (32 of 2000).

IMPACT

Effective coastal management is key to ensuring coastal sustainability. Where coastal management actions fall short, there is a negative impact on coastal resources, ecosystems, properties, and populations, all of which are detailed in this report.

RESPONSE



Coastal management is an integrated process taking into consideration policy, actions, agencies and stakeholders, regarding protection of the coastal environment, the sustainable use of resources and the conservation of biodiversity and habitats. However, the implementation of the ICM Act remains a challenge for KZN (Goble *et al*. 2017), underpinned by a lack of staff and funds available. Coastal monitoring should be integrated horizontally because it requires the participation of government institutions, the private sector, NGOs, academics, scientists, etc.

Improved coastal management for KZN is critical; this requires additional human and financial resources. While this coast still delivers many goods and services, appeals to tourists, and generates jobs, the advent of climate change, growth in tourism and the increased Blue Economy-sponsored industrial development is resulting in increased pressure on the KZN coastal environment. Thus, urgent action is required and improved political will is essential. A key step is the re-establishment of the KZN PCC and technical sub-committees as allowed by the ICM Act.

Data requirements
Coastal management is the overarching theme for governance, and to a large degree needs to speak to all the themes in this report. Relevant legislation, policies and guidelines are needed to facilitate holistic, sustainable management.

9.2 MARINE PROTECTED AREAS

Dr Bruce Mann (ORI) and Tamsyn Livingstone (Ezemvelo KZN Wildlife)

INTRODUCTION

Marine protected areas (MPAs) in South Africa are, by definition, areas of the ocean (which may include the adjacent coast) that have been proclaimed as protected areas in terms of the National Environmental Management: Protected Areas Act (57 of 2003). MPAs are primarily established to protect marine biodiversity and to assist fisheries management by providing a refuge for overexploited stocks and to seed adjacent areas by spillover (Attwood *et al.* 1997a). They can also provide important functions in terms of tourism, scientific research, marine education and offer resilience to climate change (Roberts *et al.* 2017). MPAs range greatly in size and can be zoned from complete no-go, no-take restricted areas to controlled areas where different specified forms of human use are allowed (Edgar *et al.* 2014). KZN has four relatively large MPAs including iSimangaliso (10715km^2), uThukela (4100km^2), Aliwal Shoal (678km^2) and Protea Banks (1191km^2), all of which are zoned for multiple use (Figure 9.1).

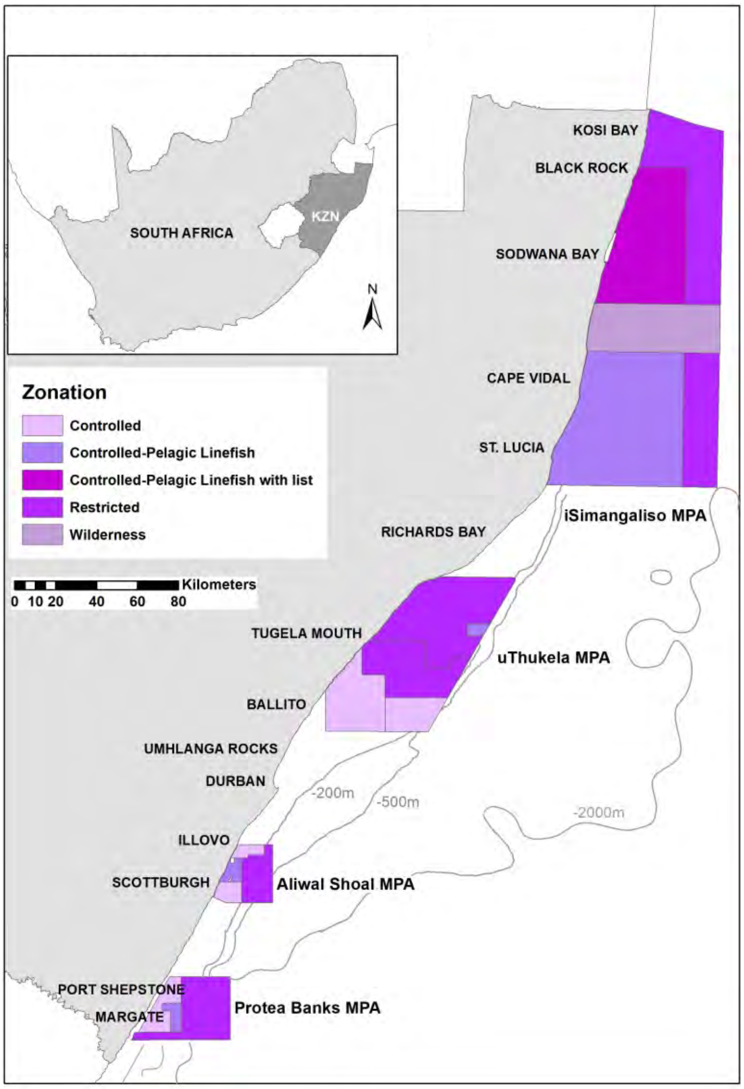


Figure 9.1: Current MPAs and management zones in KZN

DRIVERS

South Africa is a signatory to several international protocols and conventions such as the Convention for Biological Diversity (CBD), the Jakarta Mandate, the World Summit for Sustainable Development (WSSD), etc. (Attwood 1997b). The country is therefore obliged to try to achieve international targets established for biodiversity protection. In addition, the increasing realisation of the value of MPAs is helping to fuel greater efforts to establish more MPAs and ensure their wise management both locally and globally.

Threats to MPAs are ever present and the recent opening of no-take areas within the Tsitsikamma and Dwesa-Cwebe MPAs are stark reminders of some of the challenges facing MPA management in South Africa (Lombard *et al.* 2020).

PRESSURES

The biodiversity of our oceans is under increasing threat from overfishing, pollution, coastal development, climate change and many other anthropogenic activities. MPAs are increasingly being promoted as an effective method of helping to mitigate these threats. Globally, the Aichi Biodiversity Targets were set to encourage maritime nations to protect at least 10% of the world's oceans (in terms of surface area) in MPAs by 2020 (O'Leary *et al.* 2016). Excluding the Prince Edward Islands MPA, South Africa only managed to protect 5. 4% of her exclusive economic zone (EEZ) in MPAs by 2019 (Sink *et al.* 2019). However, more recent research has suggested that a better target would be to protect at least 30% of the world's oceans in MPAs (O'Leary *et al.* 2016). As a nation, South Africa therefore still has a long way to go to achieve this level of protection of its EEZ.

STATE

Historic perspective

Despite not having achieved the Aichi targets by 2020, South Africa still has a proud history of establishing MPAs, with the Tstitsikamma National Park MPA established in South Africa in 1964 (Lombard *et al.* 2020). In KZN the St Lucia Marine Reserve and the Trafalgar Marine Reserve were established in 1979 (Mann *et al.* 1998). This was followed by the Maputaland Marine Reserve (1986) and the Aliwal Shoal MPA (2004). These came about, largely thanks to the foresight of early conservationists in Ezemvelo (then Natal Parks Board) and the Oceanographic Research Institute (ORI). These efforts where further improved by the Coastal and Marine Biodiversity Plan for KZN otherwise known as the SeaPLAN project developed by EKZNW (Harris *et al.* 2012).

To date, management plans have only been implemented for the iSimangaliso and Aliwal Shoal MPAs and monitoring of MPA effectiveness has largely focused on the iSimangaliso MPA, especially in terms of turtles (Nel *et al.* 2013), coral reefs (Schleyer 2000), inshore reef fish (Mann *et al.* 2016a, 2016b) and offshore reef fish (Garratt 1993, Floros 2013, Dames *et al.* 2019).

Current state

The SeaPLAN research has since fed into the Operation Phakisa process and led to the recent (2019) establishment of 20 new Marine Protected Areas (MPAs) for the country. Importantly for KZN, the uThukela and the Protea Banks MPA (2019) were established. Additionally, this process led to substantial increases in size as well as the re-zonation of the St Lucia and Maputaland MPAs (now called the iSimangaliso MPA) and the Aliwal Shoal MPA (RSA 2019). The small Trafalgar MPA was also incorporated into the new Protea Banks MPA.

Together these MPAs cover 16 684km^2 of ocean space offshore of KZN and with the other newly declared MPAs they now protect 5.4% of South Africa's EEZ. While approximately 40% of these MPAs are comprised of no-take restricted areas, most of these fall into the deeper offshore waters, leaving many of the shallower ecosystems and communities still vulnerable to pressures such as fishing. The establishment of these new MPAs has, however, provided a large amount of protection to the marine ecosystems off the KZN coast from more destructive pressures such as offshore mining and trawling.

IMPACT

Establishment of a well-designed and well-managed network of MPAs within the KZN EEZ (and the broader South African EEZ) is critical to the future sustainable development of the province (and the country). Amongst other factors, this will ensure an element of resilience to overfishing and climate change, as well as provide important opportunities for ecotourism, research and education. Without our MPAs, the province would face greatly increased risk from overfishing and habitat destruction (e.g., from activities such as offshore mining and oil and gas exploration), as well as reduced resilience to the imminent threats of climate change. It is thus essential that every effort is made to safeguard our MPAs and to manage them wisely to ensure the greatest benefit to society.

RESPONSE

With KZN already having achieved a well-designed network of MPAs in the provincial EEZ, the focus must now fall on developing and implementing effective management plans for these MPAs and ensuring that the organisations delegated with management responsibility have sufficient capacity to undertake the work required. This must include monitoring programmes to determine MPA effectiveness. This process must be undertaken in full consultation with all

An aerial photograph of the iSimangaliso Inshore Wilderness Zone in the iSimangaliso Marine Protected Area looking south towards Leven Point
Photo: Bruce Mann

relevant stakeholders. However, further efforts should also be made to incorporate more key habitats, especially within shallower inshore ecosystems within existing MPAs, into no-take areas, to increase the levels of full protection. Furthermore, as much of our more tropical marine biodiversity is shared with Mozambique, greater efforts should be made with the Mozambican authorities to ensure strong transboundary collaboration, especially regarding the adjacent Ponto do Ouro and iSimangaliso MPAs.

GAPS

One of the glaring gaps in biodiversity conservation along the KZN coast is the lack of proclaimed estuarine protected areas (EPAs) (Whitfield *et al.* 2020). Estuarine habitats play a critical role in the life cycles of many marine fish and invertebrate species which use them as important nursery areas (Whitfield 1998). Considering the degraded state of many of KZN's estuaries (Harrison and Whitfield 2006; Section 5.1), concerted efforts need to be made to identify and protect healthy, productive estuaries in the province.

Data Requirements

When establishing an MPA it is important to realise that not just any section of ocean and/or coast will do. A much more effective approach is to plan a rational network of MPAs to maximise marine biodiversity protection and at the same time minimise costs. This requires a substantial amount of data, both in terms of mapping marine biodiversity (including habitats, species distributions and processes) as well as determining spatial threat/cost layers. Software such as MARXAN can then be used to determine Critical Biodiversity Areas (CBAs) using an iterative approach (Lagabrielle *et al.* 2018). While this has been done for much of the South African EEZ (Sink *et al.* 2019), there is still much refinement required and ground-truthing is needed where biodiversity surrogates have been used (Livingstone 2018). Once an MPA has been established following the required public participation process, then a rational management plan needs to be implemented to ensure that the MPA achieves its set objectives and does not simply become a “Paper Park”. Part of the management plan should include a well-designed monitoring programme to help measure MPA effectiveness (Pomeroy *et al.* 2004).

10 CONCLUSIONS

Durban's Golden Mile
Photo: Kierran Allen

CHAPTER 10: CONCLUSIONS

CONCLUSIONS

Dr Bronwyn Goble (ORI)

SUMMARY

This State of the Coast Report presents key findings relating to the state of the KZN coastal zone, according to seven main themes: overarching, climate variability, coastal environment, marine environment, economic environment, human environment and governance. Several cross-cutting issues can be identified which may have the potential to greatly disrupt the normal processes. Examples include climate change, coastal sand winning, oil and gas exploration and changes in human settlements. In addition, possible emerging issues, such as water quality and new diseases relating to mariculture and mining operations may be encountered.

The development of this SOC report allows for the identification and prioritisation of management interventions towards sustainability in the coastal zone. Priority actions are targeted at specific issues so that KZN will best meets its obligations in terms of the ICM Act and the Provincial Coastal Management Programme (CMP). These key actions are outlined in Table 10.1. The actions detailed speak to the impacts and state of the seven spheres and should be considered in the development of coastal management and monitoring programmes going forward.

Table 10.1: Summary of state, trend and actions for the KZN coast.

			Outlook		
Sphere	Topic		State	Trend	Key Actions
OVERARCHING DRIVERS	The Blue Economy	The Blue Economy	Moderate	Improving	• Review of Operation Phakisa: 2014 Ocean's Economy programme. • Introduction of cleaner energy alternatives. • Evaluate viability to desalinate sea water for use on land.
	Human Settlements	Human Settlements	Moderate	Stable	• National imperatives are the provision of housing, water and sanitation - these need to be carefully managed to ensure impacts on the receiving natural environment are minimised.
	Pollution	Pollution	Poor	Declining	• Improve development and maintenance of sewerage infrastructure. • Re-instituting the Green Drop programme – will ensure systems in place to monitor wastewater treatment works. • Regular, systematic monitoring of receiving waters. • Marine laboratory capability must be improved. • Litter boom projects and litter clean-ups are important. • Paradigm shifts regarding waste: in the way we generate, dispose and accept responsibility for solid waste.

			Outlook		
Sphere	Topic		State	Trend	Key Actions
CLIMATE VARIABILITY	Climate Change		Moderate	Stable	• Determine a preliminary risk assessment of sea-level rise related impacts for KZN. • The risk lines associated with scenarios of sea-level rise, that inform the CMLs, are important.
	Extreme Events		Moderate	Stable	• Monitoring system for early warning of weather / storm events. • Stricter development controls: reduce the number and value of buildings and non-essential infrastructure. • Shoreline management plans (reports) implemented by all municipalities. • Investigate sand replenishment methods.
	Oceanographic Events		Moderate	Stable	• Long term in-situ observations of the Agulhas Current are needed to better understand its behaviour and its response to anthropogenic climate change (This could be a student project).
COASTAL ENVIRONMENT	Sandy Shores		Moderate	Declining	• Municipalities need to restore and maintain coastal ecological infrastructure. • Re-establish natural sand supplies to the coast to replenish sand-starved beaches (where possible). • Identify ecological or biological indicators that monitor beach health in addition to the physical metric of coastal development and other landcover change.
	Swamp Forests		Poor	Declining	• A report on Swamp Forest cover should be tracked through focused monitoring that quantifies change in habitat area and species composition. • A report on factors driving change, such as those related to human activities, should be incorporated to identify cause-effect relationships. • Education and awareness can be improved: signboards at all sites and citizen science participation to ensure ownership and protection (possibly through a student project).
	Rocky Shores		Moderate	Declining	• Improved management of rocky shore subsistence fisheries is needed. • Management interventions are needed at Isipingo: wastewater effluent and increased plastic pollution are affecting rocky shore communities. • Long-term monitoring at rocky shore sites is required – report on status, use, compliance annually. • Biomonitoring is required to monitor indicator species for water quality and heavy metal pollution.
	Coastal Lakes		Poor	Declining	• A strategic conservation plan for coastal lakes needs to be developed and adopted. • A protocol for developing Lake Management Plans (comparable with EMPs) must be established. • Identify and protect buffer areas around lakes (such as the EFZ and CMLs). • Address compliance and enforcement, which at present is weak. • Environmental water requirement studies for coastal lakes. • Systematic monitoring of lakes needed to consider a wide range of factors.
	Wetlands		Poor	Declining	• The 500 m buffer needs firm enforcement and extension where needed – status report and compliance needed. • Reports on groundwater are required to better map groundwater compartments and determine accurate water budgets.
	Coastal Vegetation		Poor	Declining	• The CBD targets should be implemented, particularly target 5 (by 2025), which requires extensive governmental interaction across all sectors and stakeholders. • CBD targets adopted, remaining vegetation types identified and documented. • Protected Area expansion should occur in vegetation types that are not adequately protected.

			Outlook		
Sphere	Topic		State	Trend	Key Actions
ESTUARINE ENVIRONMENT	Estuaries		Poor	Declining	• Compliance is inadequate and enforcement with legislation is poor. • The Ecological Water Requirements (EWR) and estuarine flow requirements for KZN estuaries are a priority. • All existing discharges to estuaries should comply with the provisions of the ICM and the National Water Acts. • Estuary Working Group to be established to provide scientific and technical support to committees that report to national structures. • Seventy percent of KZN estuaries do not have plans for formal management – authorities need to act. • "Protocol for Requests to Breach Estuary Mouths in KZN: Mouth Maintenance Management Plans" needs to be implemented effectively. • New developments should be set well back from the EFZ, also to mitigate against the climate change risks of flooding and sea level rise and should consider the CMLs. • Water quality monitoring under the National Estuarine Monitoring Programme (NEsMP) of the Department of Water and Sanitation established in 2008 must be re-initiated.
	Mangroves		Poor	Declining	• Protection of existing stands of mangroves – regular reporting on status, diversity, blue carbon. • Research is needed to quantify the importance of our mangrove ecosystems as blue carbon sinks. • Specific local conservation actions - e.g., mouth management plan and freshwater baseflow allocation to Mlalazi Estuary. • All mangrove habitats in KZN should be considered critically endangered ecosystems and managed accordingly.
	Submerged Macrophytes		Poor	Declining	• Status of submerged macrophytes documented - track the health and survival of submerged macrophytes (Kosi, St Lucia, uMhlathuze and uMgobezeleni estuaries). • Restoration efforts must focus on establishing riparian buffer zones, maintaining normal marine connectivity and control nutrient input (plans to be approved by EDTEA).
MARINE ENVIRONMENT	Coral Reefs		Moderate	Declining	• Monitoring of proposed indicator organisms and trends in the levels of the OCPs to arrive at sensible responses to and mitigation of this pollution. • Greater enforcement and compliance and an improved system of closed sanctuaries. • International adherence to IPCC recommendations to mitigate climate change. • Report on overall management plan including OCP, DDTT, compliance and IPCC recommendations.
	Rocky Reefs		Moderate	Stable	• Ongoing invertebrate catch statistics monitoring - provides background information on trends and informs management recommendations to ensure their sustainable harvest. • Research needed for long-term monitoring of the marine invertebrate resources.
	Soft Sediments		Moderate	Declining	• Improving foundational biodiversity knowledge of smaller invertebrates. • Detailed mapping of physical features, sediment distribution and soft-sediment habitats to inform Critical Biodiversity Area (CBA) maps. • Support new generations of marine taxonomists. • Fluvially-dependent marine sediment ecosystems must receive vital quantities and good quality of freshwater. • Cross-sector and cross-realm plans need to be developed and consider the coast-marine connectivity. • Fisheries management plans for fishing in soft-sediment habitats. • Climate change impacts: strategy for detecting and monitoring change. • Awareness campaigns to communicate KZN's soft sediment biological assets and value are needed.

Sphere	Topic		Outlook: State	Outlook: Trend	Key Actions
MARINE ENVIRONMENT	Pelagic Environment		Moderate	Stable	• Annual detailed report on pelagic landings, marine mammal monitoring, turtle nesting and other vulnerable species. • Research into the understanding of the Agulhas Current. • Long-term in situ monitoring, remote sensing and improved ocean models.
	Coastal Access		Moderate	Stable	• Municipalities to report on status of coastal access. • Provincial government to assist local municipalities with monitoring and regulating coastal access.
HUMAN ENVIRONMENT	Small-scale Fisheries		Poor	Declining	• Government needs to provide sufficient management capacity to effectively support and manage the SSF. • Effective monitoring programme to understand impact of harvesting by SSF communities on targeted resources.
	Recreational Fishing		Moderate	Stable	• Ensure the health of fish and invertebrate populations by protecting key habitats. • Improve angler awareness and compliance – marketing strategy developed and implemented. • KZN-MPAs need to have proper management plans. • A well-designed angler awareness programme is required to ensure that anglers understand the rationale behind fishing regulations and to ensure improved compliance.
	Boat-based Activities		Moderate	Stable	• The KZN BLSMS should be maintained. • The number of scuba diving operators permitted within MPAs should be managed based on the capacity of diving reefs. • Permit fees from both the diving operators and diving information documented – annual report.
ECONOMIC ENVIRONMENT	Ports & Shipping		Moderate	Improving	• Environmental management plan for ports is available and should be supported. • Issues related to pollution are being addressed through the ICCMSBW and the South African drafted Ballast Water Management Bill (2013).
	Tourism		Moderate	Improving	• A achievable target for KZN tourism is keeping the number of KZN's Blue Flag beaches (Blue flag inventory). What requires careful management is the provision of additional services such as ablution and parking facilities. • Coastal tourism strategy report and public awareness campaigns are needed.
	Aquaculture		Moderate	Stable	• South Africa's current environmental legislation is sufficient to manage the aquaculture sector. • Provision must be made to incorporate better management practices as pressure increases to develop the sector in KZN. • Effective monitoring of operations will be key to growing the KZN aquaculture sector in an environmentally sustainable manner (Review and update past reports).
	Agriculture		Moderate	Stable	• Future growth of the Agri-business sector needs to be managed to ensure long-term sustainability and reduced impacts on the natural environment. • Land reform is a key factor to be addressed in terms of agricultural lands. • Diversification in farming is critical. • A broader approach to agriculture by fostering the small-scale farming sector through strengthened technical support is needed. • A report on small scale farming supported as a viable alternative needed.
	Manufacturing & Industry		Moderate	Improving	• The department responsible for Economic Development has endeavoured to develop industry-oriented interventions to stimulate the local economy. Report on developing IEH as a way of driving industrial development throughout KZN – this needs to consider the needs of the receiving environment.

			Outlook		
Sphere	**Topic**		**State**	**Trend**	**Key Actions**
ECONOMIC ENVIRONMENT	Commercial Fishing		Poor	Declining	• The recent promulgation of MPAs provides reasonable protection for several marine ecosystems. • Inadequate compliance and monitoring of commercial fisheries generally – requires an annual report.
	Coastal Dune Mining		Moderate	Stable	• Monitoring and enforcement of this legislation remains key. • To unlock the post-extraction, downstream value chain of titanium, there needs to be significant investment into research and development facilities (Review and prospects).
	Sand Mining		Poor	Declining	• Clarity over management of environmental best practice, responsibility and enforcement of remediation of sites. • Environmental best practice should be adopted and after mining, remediation of the site should be enforced. • Consistent environmental monitoring is required. • Detailed quantitative investigations are required on the biophysical effect of sand mining in the local context.Increased public awareness - develop media campaigns. • Detailed mining inventories are required - to inform the scale of mining pressure on aquatic coastal systems. • Technical report on sustainable alternative materials for use in industry and construction.
	Offshore Mining		Moderate	Declining	• National protocols and procedures finalised (Green Paper).
	Oil & Gas Exploration		Moderate	Declining	• Ongoing efforts to improve legislation and regulations pertaining to offshore hydrocarbon minimisation and green products are required. • Needs to be a phase-out of all fossil fuel usage. In keeping with the Paris Agreement, to limit warming to 1.5-2°C. • There should be no new developments aimed at hydrocarbon extraction; to negate the knock-on effects of extraction.
GOVERNANCE ENVIRONMENT	Coastal Management		Moderate	Declining	• Improved coastal management for KZN is critical – this requires additional human and financial resources. • Develop a marketing plan to ensure stronger advocacy - urgent action is required and improved political will. • Re-establishment of the KZN PCC and technical sub-committees is imperative.
	Marine Protected Areas		Good	Improving	• The focus must be on developing and implementing effective management plans. • Monitoring programmes to determine MPA effectiveness.

ACTIONS & WAY FORWARD

It is critical that this SOCR leads to action. Some focus areas which should be considered in conjunction with the KZN Coastal Management Programme are as follows:

1. GOVERNANCE

Human and financial resources are critically needed to improve coastal management and the management of critical ecosystems within KZN. Funds need to be made available for building capacity for critically under-resourced and under-skilled areas such as marine laboratory personal and training for the next generation of marine scientists and managers.

Current governance frameworks are under-resourced. Greater enforcement of legislation is important in improving overall governance and compliance. Additionally, governance frameworks need to be clear: who is responsible for management, inspection, and enforcement. National protocols and procedures must be put in place to ensure that due process and international best practice is followed. Provision must be made to incorporate better management practices as pressure increases to develop the sector in KZN.

Management plans need to be developed in accordance with the ICM Act, however greater attention and funding needs to be given to compliance and enforcement of these plans. Of critical importance is that the KZN PCC and sub-working groups need to be re-established. These bodies can guide, advise and provide scientific support for the implementation of such plans for the KZN province.

2. AWARENESS AND EDUCATION

Awareness, education, and knowledge sharing are critically important to improving the overall understanding as to the value of the coastal environment, its ecosystems, and resources. There are several ways to accomplish this, such as signage at key sites, training on topics relating to legislation and policy; but importantly we need to instill change in the thinking around our coastal environment, its resources, and our impact on this environment. There needs to be a paradigm shift as to the way we generate, dispose and accept responsibility for solid waste. Awareness campaigns also need to highlight specific coastal ecosystems and their value, such as coastal lakes, estuaries, soft-sediments, mangroves, sandy shores etc.

3. PLANNING

Climate change projections highlight increased risk for coastal areas, thus planning for future risk through the determination and enforcement of CMLs for the coast and estuaries is imperative in reducing risk to infrastructure and properties. The implementation and enforcement of this, while challenging, is critical and any new developments need to comply with CMLs and buffer zones. Additionally, new developments need to consider process linkages and biological connectivity of coastal and marine ecosystems. Many coastal ecosystems require detailed mapping to ensure better long-term management and spatial planning.

Measures to replenish sand need to be critically assessed and implemented, both coastal and marine ecosystems are being adversely affected by the quantities and quality of sediment removed. Where possible, natural sand supplies should be reinstated and better maintained, while in their absence alternatives need to be considered, planned and budgeted for. Importantly, authorities need to take urgent action against illegal sand mining operations.

4. MAINTENANCE OF INFRASTRUCTURE

Coastal areas are being adversity affected by poorly managed infrastructure daily. Examples include failing sewage infrastructure and collapsing shore defence measures. It is therefore imperative that resources be allocated to the development and maintenance of infrastructure. Importantly, waste removal services to coastal communities need to be improved and existing discharges to estuaries need to be improved to comply with the provisions of the ICM and the National Water Acts.

5. LONG-TERM MONITORING

Long-term monitoring is critical for better understanding the state of, and changes to coastal ecosystems and resources. It is important that authorities allow financial resources for long-term monitoring. Core monitoring highlighted in this report include (but not limited to):

- Monitoring of rocky shores to identify status and trends.
- Monitoring key estuaries to track the health of submerged macrophytes.
- Monitoring of levels of OCPs pollution.
- Monitoring of indicator species for water quality and heavy metal pollution.
- Monitoring to determine MPA effectiveness.
- Monitoring of harvesting by SSF communities to manage targeted resources.
- Monitoring invertebrate catch statistics.
- Monitoring of swamp forest cover to quantify change in habitat area and species composition.
- Monitoring of commercial fisheries compliance needs to be increased.
- Monitoring and regulating coastal access are needed.
- Monitoring of estuaries is required, including health status, extent and distribution of habitats, alien species, indigenous species, resource species.
- Monitoring wastewater treatment works, via re-instituting the Green Drop programme is critical. Regular, systematic monitoring of receiving waters should also be performed.
- Long-term insitu observations, remote sensing and improved ocean models of the Agulhas Current are needed.
- Systematic monitoring of lakes is required and needs to consider a wide range of factors.
- The KZN BLSMS should be maintained to ensure ongoing monitoring of boat launching activities.

GLOSSARY
SCIENTIFIC NAMES
REFERENCES

Fisherman enjoying KZN coastal zone
Photo: Kierran Allen

GLOSSARY
SCIENTIFIC NAMES
REFERENCES

GLOSSARY

Acroporidae: Staghorn corals, a family of stony corals.

Agulhas Current: This is the western boundary current of the southwest Indian Ocean, flowing south along the east coast of Africa.

Aitchi Biodiversity Targets: Provides stakeholders with a quick set of guidelines to the 20 main biodiversity conservation targets.

Anoxic: Deficient in oxygen.

Apartheid: A policy of racial segregation that existed in South Africa until the early 1990s.

Benthic: Associated with the seafloor, either sessile (attached) organisms or moving close to the bottom.

Bioprospecting: The search for, and use of, plant and animal species from which biochemicals can be extracted and processed for commercial use.

Blue Carbon: Carbon captured by the ocean and coastal ecosystems across the world.

Blue Economy: The sustainable use of ocean resources for economic expansion while maintaining the health of marine and coastal ecosystems.

Calcareous epiphytes: Plant or animal organisms that secrete a calcareous skeleton and that for most of its life is attached to the living outer tissues of the plant.

Climate Change: Climate change includes both the global warming caused by humans, and its impacts on Earth's weather patterns.

Coastal reed-bed wetlands: Wetlands dominated by a perennial, flood-tolerant grass that grows to over 2 m high.

CoastKZN: An interactive web-based information portal which aims to inform and share knowledge about the KZN coastal and estuarine environments.

Coral Bleaching: A process where corals become white due to stressors such as changes in temperature, light, or nutrients.

Covid-19: An international pandemic caused by and infectious virus (SARS-CoV-2) that results in moderate to severe respiratory disease.

Detritus: Dead particulate organic material from dissolved organic material.

Eelgrass: Seagrass that grows in temperate waters often forming extensive underwater meadows.

Estuarine Functional Zone (EFZ): An area in and around an estuary which includes the open water area, estuarine habitat, and the surrounding floodplain area. It is a spatial delineation and sensitive area requiring environmental authorisation for developments.

Homeland: Areas to which most of the black South African population were moved during the Apartheid era to restrict them from living in urban areas.

Humic: The by-product of decaying organic matter.

Hydroperiod: The period in which a soil area is waterlogged.

Ice ages: A long period in which the Earth's surface and atmosphere decreased in temperature resulting in the presence or expansion of continental and polar ice sheets and alpine glaciers.

Indian Ocean Coastal Belt (IOCB): A region of coastal dunes and coastal grassy plains in KwaZulu-Natal and the Eastern Cape.

Intertidal: The area above the water level at low tide and underwater at high tide (area within the tidal range).

IUCN Red List of Ecosystems: A global framework for monitoring and identifying ecosystems most at risk of biodiversity loss

Jakarta mandate (Marine and coastal biological diversity): A global consensus on the importance of marine and coastal biological diversity.

Lacustrine: Formed living in or growing in lakes; sedimentary deposits formed at the bottom of ancient lakes.

Lentic systems: non-flowing waters (closed systems).

Littoral drift: The movement of sand and silt along the coast, driven by waves and currents.

Macrophytes: Aquatic plants large enough to be seen by the naked eye.

Maputaland Coastal Plain: A natural region of Southern Africa located in the northern part of the KZN Province.

Millennial Development Goals: Eight goals that UN Member States have agreed to try to achieve by the year 2015.

Nairobi Convention: A partnership between governments, civil society and the private sector working towards a prosperous Western Indian Ocean Region with healthy rivers, coasts, and oceans.

Operation Phakisa: A South African government initiative designed to fast track the implementation of the Oceans Economy to find solutions on critical development issues highlighted in the National Development Plan.

Pelagic: Living or occurring in the open sea.

RAMSAR Convention: An international treaty for the conservation and sustainable use of wetlands.

Sea-level rise: An increase in the level of the world's oceans.

Sediment transport process: A process that moves sand along the shoreline and creates the distinctive sandy beaches along the KZN coast.

Source-to-Sea Initiative: A DFFE programme that focuses on managing sources of litter, particularly from catchments that are upstream which transport litter into the ocean and coastal areas through rivers and tributaries.

Submerged macrophytes: Aquatic plants growing below the water surface.

Subtidal: Part of the zone lying below the low-tide mark but still shallow and close to shore.

Sustainable Development: An organising principle for meeting present human development goals without compromising the present and future integrity and ability of natural systems to provide the natural resources and ecosystem services on which the economy and society depend.

Sustainable Development Goals: A set of interconnected global goals set up by the UN General Assembly in 2015, intended to serve as a blueprint for achieving a sustainable future for all.

Teal carbon: Fresh-water, non-tidal ecosystems, which can have carbon sink capacity.

Total allowable effort (TAE): A measure that specifies the maximum level of fishing effort that can be applied to a fish stock during a specific period, agreed to by fishery managers to achieve certain objectives.

Transnet: South African rail, port and pipeline company which runs operations in railways and harbours.

Zooplankton: A diverse group of animals found in oceans, bays, and estuaries.

SCIENTIFIC NAMES

*Acanthaster planci***:** Crown-of-thorns starfish

Aprion virescens: Green jobfish

Argyrosomus japonicus: Dusky kob

Avicennia marina: White mangrove

Barringtonia racemose: Powderpuff tree (protected tree)

Bruguiera gymnorhiza: Black mangrove

Ceratophyllum demersum: Hornwort

Ceriops tagal: Indian mangrove

Charonia tritonis: Giant triton

Cheimerius nufa: Santer

Chromalaena odorata: Chromolaena is one of the most invasive alien shrubs

*Chrysoblephus anglicus***:** Englishman

Chrysoblephus puniceus: Slinger

Codium platylobium: Macroalgae (Chlorophyta)

Colocasia esculenta: Taro, amadumbes

Corbicula fluminea: Invasive mollusc

Coryphaena hippurus: Dorado

Cymatoceps nasutus: Black musselcracker

Cyprinus carpio: Carp

Ctenopoma multispine: Many-spined climbing perch

*Diplodus sargus capensis***:** Blacktail

Drupella spp.: Predacious gasteropod snail

Epinephelus tukula: Potato grouper

Fenneropenaeus indicus: Marine white prawn

Ficus trichopoda: Swamp fig (protected tree)

Hibiscus tiliaceaus: Coast hibiscus,

Halodule universis: A species of seagrass in the family Cymodoceaceae

Hyperolius pickersgilli: Pickersgill's reed frog (endangered)

Juncus kraussii: Nceme grass

Kraussillichinus kraussi: Sand prawn

Lantana camara: Tickberry

Lethrinus scoparious: Natal emperor

Lichia amia: Garrick/leervis

Lumnitzera racemosa: Tonga mangrove

Macrobrachium rosenbergii: Brackish/freshwater prawn

Microctenopoma intermedium: Blackspot climbing perch

Micropterus spp.: Bass

Micropterus salmoides: Largemouth bass (introduced)

Microsorum punctatum: Fishtail Fern

Najas horridam, N.marina: Aquatic plants - Najadaceae

Nephrolepsis biserrate: Giant sword fern

Nymphaea nouchali var. *caerulea:* Water lily

Oreochromis mossambicus: Mozambique tilapia

Panulirus Homarus: Spiny lobster

Penaeus monodon: Tiger prawn

Pereskia: Spanish gooseberry

Perna perna: Brown mussels

Petrus rupestris: Red steenbras

Phragmites spp.: Reeds

Pistia stratiotes: Water lettuce

Poecilia reticulata: Guppy

Polysteganus undulosus: Seventy-four

Pontederia crassipes: Water hyacinth

Pomadassys commersonnii: Spotted grunter

Pomatoleios kraussi: blue coral worm (Annelida)

Pomatomus saltatrix: Shad/elf

Potamogeton sweinfurthii: Pondweed - Potamogetonaceae

Pterygoplichthys disjunctivus: Vermiculated sailfish catfish

Pyura stolonifera: Red bait

Raphia australi: Giant raffia palm

Rhizophora mucronata: Red mangrove

Ruppia cirrhosa: Spiral tasselweed

Salmo trutta: Brown trout

Salvinia molesta: Kariba weed

Sarcophyton glaucum: Rough leather coral

Sarpa salpa: Karanteen/strepie

Scirpus spp.: Reeds

Scomberomorus commerson: King mackerel/cuda

Scomberomorus plurilineatus: Queen mackerel

Silhouettea sibayi: Barebreast goby (endemic, endangered)

Sinularia gravis: Leather coral (a soft coral)

Spirodela polyrrhiza: Common duckweed

Stenoclaena ternifolia: African climbing fern

Striostrea margaritacea: Cape rock oysters

Stukenia pectinate: Sago pondweed

Syzygium cordatum: Water berry

Tarebia granifera: Invasive gasteropod

Theonella swinhoei: Swinhoe's Sponge

Thunnus albacares: Yellowfin tuna

Tridacna spp.: Giant Clams

Typha spp.: Reeds

Utricularia spp.: Bladderworts- carnivorous plants

Varuna litterata: Catadromous paddler crab

Voacanga thouarsii: Wild frangipani - Apocynaceae

Xiphophoraus helleri: Swordtails

Xylocarpus granatum: Cannonball mangrove

Zostera capensis: Dwarf eelgrass

REFERENCES

CHAPTER 1: INTRODUCTION & BACKGROUND

Celliers, L., Breetzke, T., Moore, L. and Malan, D., **2009.** *A User-friendly Guide to South Africa's Integrated Coastal Management Act.* The Department of Environmental Affairs and SSI Engineers and Environmental Consultants. Cape Town, South Africa, 100 pp.

Creel, L., **2003.** *Ripple Effects: Population and Coastal Regions, Making the Link*. Population Reference Bureau, Washington, DC, 8 pp.

DEA (Department of Environmental Affairs) and Royal Haskoning, **2017.** *An updated user-friendly guide to South Africa's Integrated Coastal Management Act. Department of Environmental Affairs, Cape Town, South Africa,* 138 pp.

DEA (Department of Environmental Affairs), **2014.** *The National Coastal Management Programme of South Africa.* Cape Town, South Africa, 313 pp.

Kristensen, P., **2004**. *The DPSIR Framework.* Paper presented at the workshop on a comprehensive / detailed assessment of the vulnerability of water resources to environmental change in Africa using river basin approach, 27-29 September 2004. Nairobi, Kenya.

EDTEA (Department of Economic Development, Tourism and Environmental Affairs), **2019**. *KwaZulu-Natal Coastal Management Programme.* KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs, Pietermaritzburg.

DAEA&RD (Department of Agriculture, Environmental Affairs and Rural Development), **2010.** *KwaZulu-Natal State of the Environment Report 2004.* KwaZulu-Natal Provincial Government, Pietermaritzburg.

Preston-Whyte, R.A. and Tyson, P.D., **1988.** *The Atmosphere and Weather of Southern Africa*. Oxford University Press, Cape Town.

CHAPTER 2: OVERARCHING DRIVERS

2.1 THE BLUE ECONOMY

Bertazzo, S., **2018**. *What on Earth is the 'blue economy'?* Online: https://www.conservation.org/ blog/what-onearth-is-the-blue-economy [Accessed 23 November 2021].

Bok, A., **1998.** *Ornamental fish culture – Phase 1. Final report. In*: Oceanographic Research Institute. Research during the period April 1997 to March 1998. ORI Unpublished Report 153, Oceanographic Research Institute, 49-50.

Commonwealth of Nations, **2021**. Blue Economy. Commonwealth of Nations. Online: https://thecommonwealth.org/blue-economy [Accessed 23 November 2021].

FAO (Food and Agriculture Organization), **2020**. The State of World Fisheries and Aquaculture 2020. Online: The State of World Fisheries and Aquaculture 2020 (fao.org) [Accessed 13 October 2021].

Goble, B.J., **2014**. Sand Mining in Estuaries*. In*: Goble, B.J., van der Elst R.P. and Oellermann, L.K., (eds.). *Ugu Lwethu – Our Coast: A profile of coastal KwaZulu-Natal.* KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs and the Oceanographic Research Institute, Pietermaritzburg, 202 pp.

United Nations, **2015.** Conserve and sustainably use the oceans, seas and marine resources for sustainable development. UN Department of Economic and Social Affairs: Sustainable Development. Goal 14 | Department of Economic and Social Affairs (un.org)

United Nations, **2021.** *Diving into the blue economy*. United Nations, Department of Economic and Social Affairs. Online: www.un.org/en/desa/diving-blue-economy [Accessed 23 November 2021].

Van der Elst, R.P. and Goble, B.J., **2014.** The Coastal Economy**.** *In*: Goble, B.J., van der Elst R.P. and Oellermann, L.K., (eds.). *Ugu Lwethu – Our Coast: A profile of coastal KwaZulu-Natal*. KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs and the Oceanographic Research Institute, Pietermaritzburg, 202 pp.

World Bank and United Nations Department of Economic and Social Affairs, **2017.** *The Potential of the Blue Economy: Increasing Long-term Benefits of the Sustainable Use of Marine Resources for Small Island Developing States and Coastal Least Developed Countries.* World Bank, Washington DC.

WWF (The Worldwide Fund for Nature), **2018.** *Principles for a sustainable Blue Economy. WWF Policy* document, 5 pp. Principles for a Sustainable Blue Economy | WWF (panda.org)

WWF (The Worldwide Fund for Nature), **2020.** What a 'blue economy' really is – WWF's perspective. Online: https://www.panda.org/wwf_new/?249111/ What-a-blue-economy-really-is [Accessed 23 November 2021].

2.2 HUMAN SETTLEMENTS

Agardy, T. and Alder, J., **2005.** Coastal systems. *In:* Hassan, R., Scholes, R. and Ash, N., (eds.). *Ecosystems and Human Well-Being: Current Status and Trends.* Island Press, Washington DC, 513-549.

Beater, B.E. and Maud, R.R., **1963.** The Occurrence of a Coastal Midden near Umhlanga Rocks, Natal. *The South African Archaeological Bulletin*, **18**, (69), 21-23. Online: www.jstor.org/stable/3887491 [Accessed 25 August 2021].

DAEA & RD (Department of Agriculture, Environmental Affairs and Rural Development), **2010.** *KwaZulu-Natal State of the Environment Report 2004*. KwaZulu-Natal Provincial Government, Pietermaritzburg.

DEA (Department of Environmental Affairs), **2012**. *2nd South Africa Environment Outlook.* A report on the state of the environment. Department of Environmental Affairs, Pretoria, 328 pp.

DEA (Department of Environmental Affairs), **2016.** *State of the Oceans and Coasts around South Africa 2015 Report Card.* Report No. 15. RP348/2016. Department of Environmental Affairs, Pretoria, South Africa.

DEA & DP (Western Cape Department of Environmental Affairs and Development Planning), **2018**. *State of Environment Outlook Report for the Western Cape Province 2014-2017*. Cape Town, South Africa.

Du Plessis, C. and Landman, K., **2002**. *Sustainability Analysis of Human Settlements in South Africa*. CSIR, Pretoria, South Africa, 133 pp.

EDTEA (Department of Economic Development, Tourism and Environmental Affairs), **2017.** *KZN Environmental Outlook Report 2017.* KZN Department of Economic Development, Tourism and Environmental Affairs, 235 pp.

Guy, D., **2021**. Looting, fires, poison, lagoon, IOL. Online: https://www.iol.co.za/ios/news/looting-fires-poison-lagoon-f1d40665-670d-4bbe-9063-e2b4033b7df7 [Accessed 24 November 2021].

Horwitz, L., Maggs, T. and Ward, V., **1991.**Two shell middens as indicators of shellfish exploitation patterns during the first millennium AD on the Natal north coast. *Natal Mus J of Humanities,* **3**, 1-28 pp.

IUCN (International Union for Conservation of Nature), **2007**. *Percentage of total population living in coastal areas, sustainable development indicators – methodology sheets*. Online: www.un.org/esa/sustdev/natlinfo/indicators/methodology_sheets/oceans_seas_coasts/pop_coastal_areas.pdf [Accessed 09 February 2022].

Le Roux, A., **2014**. *Iron Age fauna from Sibudu Cave, KwaZulu-Natal, South Africa.* MSc Dissertation. School of Geography, Archaeology and Environmental Studies, Faculty of Science University of the Witwatersrand, Johannesburg, South Africa.

Marean, C.W., **2010.** Pinnacle Point Cave 13B (Western Cape Province, South Africa) in context: The Cape Floral kingdom, shellfish, and modern human origins. *Journal of Human Evolution,* **59** (2010), 425-443.

Mc Granahan, G., Balk, D. and Anderson, B., **2007**. The rising tide: Assessing the risks of climate change and human settlements in low elevation coastal zones. *Environment & Urbanization* (International Institute for Environment and Development: IIED), **19**(1), 17-37.

Mukheibir, P. and Ziervogel, G., **2006.** *Framework for adaptation to climate change in the City of Cape Town* (FAC4T). City of Cape Town.

Ndegwa, D., Horner, D. and Esau, F., **2004**. *The links between migration, poverty and health: Evidence from Khayelitsha and Mitchell's Plain.* Centre for Social Science Research (CSSR) Working Paper No. 73. UCT.

ORI (Oceanographic Research Institute), **2013.** *Southern African Marine Linefish Species Profile*, Special Publication No. 9.

ORI (Oceanographic Research Institute), **2015.** *Offshore fisheries of the South-west Indian Ocean: their status and impact on vulnerable species.* Van der Elst, R. and Everett, B. (eds.), Oceanographic Research Institute and the Western Indian Ocean Marine Sciences Association (WIOMSA).

Schoute-Vanneck, C.A. and Walsh, R.C., **1959.** The Shell Middens at the Ingane River Mouth, Natal South Coast. *The South African Archaeological Bulletin*, **14**(54), 43-55. Online: www.jstor.org/stable/ 3886636 [Accessed 25 August 2021].

Schoute-Vanneck, C.A., **1958.** The Shell Middens on the Durban Bluff. *The South African Archaeological Bulletin,* **13**(50), 43-54. Online: www.jstor.org/stable/ 3886895 [Accessed 25 August 2021].

Small C. and Nicholls R.J., **2003**. A global analysis of human settlement in the coastal zones. *Journal of Coastal Research*, **19**(3), 584-599.

Stats SA (Statistics South Africa), **2006**. *Mid-year population estimates, South Africa 2006.* Statistical release P0302, Stats SA, Pretoria.

Stats SA (Statistics South Africa), **2016a**. *Community Survey 2016. Statistical Release P0301*, 107 pp., Stats SA, Pretoria.

Stats SA (Statistics South Africa), **2016b.** GHS Series Volume VII, Housing from a human settlement perspective. In-depth analysis of the General Household Survey data 2002–2014. Statistics South Africa, Pretoria.

Stats SA (Statistics South Africa), **2020**. *Statistical Release P0302:* Mid-year population estimates 2019. www.statssa.gov.za/publications/P0302/P03022019.pdf

Tibbetts, J., **2002**. Coastal Cities: Living on the edge. *Environmental Health Perspectives*, 110, 11.

Tongaat Hulett, **2018.** *Cornubia. Building Tomorrow*. Online: https://cornubia.co.za/ [Accessed 04 February 2022].

UN Atlas of the Oceans, **2016**. *Human Settlements on the Coast*, UN atlas of the oceans. Online: http://www.oceansatlas.org/subtopic/en/c/11/ [Accessed 24 November 2021].

UNEP, **2006.** *Marine and coastal ecosystems and human well-being: A synthesis report based on the findings of the Millennium Ecosystem Assessment*. UNEP, 76 pp.

United Nations, **2018**. *68% of the world population projected to live in urban areas by 2050, says UN. United Nations.* www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

2.3 POLLUTION

Agunbiade, F.O. and Moodley, B., **2014**. Pharmaceuticals as emerging organic contaminants in Umgeni River water system, KwaZulu-Natal, South Africa. *Environmental monitoring and assessment*, **186**(11), 7273-7291.

APWC (Asia Pacific Waste Consultants), **2020**. Port Reception Waste Facilities Audit. The Commonwealth Litter Programme, South Africa.

Begg, G.W., **1984**. The Estuaries of Natal. Part II. Pietermaritzburg, South Africa: Natal Town and Regional Planning Commission Report Vol. 55, 182 pp.

Cliff, G., Dudley, S.F., Ryan, P.G. and Singleton, N., **2002**. Large sharks and plastic debris in KwaZulu-Natal, South Africa. *Marine and Freshwater Research*, **53**(2), 575-581.

Forbes, A.T. and Demetriades N.T., **2008**. Estuaries of Durban, KwaZulu-Natal, South Africa. Report for the Environmental Management Department, eThekwini Municipality.

Mann-Lang, J., Pather, M., Naidoo, T. and Ntombela, J., **2020**. A review of stranded marine turtles treated by Ushaka Sea World SAAMBR in Durban, South Africa. Indian Ocean Turtle Newsletter - Issue 32.

Naidoo, T., Thompson, R.C. and Rajkaran, A., **2020**. Quantification and characterisation of microplastics ingested by selected juvenile fish species associated with mangroves in KwaZulu-Natal, South Africa. *Environmental Pollution*, **257**, 113635.

Nahman, A. and Rigby, D., **2008**. Valuing blue flag status and estuarine water quality in Margate, South Africa. *South African Journal of Economics*, **76**(4), 721-737.

Newman, B., Arabi, S., Weerts, S., Pieters, R. and Vogt, N., **2015**. Prevalence and significance of organic contaminants and metals in aquatic ecosystems in the eThekwini area of Kwazulu-Natal. WRC Report No. 1977/1/15.

Retief, M. and Fijen, T., **2008**. New dense wastewater marine outfall system for Richards Bay. *Civil Engineering*, **2008**(7), 41-46.

Ryan, P.G., **2020**. The transport and fate of marine plastics in South Africa and adjacent oceans. *South African Journal of Science*, **116**(5-6), 1-9.

Ryan, P.G., Weideman, E.A., Perold, V., Hofmeyr, G. and Connan, M., **2021**. Message in a bottle: Assessing the sources and origins of beach litter to tackle marine pollution. *Environmental Pollution*, **288**, 117729.

Schumann, E.H., MacKay, C.F. and Strydom, N.A., **2019**. Nurdle drifters around South Africa as indicators of ocean structures and dispersion. *South African Journal of Science*, **115**(5-6), 1-9.

Segura, P.A., Takada, H., Correa, J.A., El Saadi, K., Koike, T., Onwona-Agyeman, S., Ofosu-Anim, J., Sabi, E.B., Wasonga, O.V., Mghalu, J.M. and dos Santos Junior, A.M., **2015**. Global occurrence of anti-infectives in contaminated surface waters: Impact of income inequality between countries. *Environment international*, **80**, 89-97.

Sutherland, C., Reynaert, E., Dhlamini, S., Magwaza, F., Lienert, J., Riechmann, M.E., Buthelezi, S., Khumalo, D., Morgenroth, E., Udert, K.M. and Sindall, R.C., **2021**. Socio-technical analysis of a sanitation innovation in a peri-urban household in Durban, South Africa. *Science of the Total Environment*, **755**, 143284.

Taljaard, S., Van Niekerk, L. and Weerts, S.P., **2019**. The legal landscape governing South Africa's coastal marine environment–Helping with the 'horrendogram'. *Ocean & Coastal Management*, **178**, 104801.

Wright, S.L., Thompson, R.C. and Galloway, T.S., **2013**. The physical impacts of microplastics on marine organisms: A review. *Environmental pollution*, **178**, 483-492.

CHAPTER 3: CLIMATE VARIABILITY

3.1 CLIMATE CHANGE

Bezverkhnii, V.A., **2019**. The 100 000-Year Periodicity in Glacial Cycles and Oscillations of World Ocean Level. *Izv. Atmos. Ocean. Phys*, **55**, 334-340.

Mather, A.A., **2007**. Linear and non-linear sea-level changes at Durban, South Africa. *South African Journal of Science,* **103**, 509-512.

Mather, A.A., Stretch, D.D. and Garland, G.G., **2009**. Southern African sea levels: Corrections, influences and trends. *African Journal of Marine Science*, **31**(2), 145-156.

Ramsay, P.J. and Cooper, J.A.G., **2002**. Late Quaternary Sea-Level Changes in South Africa. *Quaternary Research*, **57**(1), 82-90.

Wunsch, C. and Stammer, D., **1997**. Atmospheric loading and the oceanic “inverted barometer” effect. *Reviews of Geophysics,* **35**(1), 79-107.

3.2 EXTREME EVENTS

Barnett, K.A., **1999**. *The management of Durban's beaches: An historical perspective.* COPEDEC, Cape Town, South Africa.

Garland, G.G. and Molefi, L., **2000**. Geomorphological impacts of Inanda Dam on the Mgeni estuary, north of Durban, South Africa. *Bull. Eng. Geol. Env,* **59**, 119-126.

Mather, A.A. and Vella, G., **2007**. *Report on the March 2007 coastal erosion event for the KwaZulu-Natal.* Internal Report eThekwini Municipality.

Pfeiffer, M., Zinke, J., Dullo, C., Garbe-Schönberg, D., Latif, D.M. and Weber, M.E., **2017**. Indian Ocean corals reveal crucial role of World War II bias for twentieth century warming estimates.

Zinke, J., D'Olivo, J. P., Gey, C. J., McCulloch, M. T., Bruggemann, J. H., Lough, J. M. and Guillaume, M. M., **2019.** Multi-trace-element Sea Surface Temperature. Coral Reconstruction for the Southern Mozambique Channel Reveals Teleconnections with the tropical Atlantic. *Biogeosciences*, **16**, 695-712.

3.3 LARGE SCALE OCEANOGRAPHIC EVENTS

Backeberg, B.C., Penven, P. and Rouault, M., **2012**. Impact of intensified Indian Ocean winds on mesoscale variability in the Agulhas system. *Nature Climate Change*, **2**(8), 608-612.

Backeberg, B.C., Counillon, F., Johannessen, J.A. and Pujol, M.I., **2014**. Assimilating along-track SLA data using the EnOI in eddy resolving model of the Agulhas system. *Ocean Dynamics,* **65**, 1121-1136,

Beal, L.M. and Elipot, S., **2016.** Broadening not strengthening of the Agulhas Current since the early 1990s. *Nature*, **540**(7634), 570-573.

Braby, L., Backeberg, B.C., Ansorge, I., Roberts, M.J., Krug, M. and Reason, C.J.C., **2016**. Observed eddy dissipation in the Agulhas Current. *Geophysical Research Letters*, **43**, 8143-8150,

Braby, L., Backeberg, B.C., Krug, M. and Reason, C., **2020**. Quantifying the impact of wind-current feedback on mesoscale variability in forced simulation experiments of the Agulhas Current using an eddy-tracking algorithm*. Journal of Geophysical Research Oceans*, **125**(1),

Bryden, H.L., Beal, L.M. and Duncan, L.M., **2005**. Structure and transport of the Agulhas Current and its temporal variability. *J. Oceanogr*, **61,** 479-492.

Cheng, L., Trenberth, K.E., Fasullo, J., Boyer, T., Abraham, J. and Zhu, J., **2017**. Improved estimates of ocean heat content from 1960 to 2015*. Science Advances*, **3**(3), e1601545.

de Ruijter, W.P.M., van Leeuwen, P.J. and Lutjeharms, J.R.E., **1999**. Generation and evolution of natal pulses: Solitary meanders in the Agulhas Current. *Journal of Physical Oceanography*, **29**, 3043-3055.

de Ruijter, W.P.M., van Aken, H.M., Beier, E.J., Lutjeharms, J.R.E., Matano, R.P. and Schouten, M.W., **2004**. Eddies and dipoles around South Madagascar: Formation, pathways and large-scale impact. *Deep-Sea Research,* **51**, 383-400.

de Vos, M., Backeberg, B. and Counillon, F., **2018**. Using an eddy-tracking algorithm to understand the impact of assimilating altimetry data on the eddy characteristics of the Agulhas system*. Ocean Dynamics*, **68**, 1071-1091,

Hu, D., Wu, L., Cai, W., Gupta, A.S., Ganachaud, A., Qui, B., Gordon, A.L., Lin, X., Chen, Z., Hu, S., Wang, G., Wang, Q., Springtall, J., Qu, T., Kashino, Y., Wang, F. and Kessler, W.S., **2015**. Pacific western boundary currents and their roles in climate. *Nature,* **522,** 299-308.

Hutchings, L., Beckley, L.E., Griths, M.H., Roberts, M.J., Sundby, S. and van der Lingen, C., **2002**. Spawning on the edge: Spawning grounds and nursery areas around the southern African coastline. *Marine Freshwater Research*, **53**(1996), 307-318.

Jury, M.R., Valentine, H.R. and Lutjeharms, J.R.E., **1993***.* Influence of the Agulhas Current on summer rainfall along the southeast coast of South Africa. *Journal of Applied Meteorology*, **32**(7), 1282-1287.

Lutjeharms, J.R.E., **2006**. *The Agulhas Current*. Berlin, Springer.

Lutjeharms, J.R.E. and Ansorge, I.J., **2001**. The Agulhas Return Current. *Journal of Marine Systems*, **30**(1-2), 115-138.

Malan, N., Backeberg, B., Biastoch, V., Durgadoo, J.V., Samuelsen, A., Reason, C. and Hermes, J., **2018**. Agulhas Current meanders facilitate shelf-slope exchange on the Eastern Agulhas Bank. *Journal Geophysical Research: Oceans*, **123**, 4762-4778.

McGregor, S., Gupta, A.S. and England, M.H., **2012**. Constraining wind stress products with sea surface height observations and implications for Pacific Ocean sea-level trend attribution. *J. Clim*, **25,** 8164-8176.

Meyer, I., Braby, L., Krug, M. and Backeberg, B., **2017.** Mapping the ocean current strength and persistence in the Agulhas to inform marine energy development. *Marine Renewable Energy: Resource Characterization and Physical Effects,* 179-215. Springer, Cham.

Morris, T., Hermes, J., Beal, L., Du Plessis, M., Rae, C.D., Gulekana, M. and Ansorge, I.J., **2017**. The importance of monitoring the Greater Agulhas Current and its inter-ocean exchanges using large mooring arrays. *South African Journal of Science*, **113**(7-8), 1-7.

Rennell, J., **1832**. *An investigation of the currents of the Atlantic Ocean, and of those which prevail between the Indian Ocean and the Atlantic.* London: J.G. and F. Rivington.

Roberts, M.J., van der Lingen, C.D., Whittle, C. and van den Berg, M., **2010**. Shelf currents, lee-trapped and transient eddies on the inshore boundary of the Agulhas Current, South Africa: their relevance to the KwaZulu-Natal sardine run. *African Journal of Marine Science*, **32**(2), 423-447.

Rouault, M., White, S.A., Reason, C.J.C., Lutjeharms, J.R.E. and Jobard, I., **2002**. Ocean–atmosphere interaction in the Agulhas Current region and a South African extreme weather event. *Weather and Forecasting*, **17**(4), 655-669.

Rouault, M., Penven, P. and Pohl, B., **2009**. Warming in the Agulhas Current System since the 1980's. *Geophys. Res. Lett,* **36,** L12602.

Schouten, M.W., de Ruijter, W.P.M. and van Leeuwen, P.J., **2002**. Upstream control of Agulhas ring shedding. *Journal of Geophysical Research*, **107**(C8), 3109.

Walker, N. D., **1990**. Links between South African summer rainfall and temperature variability of the Agulhas and Benguela Current systems. *Journal of Geophysical Research: Oceans*, **95**(C3), 3297-3319.

Wu, L., Cai, W., Zhang, L., Nakamura, H., Timmermann, A., Joyce, T., McPhaden, M.J., Alexander, M., Qui, B., Visbeck, M., Chang, O. and Giese, B., **2012.** Enhanced warming over the global subtropical western boundary currents. *Nat. Clim. Chang*, **2,** 161-166.

Yang, H., Lohmann, G., Wei, W., Dima, M., Jonita, M. and Lui, J., **2016**. Intensification and poleward shift of subtropical western boundary currents in a warming climate. *J. Geophys. Res. Oceans,* **121,** 4928-4945.

Zhai, X., Johnson, H.L. and Marshall, D.P., **2010**. Significant sink of ocean-eddy energy near western boundaries. *Nature Geoscience*, **3**, 608-612.

CHAPTER 4: COASTAL ENVIRONMRNT

4.1 SANDY SHORES

Bland, L.M., Keith, D.A., Miller, R.M., Murray, N.J., Rodríguez, J.P., (eds.), **2017**. *Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria.* Version 1.1. IUCN, Gland, Switzerland.

Harris, L.R., Bessinger, M., Dayaram, A., Holness, S., Kirkman, S., Livingstone, T.C., Lombard, A.T., Lück-Vogel, M., Pfaff, M., Sink, K.J., Skowno, A.L. and van Niekerk, L., **2019a**. Advancing land-sea integration for ecologically meaningful coastal conservation and management. *Biological Conservation,* **237**, 81-89.

Harris, L.R., Poole, C.J., van der Bank, M., Sink, K.J., De Vos, D., Raw, J.L., Turpie, J., Perschke, M. and Dunga, L.V., **2019b**. *Benefits of coastal biodiversity. In*: Harris, L.R., Sink, K.J., Skowno, A.L. and Van Niekerk, L., (eds.). South African National Biodiversity Assessment 2018: Technical Report. Volume 5: Coast. South African National Biodiversity Institute, Pretoria.

Harris, L.R., Sink, K.J., Skowno, A.L., Van Niekerk, L. and Driver, A., **2019c**. *Going forward: key findings, priority action, knowledge gaps and research priorities. In*: Harris, L.R., Sink, K.J., Skowno, A.L. and Van Niekerk, L., (eds.). South African National Biodiversity Assessment 2018: Technical Report. Volume 5: Coast. South African National Biodiversity Institute, Pretoria.

Harris, L.R., Campbell, E.E., Nel, R. and Schoeman, D.S., **2014**. Rich diversity, strong endemism, but poor protection: Addressing the neglect of sandy beach ecosystems in coastal conservation planning. *Diversity and Distributions,* **20**, 1120-1135.

Harris, L.R., Nel, R., Holness, S. and Schoeman, D.S., **2015**. Quantifying cumulative threats to sandy beach ecosystems: A tool to guide ecosystem-based management beyond coastal reserves. *Ocean & Coastal Management*, **110**, 12-24.

Keith, D.A., Rodríguez, J.P., Rodríguez-Clark, K.M., Nicholson, E., Aapala, K., Alonso, A., Asmussen, M., Bachman, S., Basset, A., Barrow, E.G., Benson, J.S., Bishop, M.J., Bonifacio, R., Brooks, T.M., Burgman, M.A., Comer, P., Comín, F.A., Essl, F., Faber-Langendoen, D., Fairweather, P.G., Holdaway, R.J., Jennings, M., Kingsford, R.T., Lester, R.E., Nally, R.M., McCarthy, M.A., Moat, J., Oliveira-Miranda, M.A., Pisanu, P., Poulin, B., Regan, T.J., Riecken, U., Spalding, M.D. and Zambrano-Martínez, S., **2013.** Scientific Foundations for an IUCN Red List of Ecosystems. *PLoS ONE*, 8, e62111.

McLachlan, A., **1979**. Volumes of sea water filtered through Eastern Cape sandy beaches. *South African Journal of Science,* **75**, 75-79.

McLachlan, A., **1982**. A model for the estimation of water filtration and nutrient regeneration by exposed sandy beaches. *Marine Environmental Research*, **6**, 37-47.

McLachlan, A., **1990**. The exchange of materials between dunes and beach systems. *In*: Nordstrom, K.F., Psuty, N. and Carter, B., (eds.). *Coastal Dunes: Form and Processes.* John Wiley & Sons, Chichester.

Sink, K.J., Holness, S., Skowno, A.L., Franken, M., Majiedt, P.A., Atkinson, L.J., Bernard, A., Dunga, L.V., Harris, L.R., Kirkman, S.P., Oosthuizen, A., Porter, S., Smit, K. and Shannon, L., **2019a**. *Ecosystem Threat Status. In*: Sink, K.J., van der Bank, M.G., Majiedt, P.A., Harris, L.R., Atkinson L.J., Kirkman, S.P. and Karenyi, N., (eds.). South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm. South African National Biodiversity Institute, Pretoria.

Sink, K.J., Sibanda, S.M., Fielding, P., Skowno, A.L., Franken, M., Harris, L.R., Adams, R. and Baleta, T., **2019b**. *Ecosystem Protection Level. In*: Sink, K.J., van der Bank, M.G., Majiedt, P.A., Harris, L.R., Atkinson L.J., Kirkman, S.P. and Karenyi, N., (eds.). South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm. South African National Biodiversity Institute, Pretoria, South Africa.

Skowno, A.L., **2020**. *Land cover derived terrestrial habitat change map for South Africa (1990-2018).* National Biodiversity Assessment: Technical Report. South African National Biodiversity Institute, Pretoria, South Africa.

Skowno, A.L., Poole, C., Raimondo, D., Sink, K., van Niekerk, L., van Deventer, H., Smith-Adao, L., Harris, L., Tolley, K., Zengeya, T., Midgley, G. and Driver, A., **2019a**. *National Biodiversity Assessment 2018: An assessment of South Africa's ecosystems, species and genes.* Synthesis Report, South African National Biodiversity Institute. Department of Environmental Affairs, Pretoria.

Skowno, A.L., Raimondo, D.C., Poole, C.J., Fizzotti, B. and Slingsby, J.A., (eds.), **2019b**. *South African National Biodiversity Assessment 2018 Technical Report Volume 1: Terrestrial Realm*. South African National Biodiversity Institute, Pretoria.

4.2 SWAMP FORESTS

Adams, J.B., Fernandes, M. and Riddin, T., **2019**. *Estuarine Habitat Extent and Trend. South African National Biodiversity Assessment 2018:* Technical Report. Volume 4: Estuarine Environment. South African National Biodiversity Institute, Pretoria. South Africa. Report Number: SANBI/NAT/ NBA2018/2019/Vol3/A.

Obermeyer, A.A., Strey, R.G., **1969**. A new species of *Raphia* from Northern Zululand and Southern Mozambique. *Bothalia*, **10**(1), 29-37.

Van Deventer, H., Adams, J.B., Durand, J.F., Grobler, R., Grundling, P.L., Janse van Rensburg, S., Jewitt, D., Kelbe, B., MacKay, C.F., Naidoo, L., Nel, J.L., Pretorius, L., Riddin, T. and Van Niekerk, L., **2021**. Conservation conundrum –

Red listing of subtropical-temperate coastal forested wetlands of South Africa. *Ecological Indicators*, **130**, 108077.

Van Niekerk, L., Adams, J.B., Lamberth, S.J., MacKay, C.F., Taljaard, S., Turpie, J.K., Weerts S.P. and Raimondo, D.C., (eds.), **2019.** *South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm.* CSIR report number: CSIR/SPLA/EM/EXP/2019/0062/A. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/ NBA2018/2019/Vol3/A.

4.3 ROCKY SHORES

Blamey, L.K. and Branch, G.M., **2009**. Habitat diversity relative to wave action on rocky shores: Implications for the selection of marine protected areas. *Aquat. Conserv. Mar. Freshw. Ecosyst*, **19**, 645-657.

Branch, G. and Branch, M., **2018.** *Living shores: Interacting with southern Africa's marine ecosystems (2nd ed).* Cape Town: Penguin Random House South Africa

Burrows, M.T., Mieszkowska, N. and Hawkins, S.J., **2014**. *Marine Strategy Framework Directive Indicators for UK Rocky Shores Part 1: Defining and validating the indicators.* JNCC Report, No. 522. Peterborough.

De Bruyn, P.A., Moloney, C.L. and Schleyer, M.H., **2009.** Application of age-structured production models to assess oyster *Striostrea margaritacea* populations managed by rotational harvesting in KwaZulu-Natal, South Africa. *ICES J. Mar. Sci*, **66**, 408-419.

DEFF (Department of Environment, Forestry and Fisheries), **2020**. *Status of the South African marine fishery resources 2020.* Cape Town: DEFF

EDTEA (Economic Development Tourism and Environmental Affairs), **2017**. *KwaZulu-Natal Environment Outlook Report 2017.* Pietermaritzburg, South Africa.

Goble B.J., **2014.** *Introduction. In*: Goble, B.J., van der Elst, R.P. and Oellermann, L.K., (eds.). *Ugu Lwethu – Our Coast. A profile of coastal KwaZulu-Natal.* KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs and the Oceanographic Research Institute, Pietermaritzburg, 202 pp.

Kelly, C., Foden, W., Midgley, G., Porter, S., Lamberth, S., van der Lingen, C., Atkinson, L.J. and Robinson, J., **2019**. *Climate Change. In:* Sink, K.J., van der Bank, M.G., Majiedt, P.A., Harris, L.R., Atkinson, L.J., Kirkman, S.P. and Karenyi, N., (eds.). South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372 222

Kyle, R., Pearson, B., Fielding, P.J., Robertson, W.D. and Birnie, S.L., **1997.** Subsistence shellfish harvesting in the Maputaland Marine Reserve in northern KwaZulu-Natal, South Africa: Rocky shore organisms. *Biol. Conserv*, **82,** 183-192.

Kyriacou, K., **2017.** Intertidal shellfish as a source of protein and energy for the Middle Stone Age inhabitants of the southwestern Cape and northern KwaZulu-Natal, South Africa. *Quat. Int,* **438,** 30-39.

Marean, C.W., Bar-Mattews, M., Bernatchez, J., Fisher, E., Goldberg, P., Herries, A., Jacobs, Z., Jerardino, A., Karkanas, P., Mercier, N., Minichillo, N., Nilssen, P.J., Thompson, E., Teobolo, C., Valladas, H. and Williams, H., **2007.** Early human use of marine resources and pigment in South Africa during the Middle Pleistocene. *Nature*, **449,** 905–908.

Mead, A., Griffiths, C.L., Branch, G.M., McQuaid, C.D., Blamey, L.K., Bolton, J.J. Anderson, R.J., Dufois, F., Rouault, M., Froneman, P.W., Whitfield, A.K., Harris, L.R., Nel, R., Pillay, D. and Adams, J.B., **2013.** Human-mediated drivers of change - Impacts on coastal ecosystems and marine biota of South Africa. *African J. Mar. Sci*, **35**, 403-425.

Mvula, P.E., **2020**. *Decadal changes in rocky shore communities in KwaZulu-Natal and survey methods for future monitoring.* MSc Thesis. University of KwaZulu-Natal. Durban, South Africa.

Olbers, J., **2015**. *Rocky Shore Biodiversity Monitoring: Ezemvelo KZN Wildlife Research & Monitoring of Marine Living Resources Programme for the Department of Environmental Affairs.* Annual Report for 2014/2015. Government Gazette. Pietermaritzburg, South Africa.

Olbers, J., **2017.** *Rocky Shore Biodiversity Monitoring: Ezemvelo KZN Wildlife Research & KwaZulu-Natal Long term Biodiversity Monitoring Programme for the Department of Environmental Affairs.* Annual Report for 2016/2017. Pietermaritzburg, South Africa.

Sink, K., van der Bank, M., Majiedt, P., Harris, L., Atkinson, L., Kirkman, S. and Karenyi, N., (eds.), **2019a**. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm.* Pretoria, South Africa.

Sink, K.J., **2001**. *A hierarchical analysis of abiotic determinants and harvesting Impacts in the rocky intertidal communities of KwaZulu-Natal.* University of Cape Town.

Sink, K.J., Branch, G.M. and Harris, J.M., **2005**. Biogeographic patterns in rocky intertidal communities in KwaZulu-Natal, South Africa. *African J. Mar. Sci*, **27**, 81-96.

Sink, K.J, Harris, L.R., Skowno, A., Livingstone, T., Franken, M., Atkinson, L.J., Bernard, A., Porter, S., Cawthra, H., Currie, J., Dayaram, A., De Wet, W., Dunga, V., Filander, Z., Green, A., Herbert, D., Karenyi, N., Palmer, R., Pfaff, M., Makwela, M., McKay, F., Van Niekerk, L., Van Zyl, W., Bessinger, M., Holness, S., Kirkman, S.P., Lamberth, S. and Lück-Vogel, M., **2019b**. *Marine Ecosystem Classification and Mapping. In*: Sink, K., van der Bank, M., Majiedt, P., Harris, L., Atkinson, L., Kirkman, S. and Karenyi, N., (eds.). South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm. South African National Biodiversity Institute, Pretoria, South Africa, 1-65 pp.

Sparks, C., Odendaal, J. and Snyman, R., **2014.** An analysis of historical Mussel Watch Programme data from the west coast of the Cape Peninsula, Cape Town. *Mar. Pollut. Bull*, **87**, 374-380.

Stats SA, **2011.** *Census 2011 Statistical release – P0301.4* / Statistics South Africa. Pretoria, Statistics South Africa 2012.

Steyn, E. and van der Elst. R., **2014**. *Rocky Shores*. *In*: Goble, B.J., van der Elst, R.P. and Oellermann, L.K., (eds.). *Ugu Lwethu* – Our Coast. A profile of coastal KwaZulu-Natal. KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs and the Oceanographic Research Institute, Pietermaritzburg, 45-46 pp.

Strydom, N.A., **2008.** Utilization of shallow subtidal bays associated with warm temperate rocky shore by the late-stage larvae of some inshore fish species, South Africa. *African Zool*, **43**, 256-269.

Tomalin, B.J. and Kyle, R., **1998.** Subsistence and recreational mussel (*Perna perna*) collecting in KwaZulu-Natal, South Africa: Fishing mortality and precautionary management. *African Zool,* **33**, 12-22.

Van der Elst, R., **2020.** *Beachcombing in South Africa***.** Penguin Random House South Africa, 144 pp.

4.4 COASTAL LAKES

Boltt, R.E., **1969**. The benthos of some Southern African lakes. Part II: The epifauna and infauna of the benthos of Lake Sibaya. *Transactions of the Royal Society of southern Africa*, **38**, 249269.

Bruton, M.N., **1979**. The fishes of Lake Sibaya. *In:* Allanson, B.R., (ed.). Lake Sibaya. *Monographiae Biologicae,* **36**, 162-245. W. Junk Publishers, The Hague.

Buah-Kwofie, A. and Humphries, M.S., **2017**. The distribution of organochlorine pesticides in sediments from iSimangaliso Wetland Park: Ecological risks and implications for conservation in a biodiversity hotspot. *Environmental Pollution,* **229**, 715-723.

Coetzee, J.A., Jones, R.W. and Hill, M.P., **2014**. Water hyacinth, *Eichhornia crassipes* (Pontederiaceae), reduces benthic macroinvertebrate diversity in a protected subtropical lake in South Africa*. Biodiversity and Conservation,* **23**(5), 1319-1330.

Combrink, X., Korrûbel, J.L., Taylor, R., Kyle, R. and Ross, P., **2011**. Evidence of a declining Nile crocodile (*Crocodylus niloticus*) population at Lake Sibaya, South Africa. *South African Journal of Wildlife Research,* **41**(2), 145-157.

Hill, B.J., **1975**. The Origin of Southern African Coastal Lakes. *Transactions of the Royal Society of southern Africa*, **3**, 225-240.

Humphries, M.S. and Benitez-Nelson, C.R., **2013**. Recent trends in sediment and nutrient accumulation rates in coastal, freshwater Lake Sibaya, South Africa. *Marine and Freshwater Research,* **64**(11), 1087-1099.

Humphries, M.S., **2013**. DDT residue contamination in sediments from Lake Sibaya in northern KwaZulu-Natal, South Africa: Implications for conservation in a World Heritage Site. *Chemosphere*, **93**(8), 1494-1499.

MacKay, C.F. and Cyrus, D.P., **2000**. Available information on macroinvertebrates of the Mhlathuze coastal lakes: Setting the ecological reserve (lake water requirements). *African Journal of Aquatic Science*, **26**, 85-98.

MacKay, F., Weerts, S. and Cooper, A., **2014**. Coastal Lakes. *In*: Goble, B.J., van der Elst, R.P. and Oellermann, L.K., (eds*.*)*. Ugu Lwethu – Our Coast. A profile of coastal KwaZulu-Natal*. KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs and the Oceanographic Research Institute, Pietermaritzburg, 37-39 pp.

Smithers, J.C., Gray, R.P., Johnson, S. and Still, D., **2017**. Modelling and water yield assessment of Lake Sibhayi. *Water SA*, **43**(3), 480-491.

Van der Wateren, T., **1998**. The impact of pollution on the water quality of Lake Mzingazi: Richards Bay. MA mini thesis, Rand Afrikaans University.

Van Deventer, H., Smith-Adao, L., Collins, N.B., Grenfell, M., Grundling, A., Grundling, P-L., Impson, D., Job, N., Lötter, M., Ollis, D., Petersen, C., Scherman, P., Sieben, E., Snaddon, K., Tererai, F. and Van der Colff, D., **2019**. South African National Biodiversity Assessment 2018: Technical Report. Volume 2b: Inland Aquatic (Freshwater) Realm. CSIR report number: CSIR/NRE/ECOS/IR/2019/0004/A. South African National Biodiversity Institute, Pretoria.

Weerts, S.P. and Cyrus, D.P., **2001**. The ichthyofauna of the Mhlathuze coastal lakes: some preliminary results. *African Journal of Aquatic Science*, **26**, 99-107.

Weerts, S.P., MacKay, C.F. and Cyrus, D.P., **2014**. The potential for a fish ladder to mitigate against the loss of marine-estuarine-freshwater connectivity in a subtropical coastal lake. *Water SA*, **40**(1), 27-38.

Whitfield, A.K., Weerts, S.P. and Weyl, O.L., **2017**. A review of the influence of biogeography, riverine linkages, and marine connectivity on fish assemblages in evolving lagoons and lakes of coastal southern Africa. *Ecology and evolution*, **7**(18), 7382-7398.

4.5 WETLANDS

Baker, A., Pedentchouk, N., Routh, J. and Roychoudhury, A.N., **2017.** Climatic variability in Mfabeni peatlands (South Africa) since the late Pleistocene. *Quaternary Science Reviews,* **160**, 57-66.

Bate, G., Kelbe, B.E. and Taylor, R., **2016**. Mgobezeleni: *The linkages between hydrological and ecological drivers*. Water Research Commission (WRC) Report No. 2259/1/16. WRC, Pretoria, South Africa.

Begg, G.W., **1988.** *The wetlands of Natal (Part 2): The distribution, extent and status of wetlands in the Mfolozi catchment.* Natal Town and Regional Planning Commission Report 71, Pietermaritzburg, South Africa.

DEA (Department of Environmental Affairs) and Water Research Commission (WRC), **2018.** Presentation on the "DEA Source to Sea Initiative: Dialogue on Microbeads & Microplastics". Presented by Dr Y Petersen, Director Coastal Pollution Management at the Microplastics and Microbeads in the Environment Dialogue held on 21 November 2018, Sheraton Hotel, Pretoria, South Africa.

Dye, P.J., **1996.** Response of *Eucalyptus grandis* trees to soil water deficits. *Tree Physiology,* **16**, 233-238.

Elshehawi, S., Gabriel, M., Pretorius, L., Bukhosini, S., Butler, M., Van der Plicht, J., Grundling, P. and Grootjans, A.P., **2019.** Ecohydrology and causes of peat degradation at the Vasi peatland. *South African Mires and Peat,* **24**(33), 21 pp.

Grundling, P., Baartman, L., Mazus, H. and Blackmore A., **2000.** *Peat resources of KwaZulu-Natal wetlands: Southern Maputaland and the North and South Coast.* Council for Geoscience. Report, Pretoria, South Africa.

Grundling, P. and Blackmore, A., **1998.** *Peat Fire in the Vasi Pan Peatland. Internal Report 1998-0208,* Council for Geoscience, Pretoria, South Africa, 175 pp.

Grundling, P-L., Grootjans, A.P., Price, J.S. and Ellery, W.N., **2013.** Development and Persistence of an African Mire: How the Oldest South African Fen Has Survived in a Marginal Climate. *Catena,* **100**, 176-183.

Grundling, P-L., Grundling, A.T., Pretorius, L., Mulders J. and Mitchell, S., **2017.** *South African Peatlands: Ecohydrological characteristics and socioeconomic value.* Water Research Commission (WRC) Report No. 2346/1/17. WRC, Pretoria, South Africa.

Grundling, P-L., Grundling, A.T., Van Deventer, H. and Le Roux, J.P., **2021**. Current state, pressures and protection of South African peatlands. *Mires & Peat*, 27, article 26.

Grundling, P., Mazus, H. and Baartman, L., **1998.** *Peat Resources in Northern KwaZulu-Natal Wetlands: Maputaland.* Department of Environmental Affairs & Tourism (DEAT) Report no. A25/13/2/7.102. DEAT, Pretoria, South Africa.

Harris, L.R., Bessinger, M., Dayaram, A., Holness, S., Kirkman, S., Livingstone, T.C., Lombard, A.T., Lück-Vogel, M., Pfaff, M., Sink, K.J., Skowno, A.L. and Van Niekerk, L., **2019.** Advancing land-sea integration for ecologically meaningful coastal conservation and management. *Biological Conservation,* **237**, 81-89.

IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services), **2019**. *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.* Díaz, S., Settele, J., Brondízio, E.S., Ngo, H.T. and 26 others (eds.), IPBES, IPBES secretariat, Bonn, Germany, 56 pp.

IUCN (International Union for Conservation of Nature): SSC Amphibian Specialist Group and South African Frog Re-assessment Group (SA-FRoG), **2016**. *Hyperolius pickersgilli: The IUCN Red List of Threatened Species 2010*: e.T22692046A93334893. Online: http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22692046A93334893.en [Accessed 28 August 2018]

Janse van Rensburg, S., **2019.** *Pressures on the Maputaland Coastal Plain*. *In*: Van Deventer, H., Smith-Adao, L., Mbona, N., Petersen, C., Skowno, A., Collins, N.B., Grenfell, M., Job, N., Lötter, M., Ollis, D., Scherman, P., Sieben, E. and Snaddon, K., *South African National Biodiversity Assessment 2018: Technical Report. Volume 2a: South African Inventory of Inland Aquatic Ecosystems (SAIIAE). Version 3*, final released on 3 October 2019. Council for Scientific and Industrial Research (CSIR) and South African National Biodiversity Institute (SANBI): Pretoria, South Africa. Report Number: CSIR report number: CSIR/NRE/ECOS/IR/2018/0001/A, SANBI report number: http://hdl.handle.net/20.500.12143/5847

Joosten, H. and Clarke, D., **2002.** *Wise Use of Mires and Peatlands*. International Mire Conservation Group and International Peat Society, Jyväskylä, Finland.

Kelbe, B.E., Grundling, A. and Price, J., **2016**. Modelling water-table depth in a primary aquifer to identify potential wetland hydrogeomorphic settings on the northern Maputaland Coastal Plain, KwaZulu-Natal, South Africa. *Hydrogeology Journal*, **24**(1), 249- 265.

Le Maitre, D.C., Seyler, H., Holland, M., Smith-Adao, L., Nel, J.L., Maherry, A. and Witthüser, K., **2018.** *Identification, Delineation and Importance of the Strategic Water Source Areas of South Africa, Lesotho and Swaziland for Surface Water and Groundwater Enhancement.* Report No. TT 754/1/18, Water Research Commission (WRC), Pretoria, South Africa, 283 pp.

Miller, W.R. ,**1998**. *The bathymetry, sedimentology and seismic stratigraphy of Lake Sibaya – Northern KwaZulu-Natal*. MSc thesis. University of Natal, Durban, South Africa.

McKelvey, B. and MacKay, F., **2020**. *50% of KZN's coastal rivers and estuaries are affected by sand mining.* Ulwandle: KwaZulu-Natal' s Coastal Management Newsletter (EDTEA), 2 pp. www.coastkzn.co.za/wp-content/uploads/2020/05/Ulwandle_2019_6.pdf

Naidoo, P., Van Niekerk, M., du Toit, E., Beyers, N. and Leon, N., **2015.** Pathways to multidrug-resistant tuberculosis diagnosis and treatment initiation: A qualitative comparison of patients' experiences in the era of rapid molecular diagnostic tests. *BMC Health Services Research* (2015), **5**,488.

Nel, J.L. and Driver, A., **2015**. *National River Ecosystem Accounts for South Africa*. Discussion document for Advancing SEEA Experimental Ecosystem Accounting Project, October 2015. South African National Biodiversity Institute, Pretoria, South Africa.

Nel, J.L., Driver, A., Strydom, W.F., Maherry, A., Petersen, C.P., Hill, L., Roux, D.J., Nienaber, S., Van Deventer, H., Swartz, E. and Smith-Adao, L.B., **2011**. *Atlas of Freshwater Ecosystem Priority Areas in South Africa: Maps to Support Sustainable Development of Water Resources*. Water Research Commission (WRC) Report No. TT 500/11. WRC, Pretoria, South Africa.

Sink, K.J., van der Bank, M.G., Majiedt, P.A., Harris, L.R., Atkinson, L.J., Kirkman, S.P. and Karenyi, N., (eds.), **2019.** *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm.* South African National Biodiversity Institute, Pretoria, South Africa.

Skowno, A.L., Raimondo, D.C., Poole, C.J., Fizzotti, B. and Slingsby, J.A., (eds.), **2019**. *South African National Biodiversity Assessment 2018 Technical Report Volume 1: Terrestrial Realm.* South African National Biodiversity Institute, Pretoria, South Africa.

Snaddon, K., Robinson, J., Foden, W., Van Deventer, H., Van Rooyen, L., Genthe, B. and Sieben, E., **2019**. Chapter 3: Climate change – our changing environment from a freshwater-ecosystems perspective. *In*: Van Deventer, H., Smith-Adao, L., Collins, N.B., Grenfell, M., Grundling, A., Grundling, P-L., Impson, D., Job, N., Lötter, M., Ollis, D., Petersen, C., Scherman, P., Sieben, E.J.J., Snaddon, K., Tererai, F. and van der Colff, D., (eds.). *South African National Biodiversity Assessment 2018: Technical Report. Volume 2b: Inland Aquatic (Freshwater) Component.* CSIR report number: CSIR/NRE/ECOS/IR/2019/0004/A. South African National Biodiversity Institute, Pretoria, South Africa.

Tarrant, J. and Armstrong, A.J., **2013**. *Biodiversity Management Plan: Pickersgill's Reed Frog* (*Hyperolius pickersgilli*). Government Notice: GN 337 in Government Gazette 40058. Government Printers, Pretoria, South Africa.

Thamm, A.G., Grundling, P. and Mazus, H., **1996.** Holocene and Recent peat growth rates on the Zululand coastal plain. *Journal of African Earth Sciences,* **23**(1), 119-124.

Van Deventer, H., Smith-Adao, L., Collins, N.B., Grenfell, M., Grundling, A., Grundling, P.L., Impson, D., Job, N., Lötter, M., Ollis, D., Petersen, C., Scherman, P., Sieben, E., Snaddon, K., Tererai, F. and Van der Colff, D., **2019.** *South African National Biodiversity Assessment 2018: Technical Report. Volume 2b: Inland Aquatic (Freshwater) Realm.* CSIR report number: CSIR/NRE/ECOS/IR/2019/0004/A. South African National Biodiversity Institute, Pretoria.

Van Deventer, H., Van Niekerk, L., Adams, J., Dinala, M.K., Gangat, R., Lamberth, S.J., Lötter, M., Mbona, N., MacKay, F., Nel, J.L., Ramjukadh, C.L., Skowno, A. and Weerts, S.P., **2020.** National Wetland Map 5 – An improved spatial extent and representation of inland aquatic and estuarine ecosystems in South Africa. *Water SA*, **46**(1), 66-79.

Van Niekerk, L., Adams, J.B., Lamberth, S.J., MacKay, F., Taljaard, S., Turpie, J.K., Weerts S. and Raimondo, D. C., (eds.), **2019**. *South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm.* CSIR report number: CSIR/SPLA/EM/EXP/2019/0062/A. South African National Biodiversity Institute, Pretoria, South Africa. Report Number: SANBI/NAT/NBA2018/2019 / Vol3/A.

Verster, C. and Bouwman H., **2020**. Land-based sources and pathways of marine plastics in a South African context. *S. Afr. J. Sci,* **116**(5/6), 9.

4.6 COASTAL VEGETATION

EKZNW (Ezemvelo KwaZulu-Natal Wildlife), **2010**. *KwaZulu-Natal Provincial boundary.* Unpublished GIS coverage [kznbnd10_w31.zip]. Conservation Planning Division, Ezemvelo KZN Wildlife, Cascades, Pietermaritzburg.

EKZNW (Ezemvelo KwaZulu-Natal Wildlife), **2011**. *KwaZulu-Natal Provincial Pre-transformation Vegetation Type Map – 2011.* Unpublished GIS coverage. Conservation Planning Division, Ezemvelo KZN Wildlife, Cascades, Pietermaritzburg.

Fahrig, L., **2003.** Effects of habitat fragmentation on biodiversity. *Annual review of Ecology and Evolutionary systems*, **34**, 487-515.

Faust, C.L., McCallum, H.I., Bloomfield, L.S.P., Gottdenker, N.L., Gillespie, T.R., Torney, C.J., Dobson, A.P. and Plowright, R.K., **2018**. Pathogen spillover during land conversion. *Ecology Letters*, **21**, 471-483.

Jetz, W., Wilcove, D.S. and Dobson, A.P., **2007**. Projected impacts of climate and land-use change on the global diversity of birds. *Plos Biology*, **5**(6), e157.

Jewitt, D., **2018**. Vegetation type conservation targets, status and level of protection in KwaZulu-Natal in 2016. *Bothalia – African Biodiversity & Conservation*, **48**(1), a2294.

Jewitt, D., **2020**. *KZN Biodiversity Status Assessment Report – 2020: Natural Landscape – extent of transformation.* Unpublished report, Ezemvelo KZN Wildlife, Cascades, Pietermaritzburg.

Jewitt, D., Erasmus, B.F.N., Goodman, P.S., O'Connor, T.G., Hargrove, W.W., Maddalena, D.M. and Witkowski, E.T.F., **2015b**. Climate-induced change of environmentally defined floristic domains: a conservation-based vulnerability framework. *Applied Geography*, **63**, 33-42.

Jewitt, D., Goodman, P.S., Erasmus, B.F.N., O'Connor, T.G. and Witkowski, E.T.F., **2015a**. Systematic land-cover change in KwaZulu-Natal, South Africa: Implications for biodiversity. *South African Journal of Science* **111**(9/10), Art #2015-0019, 9 pp.

Lambin, E.F., Turner, B.L., Geist, H.J., Agbola, S.B., Angelsen, A., Bruce, J.W., Coomes, O.T., Dirzo, R., Fischer, G., Folke, C., George, P.S., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E.F., Mortimore, M., Ramakrishnan, P.S., Richards, J.F., Skånes, H., Steffen, W., Stone, G.D., Svedin, U., Veldkamp, T.A., Vogel, C. and Xu, J., **2001**. The causes of land-use and land-cover change: Moving beyond the myths. *Global Environmental Change*, **11**, 261-269.

Millenium Ecosystem Assessment (MEA), **2005.** *Ecosystems and human wellbeing: Biodiversity synthesis*. World Resources Institute, Washington, DC.

Mucina, L. and Rutherford, M.C., (eds.), **2006**. The vegetation of South Africa, Lesotho and Swaziland. *Strelitzia,* **19,** SANBI, Pretoria.

Padma, T.V., **2020.** Deforestation and disease: How natural habitat destruction can fuel zoonotic diseases. *Mongabay Series: Environment and Health.* www.india.mongabay.com

Vitousek, P.M., **1994**. Beyond global warming: Ecology and global change. *Ecology,* **75,** 1861-1876.

CHAPTER 5: ESTUARINE ENVIRONMENT

5.1 ESTUARIES

Borja, A., Basset, A., Bricker, S., Dauvin, J-C., Elliott, M., Harrison, T.D., Marques, J-C., Weisberg, S.B. and West, R., **2011**. Classifying Ecological Quality and Integrity of Estuaries. *In:* Wolanski, E., McLusky, D., (eds.). Treatise on Estuarine and Coastal Science. Academic Press, Waltham, 125-162 pp.

EDTEA (Department of Economic Development, Tourism and Environmental Affairs), **2017**. KwaZulu-Natal Environment Outlook Report, 235 pp.

Forbes, A.T. and Demetriades, N.T., **2008**. Estuaries of Durban, KwaZulu-Natal, South Africa. Prepared by Marine and Estuarine Research (MER) for Environmental Management Department of eThekwini Municipality, 28 pp.

Griffen, B.D., Belgrad, B.A., Cannizzo, Z.J., Knotts, E.R. and Hancock, E.R., **2016**. Rethinking Our Approach to Multiple Stressor Studies in Marine Environments. *Marine Ecology Progress Series*, **543**, 273-281.

Halpern, B.S., Frazier, M., Afflerbach, J., O'Hara, C., Katona, S., Lowndes, J.S., *et al.,* **2017**. Drivers and Implications of Change in Global Ocean Health Over the Past Five Years. PLoS ONE, **12**, e0178267.

Kennish, M.J., **2021**. Drivers of Change in Estuarine and Coastal Marine Environments: An Overview. *Open Journal of Ecology*, **11**, 224-239.

Miranda, N.A.F., Perissinotto, R. and Appleton, C.C., **2011**. Population Structure of an Invasive Parthenogenetic Gastropod in Coastal Lakes and Estuaries of Northern KwaZulu-Natal, South Africa. *PLoS ONE*, **6**(8), e24337.

Moslemi, J.M., Snider, S.B., MacNeill, K., Gilliam, J.F. and Flecker, A.S., **2012**. Impacts of an Invasive Snail (*Tarebia granifera*) on Nutrient Cycling in Tropical Streams: The Role of Riparian Deforestation in Trinidad, West Indies. *PLoS ONE*, **7**(6), e38806.

Nunes, M., Adams, J.B. and Van Niekerk, L., **2020**. Changes in invasive alien aquatic plants in a small, closed estuary. *South African Journal of Botany,* **135**, 317-329.

Taljaard, S., Van Niekerk, L. and Weerts, S.P., **2019**. The legal landscape governing South Africa's coastal marine environment–Helping with the 'horrendogram'. *Ocean & Coastal Management*, **178**, 104801 pp.

Van Niekerk, L. and Turpie, J.K., (eds.), **2012**. South African National Biodiversity Assessment 2011: Technical Report. Volume 3: Estuary Component. CSIR Report Number: CSIR/NRE/ECOS/ER/2011/ 0045/B. Council for Scientific and Industrial Research, Stellenbosch.

Van Niekerk, L., Adams, J.B., Bate, G.C., Forbes, N., Forbes, A., Huizinga, P., Lamberth, S.J., MacKay, F., Petersen, C., Taljaard, S., Weerts, S., Whitfield, A.K. and Woolridge, T.H., **2013**. Country-wide assessment of estuary health: An approach for integrating pressures and ecosystem response in a data limited environment. *Estuarine, Coastal and Shelf Science,* **130**, 239-251.

Van Niekerk, L., Adams, J.B., Lamberth, S.J., MacKay, F., Taljaard, S., Turpie, J.K., Weerts, S. and Raimondo, D.C., (eds,), **2019a**. South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm. CSIR report: number: CSIR/SPLA/EM/EXP/2019/0062/A. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A.

Van Niekerk, L., Adams, J.B., Allan, D.G., Taljaard, S., Weerts, S.P., Louw, D., Talanda, C. and Van Rooyen, P., **2019b**. Assessing and planning future estuarine resource use: A scenario-based regional-scale freshwater allocation approach. *Science of The Total Environment*, **657**,1000-1013.

Van Niekerk, L., Adams, J.B., James, N.C., Lamberth, S.J., MacKay, C.F., Turpie, J.K., Rajkaran, A., Weerts, S.P. and Whitfield, A.K., **2020**. An Estuary Ecosystem Classification that encompasses biogeography and a high diversity of types in support of protection and management. *African Journal of Aquatic Science,* **45**, 199-216.

Whitfield, A.K., Adams, J.B., Harrison, T.D., Lamberth, S.J., Lemley, D.A., MacKay, C.F., Van Niekerk, L. and Weyl, O.L.F., **2021**. Possible impacts of non-native plant, pathogen, invertebrate and fish taxa on the indigenous ichthyofauna in South African estuaries: A preliminary review. *Biological Invasions*, 1-19 pp.

5.2 MANGROVES

Adams, J., **2014**. Mangroves. *In*: Goble, B.J., van der Elst, R.P. and Oellermann, L. K., (eds.). *Ugu Lwethu – Our Coast. A profile of coastal KwaZulu-Natal.* KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs and the Oceanographic Research Institute, Pietermaritzburg, 40-41 pp.

Adams, J.B. and Human, L.R.D., **2016**. Investigation into the mortality of mangroves at St Lucia Estuary. *Southern African Journal of Botany*, **107**, 121-128

Adams, J.B. and Rajkaran, A., **2020**. Changes in mangroves at their southernmost African distribution limit. *Estuarine, Coastal and Shelf Science*, **247**, 1-11.

Bedin, T., **2001**. The progression of a mangrove forest over a newly formed delta in the Umhlatuze Estuary, South Africa. *Southern African Journal of Botany*, **67**, 433–438.

Peer, N., Rajkaran, A., Miranda, N.A.F., Taylor, R.H., Newman, B., Porri, F., Raw, J.L., Mbense, S.P., Adams, J.B. and Perissinotto, R., **2018.** Latitudinal gradients and poleward expansion of mangrove ecosystems in South Africa: 50 years of Macnae's first assessment. *African Journal of Marine Science*, **40**, 101-120.

Raw, J.L., Rishworth, G.M., Perissinotto, R. and Adams, J.B., **2018**. Population fluctuations of *Cerithidea decollate* (Gastropoda: Potamididae) in mangrove habitats of the St Lucia Estuary, South Africa. *African Journal of Marine Science*, **40**, 461-466.

Taylor, R., **2020.** Mangrove colonization of the Mlalazi Estuary, South Africa: a response to artificial breaching. *African Journal of Aquatic Science*.

Van Niekerk, L., Adams, J.B., Lamberth, S.J., MacKay, F., Taljaard, S., Turpie, J.K., Weerts, S. and Raimondo, D.C., (eds.), **2019.** *South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm.* CSIR report number: CSIR/SPLA/EM/EXP/2019/0062/A. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A.

5.3 SUBMERGED MACROPHYTES

Adams, J. B., **2016**. Distribution and status of *Zostera capensis* in South African estuaries — A review. *South African Journal of Botany*, **107**, 63-73.

Adams, J.B., Nondoda, S. and Taylor R.H., **2013**. Macrophytes. *In: Ecology and Conservation of Estuarine Ecosystems: Lake St Lucia as a model.* Perissinotto, R., Stretch, D.D. and Taylor, R.H., (eds.), Cambridge University Press, New York, USA. pp. 209-225. ISBN 978 1 107 01975-1.

Nunes, M., Adams, J.B. and van Niekerk, L., **2020.** Changes in invasive alien aquatic plants in a small, closed estuary. *South African Journal of Botany*, **135**, 317-32.

Van Niekerk, L., Adams, J.B., Lamberth, S.J., MacKay, C.F., Taljaard, S., Turpie, J.K., Weerts S.P. and Raimondo, D.C., (eds.), **2019**. *South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm*. CSIR report number: CSIR/SPLA/EM/EXP/2019/0062/A. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/ NBA2018/2019/Vol3/A.

Wasserman, J., Claassens, L. and Adams, J.B., **2020**. Mapping subtidal estuarine habitats using a remotely operated underwater vehicle (ROV). *African Journal of Marine Science*, **42**, 123-128.

CHAPTER 6: MARINE ENVIRONMENT

6.1 CORAL REEFS

Bouwman, H., Viljoen, I.M., Quinn, L.P. and Polder, A., **2013.** Halogenated pollutants in terrestrial and aquatic bird eggs: Converging patterns of pollutant profiles and impacts and risks from high levels. *Environ. Res*, **126**, 240-253.

Buah-Kwofie, A., Humphries, M.S., **2017**. The distribution of organochlorine pesticides in sediments from iSimangaliso Wetland Park: Ecological risks and implications for conservation in a biodiversity hotspot. *Environmental pollution*, **229**, 715-723.

Celliers, L., **2001**. *Effects of a crown-of-thorns starfish outbreak relative to other disturbances on marginal, high-latitude coral communities at Sodwana Bay, South Africa*. PhD thesis, University of Natal.

Celliers, L. and Schleyer, M.H., **2006**. Observations on the behaviour and character of an *Acanthaster planci* (L.) aggregation in a high-latitude coral community in South Africa. *Western Indian Ocean Journal of Marine Science,* **5**, 105-113.

Celliers, L. and Schleyer, M.H., **2002**. Coral bleaching on high latitude marginal reefs at Sodwana Bay, South Africa. *Marine Pollution Bulletin,* **44**, 1380-1387.

English, S., Wilkinson, C. and Baker, V., **1994.** *Survey Manual for Tropical Marine Resources*. Australian Institute of Marine Science, Townsville, 358 pp.

Floros, C., Schleyer, M.H. and Maggs, J.Q., **2013.** Fish as indicators of diving and fishing pressure on high-latitude coral reefs. *Ocean & Coastal Management,* **84**, 130-139.

Floros, C., Schleyer, M.H., Maggs, J.Q. and Celliers, L**., 2012**. Baseline assessment of high-latitude coral reef fish communities in southern Africa. *African Journal of Marine Science*, **34**, 55-69.

Glynn, P.W., Rumbold, D.G. and Snedaker, S.C., **1995**. Organochlorine pesticide residues in marine sediment and biota from the northern Florida reef tract. *Mar. Poll. Bull*, **30**, 397-402.

Glynn, P.W., Szmant, A.M., Corcoran, E.F. and Cofer-Shabica, S.V., **1989**. Condition of coral reef cnidarians from the northern Florida reef tract: Pesticides, heavy metals, and histopathological examination. *Mar. Poll. Bull*, **20**, 568-576.

Maharaj, R., Mthembu, D.J. and Sharp, B.L., **2005**. The impact of the reintroduction of DDT on malaria transmission in KwaZulu-Natal, South Africa. *S. Afr. Med. J*, **95**, 871-874.

Markey, K.L., Baird, A.H., Humphrey, C. and Negri, AP., **2007.** Insecticides and a fungicide affect multiple coral life stages. *Mar. Ecol. Prog. Ser*, **330,** 127-137.

Meyer, R., Talma, A.S., Duvenhage, A.W.A., Eglington, B.M., Taljaard, J., Botha, J.P., Verwey, J. and van der Voort, I., **2001**. *Geohydrological investigation and evaluation of the Zululand Coastal Aquifer.* Water Research Commission Report No. 221/1/1. 51 pp.

Porter, S., Schleyer, M., Sink, K. and Pearton, D., **2018a.** South African National Chapter. *In*: Gudka, M., Obura, D., Mwaura, J., Porter, S., Yahya, S. and Mabwa, R., (eds.). *Impact of the 3rd global coral bleaching event on the Western Indian Ocean in 2016*. Global Coral Reef Monitoring Network (GCRMN)/Indian Ocean Commission, 67 pp.

Porter, S.N., Humphries, M.S., Buah-Kwofie, A. and Schleyer, M.H., **2018b**. Accumulation of organochlorine pesticides in reef organisms from marginal coral reefs in South Africa and links with coastal groundwater. *Marine Pollution Bulletin,* **137,** 295-305.

Porter, S.N. and Schleyer, M.H., **2017.** Long-term dynamics of a high-latitude coral reef community at Sodwana Bay, South Africa. *Coral Reefs,* **36**, 369-382.

Porter, S. and Schleyer, M.H., **2019**. Environmental variation and how its spatial structure influences the cross-shelf distribution of high-latitude coral communities in South Africa. *Diversity,* **11**, 57.

Schleyer, M.H., Floros, C., Laing, S.C.S., Macdonald, A.H.H., Montoya-Maya, P.H., Morris, T., Porter, S.N. and Seré, M.G., **2018.** What can South African reefs tell us about the future of high-latitude coral systems? *Marine Pollution Bulletin,* **136**, 491-507.

Schleyer, M.H and Porter, S.N., **2018.** Drivers of soft and stony coral community distribution on the high-latitude coral reefs of South Africa. *Advances in Marine Biology,* **80,** 1-55.

Schleyer, M.H., **1998**. Observations on the incidence of crown-of-thorns starfish in the Western Indian Ocean. *Reef Encounter,* **23**, 25-27.

Schleyer, M.H., Kruger, A. and Celliers, L., **2008**. Long-term community changes on high-latitude coral reefs in the Greater St Lucia Wetland Park, South Africa. *Marine Pollution Bulletin,* **56**, 493-502.

Schleyer, M.H. and Tomalin, B.J., **2000.** Ecotourism and damage on South African coral reefs with an assessment of their carrying capacity. *Bulletin of Marine Science,* **67**, 1025-1042.

Séré, M.G., Tortosa, P., Chabanet, P., Turquet, J., Quod, J.P. and Schleyer, M.H., **2015**. Identification and prevalence of coral diseases on three Western Indian Ocean coral reefs. *Diseases of Aquatic Organisms*, **114**, 249-261**.**

6.2 ROCKY REEFS

Berry, P.F., **1970**. *Mating behaviour, oviposition and fertilization in the spiny lobster* Panulirus homarus *(Linnaeus).* Investigational Report of the Oceanographic Research Institute, South Africa.

Berry, P.F., **1971a.** *The spiny lobsters (Palinuridae) of the east coast of southern Africa: Distribution and ecological notes.* Investigational Report of the Oceanographic Research Institute, South Africa.

Berry, P.F., **1971b**. *The biology of the spiny lobster Panulirus homarus (Linnaeus) off the east coast of South Africa.* Investigational Report of the Oceanographic Research Institute, South Africa.

Berry, P.F., **1974**. A revision of the *Panulirus homarus*-group of spiny lobsters (Decapoda, Palinuridae). *Crustaceana,* **27**, 31-42.

Berry, P.F., **1978**. Reproduction, growth and production in the mussel, *Perna perna* (Linnaeus), on the east coast of South Africa. *Investigational Report of the Oceanographic Research Institute*, South Africa.

Berry, P.F., **1982**. Biomass and density of detritivores on a littoral rocky reef on the Natal coast, with an estimate of population production for the ascidian*, Pyura stolonifera*. *Investigational Report of the Oceanographic Research Institute*, South Africa.

De Bruyn, P.A., Moloney, C.L. and Schleyer, M.H., **2008**. Application of age-structured production models to assess oyster *Striostrea margaritacea* populations managed by rotational harvesting in KwaZulu-Natal, South Africa.

Greyling, C.J., **2018**. *Trophic transfer of metals and OCP's in organisms from a warm temperate and a subtropical intertidal rocky shore*. MSc Thesis, North-West University, 106 pp.

Jackson, L. F., **1976**. Aspects of the intertidal ecology of the east coast of South Africa. *Investl Rep. Oceanogr. Res. Inst. S.Afr,* **46**(72), 10.

Porter, S., Branch, G. and Sink, K., **2013**. Biogeographic patterns on shallow subtidal reefs in the Western Indian Ocean. *Marine Biology,* **160**, 1271-1283.

Reddy, M.M., Macdonald, A.H.H., Groeneveld, J.C. and Schleyer, M.H., **2014**. Phylogeography of the scalloped spiny-lobster *Panulirus homarus rubellus* in the southwest Indian Ocean. *Journal of Crustacean Biology,* **34**, 773-781.

Robertson, W.D., **2002**. *Management procedures for small-scale invertebrate fisheries on the KwaZulu-Natal coast, South Africa*. PhD. thesis, University of Natal.

Schleyer, M.H., **1991.** *A study of the oyster, Striostrea margaritacea (Lamarck): Final Report*. *In*: Report on research during the period April 1990 to March 1991. Unpublished Report, Oceanographic Research Institute, **70**, 7-17.

Sink, K.J., Branch, G.M. and Harris, J.M., **2005**. Biogeographic patterns in rocky intertidal communities in KwaZulu-Natal, South Africa. *African Journal of Marine Science,* **27**(1), 81-96.

Smale, M.J., **1978**. Migration, growth and feeding in the Natal rock lobster. *Investigational Report of the Oceanographic Research Institute,* South Africa.

Steyn, E., Fielding, P.J. and Schleyer, M.H., **2008.** The artisanal fishery for East Coast rock lobster *Panulirus homarus* along the Wild coast, South Africa. *African Journal of Marine Science,* **30**, 489-495.

Steyn, E. and Schleyer, M.H., **2009**. Assessment of management options for the East Coast rock lobster *Panulirus homarus. Report prepared for Ezemvelo KwaZulu-Natal Wildlife, Oceanographic Research Institute,* Durban, 26 pp.

Steyn, E. and Schleyer, M.H., **2011**. Movement patterns of the East Coast rock lobster *Panulirus homarus rubellus* on the coast of KwaZulu-Natal, South Africa. *New Zealand Journal of Marine and Freshwater Research,* **45**, 85-101.

Steyn, E. and Schleyer, M.H., **2014**. *Recreational shellfish collection in KZN: Data from 2008-2012 questionnaire surveys*, 39 pp. (ORI Unpublished Report 313).

6.3 SOFT SEDIMENTS

Atkins, J.P., Gregory, A.J., Burdon, D. and Elliott, M., **2011**. Managing the Marine Environment: Is the DPSIR Framework Holistic Enough? *Systems Research and Behavioural Science*, **28**(5), 497-508.

Birchenough, S.N.R., Reiss, H., Degraer, S., Mieszkowska, N., Borja, Á., Buhl-Mortensen, L. and Wätjen, K., **2015**. Climate change and marine benthos: A review of existing research and future directions in the North Atlantic. *Wiley*

Interdisciplinary Reviews: Climate Change, **6**(2), 203-223.

Borja, Á., Belzunce, M.J., Garmendia, J.M., Rodríguez, J.G., Solaun, O. and Zorita, I., **2011**. Impact of Pollutants on Coastal and Benthic Marine Communities. *In*: Sanchex-Bayo, F., can den Brink, P., Mann, R.M., (eds.). Ecological Impacts of Toxic chemicals, Bentham Books, 281 pp.

Breetzke, T., Parak, O., Celliers, L., Mather, A. and Colenbrander, D.R., (eds.), **2008**. Living with coastal erosion in KwaZulu-Natal: A short-term, best practice guide. KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs, Pietermaritzburg, 13 pp.

Carrier-Belleau, C., Drolet, D., McKindsey, C.W. and Archambault, P., **2021**. Environmental stressors, complex interactions and marine benthic communities' responses. *Scientific Reports*, **11**(1).

de Lange, W., Nahman, A. and Theron, A., **2008**. External costs of sand mining in rivers: Evidence from South Africa. CSIR Unpublished Report.

Driver, A., Maze, K., Rouget, M., Lombard, A.T., Nel, J., Turpie, J.K., Cowling, R.M., Desmet, P., Goodaaan, R., Harris, J., Jonas, Z., Reyers, B., Sink, K. and Strauss, T., **2005**. National Spatial Biodiversity Assessment 2004: Priorities for biodiversity conservation in South Africa. Strelitzia 1 7. South African National Biodiversity Institute, Pretoria.

Dugan, J., Airoldi, L., Chapman, M., Walker, S., Schlacher, T., Wolanski, E. and McLusky, D., **2011**. Estuarine and coastal structures: Environmental effects, a focus on shore and nearshore structures. Treatise on estuarine and coastal science, **8**, 17-41.

Ellingsen, K.E., **2002**. Soft-sediment benthic biodiversity on the continental shelf in relation to environmental variability. *Marine Ecology Progress Series*, **232**, 15-27.

Engelbrecht, L., Green, A.N., Cooper, J.A.G., Hahn, A., Zabel, M. and Mackay, C.F., **2020**. Construction and evolution of submerged deltaic bodies on the high energy SE African coastline: The interplay between relative sea level and antecedent controls. *Marine Geology*, **424**.

Fennessy, S.T. and Groeneveld, J.C., **1997**. A review of the offshore trawl fishery for crustaceans on the east coast of South Africa. *Fisheries Management and Ecology*, **4**, 135-147.

Gray, J.S. and Elliott, M., **2009**. Ecology of Marine Sediments: From Science to Management (2nd ed). New York: Oxford University Press.

Green, A.N., **2009**. Sediment dynamics on the narrow, canyon-incised and current-swept shelf of the northern KwaZulu-Natal continental shelf, South Africa. *Geo-Marine Letters*, **29**, 201-219.

Green, A.N. and MacKay, C.F., **2016**. Unconsolidated sediment distribution patterns in the KwaZulu-Natal Bight, South Africa: The role of wave ravinement in separating relict versus active sediment populations. *African Journal of Marine Science*, **38**, S65-S74.

Griffiths, C.L., Robinson, T.B., Lange, L. and Mead A., **2010**. Marine biodiversity in South Africa: an evaluation of current states of knowledge. *PLoS One 5: e12008*.

KwaZulu-Natal Provincial Government, **2019/2020**. Socio-economic Review and Outlook. ISBN: 1-920041-43-5

Lamberth, S.J., Drapeau, L. and Branch, G.M., **2009**. The effects of altered freshwater inflows on catch rates of nonestuarine-dependent fish in a multispecies nearshore linefishery. *Estuarine, Coastal and Shelf Science*, **84**, 527-538.

Lohrer, D. and Hancock, N., **2004**. Marine soft sediments: More diversity than meets the eye. *Water & Atmosphere*, **12**, 26-27.

Lutjeharms, J.R.E., **2006**. The Agulhas Current. Berlin, Springer-Verlag.

McClurg, T. 1**988**. Benthos of the Natal continental shelf. *In:* Schumann, E.H. (ed). *Coastal ocean studies off Natal, South Africa*. *Lecture Notes on Coastal and Estuarine Studies.* Volume **26**. Germany: Springer-Verlag. p. 178-208.

MacKay, C.F., Untiedt, C.B. and Hein, L., **2016**. Local habitat drivers of macrobenthos in the northern, central and southern KwaZulu-Natal Bight, South Africa. *African Journal of Marine Science*, **38**(Supplement), S105-S121.

Porter, S.N., Humphries, M.S., Buah-Kwofie, A. and Schleyer, M.H., **2018**. Accumulation of organochlorine pesticides in reef organisms from marginal coral reefs in South Africa and links with coastal groundwater. *Marine Pollution Bulletin*, **137**, 295-305.

Reiss, H., Degraer, S., Duineveld, G.C.A., Kröncke, I., Aldridge, J., Craeymeersch, J.A. *et al.*, **2010**. Spatial patterns of infauna, epifauna and demersal fish communities in the North Sea. *ICES Journal of Marine Science,* **67**, 278-293.

Scharler, U.M., Ayers, M.J., de Lecea, A.M., Pretorius, M., Fennessy, S.T., Huggett, J.A. *et al.*, **2016**. Riverine influence determines nearshore heterogeneity of nutrient (C, N, P) content and stoichiometry in the KwaZulu-Natal Bight, South Africa. *African Journal of Marine Science*, **38**(Supplement), S193-S203.

Scrutton, R., **1982**. Passive continental margins: A review of observations and mechanisms. Dynamics of passive margins. American Geophysical Union Washington DC, 5-11.

Sheppard, J.N. and MacKay, C.F., **2018**. Using historic land cover data to predict estuarine macrobenthos characteristics in South Africa. *Journal of Coastal Research*, **345**, 1116-1128

Sink, K., Holness, S., Harris, L., Majiedt, P., Atkinson, L., Robinson, T., Kirkman, S., Hutchings, L., Leslie, R., Lamberth, S., Kerwath, S., von der Heyden, S., Lombard, A., Attwood, C., Branch, G., Fairweather, T., Taljaard, S., Weerts, S., Cowley, P., Awad, A., Halpern, B., Grantham, H. and Wolf, T., **2012**. National Biodiversity Assessment 2011: Technical Report. Volume 4: Marine and Coastal

Component. South African National Biodiversity Institute, Pretoria, 325 pp.

Sink, K.J., van der Bank, M.G., Majiedt, P.A., Harris, L.R., Atkinson, L.J., Kirkman, S.P. and Karenyi, N., (eds.), **2019**. South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm. South African National Biodiversity Institute, Pretoria, South Africa.

Snelgrove, P.V.R., **1999**. Getting to the bottom of marine biodiversity: Sedimentary habitats. *Bioscience*, **49**, 129-38.

Snelgrove, P.V.R. and Butman, C.A., **1994**. Animal-sediment relationships revisited: Causes versus effects. *Oceanography and Marine Biology Annual Review*, **32**, 111-177.

Thrush, S.F. and Dayton, P.K., **2002**. Disturbance to marine benthic habitats by trawling and dredging: Implications for marine biodiversity. *Annual Review of Ecology and Systematics*, **33**(1), 449-473.

UNEP-Nairobi Convention and WIOMSA, **2015**. The Regional State of the Coast Report: Western Indian Ocean. UNEP and WIOMSA, Nairobi, Kenya, 546 pp.

Untiedt, C.B. and MacKay, C.F., **2016**. Distribution and feeding modes of macrobenthos within three oceanographic feature areas of the KwaZulu-Natal Bight, South Africa. *African Journal of Marine Science,* **38**(Supplement), S91-S104.

Van Niekerk, L., Adams, J.B., Lamberth, S.J., MacKay, F., Taljaard, S., Turpie, J.K., Weerts S. and Raimondo, D. C., (eds.), **2019**. *South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm.* CSIR report number: CSIR/SPLA /EM/EXP/2019/0062/A. South African National Biodiversity Institute, Pretoria, South Africa. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A.

6.4 PELAGIC ENVIRONMENT

Beal, L.M. and Elipot, S., **2016**. Broadening not strengthening of the Agulhas Current since the early 1990s. *Nature,* **540**(7634), 570-573.

Beal, L.M., Elipot, S., Houk, A. and Leber, G.M., **2015**. Capturing the transport variability of a western boundary jet: Results from the Agulha Current time-series experiment (ACT). *J. Phys. Oceanogr*, **45**, 1302-1324.

Beckley, L.E., **1993.** Linefish larvae and the Agulhas current. *In*: Beckley, L.E. and van der Elst, R.P., (eds.). Fish, Fishers and Fisheries (Proceedings from the second South African Marine Linefish Symposium, Durban, 23-24 October 1992). *Oceanographic Research Institute. Special repor:t No. 2.*, 57-63.

de Lecea, A.M., Smit, A.J. and Fennessy, S.T., **2016**. Riverine dominance of a nearshore marine demersal food web: Evidence from stable isotope and C/N ratio analysis. *African Journal of Marine Science,* **38**, S181-S192.

Fennessy, S.T., Roberts, M.J. and Barlow, R.G., **2016**. An editorial synthesis of the ACEP project: Ecosystem Processes in the KwaZulu-Natal Bight. *African Journal of Marine Science,* **38**, S217-S223.

Findlay, K., Best, P. and Meyer, M., **2011**. Migrations of humpback whales past Cape Vidal, South Africa, and an estimate of the population increase rate (1988–2002). *African Journal of Marine Science,* **33**, 375-392.

Fitchett, J.M., Grab, S.W. and Portwig, H., **2019**. Progressive delays in the timing of sardine migration in the southwest Indian Ocean. *South African Journal of Science,* **115**(7-8), 1-6.

Fréon, P., Coetzee, J.C., van der Lingen, C.D., Connell, A.D., O'Donoghue, S.H., Roberts, M.J., Demarcq, H., Attwood, C.G., Lamberth, S.J. and Hutchings, L., **2010.** A review and tests of hypotheses about causes of the KwaZulu-Natal sardine run. *African Journal of Marine Science,* **32**, 449-479.

Heydorn, A.E.F., Bang, N.D., Pearce, A.F., Flemming, B.W., Carter, R.A., Schleyer, M.H., Berry, P.F., Hughes, G.R., Bass, A.J., Wallace, J.H., van der Else, R.P., Crawford, R.J.M. and Shelton, P.A., **1978.** Ecology of the Agulhas Current region: An assessment of biological responses to environmental parameters in the south-west Indian Ocean. *Transactions of the Royal Society of South Africa,* **43**(2), 151-190.

Horton, M. and van der Lingen, C.D., **2019.** Comparative trophic ecology of Cape anchovy *Engraulis encrasicolus* and Natal anchovy *Stolephorus holodon* off South Africa's east coast. *African Journal of Marine Science,* **41**(3), 269-279.

Hutchings, L., Beckley, L.E., Griffiths, M.H., Roberts, M.J., Sundby, S. and van der Lingen, C., **2002**. Spawning on the edge: Spawning grounds and nursery areas around the Southern African coastline. *Marine and Freshwater Research,* **53**(2), 307-318.

Lamont, T., van den Berg, M.A. and Barlow, R.G., **2016.** Agulhas Current influence on the shelf dynamics of the KwaZulu-Natal Bight. *Journal of Physical Oceanography,* **46**(4), 1323-1338.

Lutjeharms, J. R., **2006.** The coastal oceans of south-eastern Africa (15° W). *In*: Robinson, A.R. and Brink, K.H., (eds.). *The sea*, **14**, 783-834. Harvard University Press.

Mann, B.Q., (ed.), **2013**. *Southern African marine linefish species profiles*. Oceanographic Research Institute. Special Publication No. 9, 357 pp.

Oceanographic Research Institute, (ORI). no year. Unpublished data.

Prell, W.L., Hutson, W.H. and Williams, D.F., **1979.** The Subtropical Convergence and Late Quaternary circulation in the Southern Ocean. *Mar. Micropaleontol*, **4**, 225-234.

Pretorius, M., Huggett J.A. and Gibbons M.J., **2016**. Summer and winter differences in zooplankton biomass, distribution and size composition in the KwaZulu-Natal Bight, South Africa. *African Journal of Marine Science,* **38,** S155-S168.

Roberts, M.J., van der Lingen, C.D., Whittle, C. and van den Berg, M., **2010**. Shelf currents, lee-trapped and transient eddies on the inshore boundary of the Agulhas Current, South Africa: their relevance to the KwaZulu-Natal sardine run. *African Journal of Marine Science,* **32**, 423-447.

Rouault, M., Penven, P. and Pohl, B., **2009**. Warming in the Agulhas Current system since the 1980's. *Geophys. Res. Lett*., **36**, L12602.

Schumann, E.H., **1988**. Physical oceanography off Natal. *Coastal Ocean Studies off Natal, South Africa*, **26**, 101-130.

Winter, A. and Martin, K., **1990**. Late Quaternary history of the Agulhas current. *Paleoceanography*, **5**(4), 479-486.

CHAPTER 7: HUMAN ENVIRONMENT

7.1 COASTAL ACCESS

DEA (Department of Environmental Affairs), **2014.** *National Coastal Access Strategy for South Africa 2014*. Strategy 2 to the Implementation of the ICM Act. Cape Town: Department of Environmental Affairs, 35 pp.

EDTEA (Department of Economic Development, Tourism and Environmental Affairs), **2017**. *KwaZulu-Natal Coastal Management Programme*, KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs, Pietermaritzburg.

EDTEA (Department of Economic Development, Tourism and Environmental Affairs), **2019**. *Coastal Access Situational Analysis for KwaZulu-Natal: A Support Tool for Local Municipalities.* KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs and the Oceanographic Research Institute, Durban.

Mann, B.Q., Khumalo, D., Maggs, J.Q., Els, M. and Mselegu, X., **2018.** *Boat Launch Site Monitoring System (BLSMS): 2017 Annual Report*. Unpublished Report, Oceanographic Research Institute, Durban. No. 345, 57 pp.

7.2 SMALL SCALE FISHERIES

Beckley, L.E. and Fennessy, S.T., **1996.** The beach-seine fishery off Durban, KwaZulu-Natal. *South African Journal of Zoology*, **31**(4), 186-192.

Everett, B.I., (ed.), **2014**. *An inventory and brief description of the marine and estuarine fisheries along the KwaZulu-Natal coast*. ORI Unpublished Report 312. Oceanographic Research Institute, Durban, 106 pp.

Harris, L.R., Majiedt, P., Sink, K.J., Skowno, A.L., Van Niekerk, L., Holness, S., Adams, J.B., Currie, J.C., Dunga, L.V., Lamberth, S., MacKay, C.F., Miza, S., Perschke, M. and Taljaard, S., **2019.** Pressures and ecological condition. *In*: Harris, L.R., Sink, K.J., Skowno, A.L. and Van Niekerk, L., (eds.). *South African National Biodiversity Assessment 2018: Technical Report. Volume 5: Coast*. South African National Biodiversity Institute, Pretoria, 68-145 pp.

Lambeth, S., (no year). Department of Forestry, Fisheries and the Environment (DFFE). Unpublished data.

Kramer, R.W., Mann, B.Q., Dunlop, S.W., Mann-Lang, J.B., Robertson-Andersson, D., **2017**. Changes in recreational shore anglers' attitudes towards, and awareness of, linefish management along the KwaZulu-Natal coast, South Africa. *African Journal of Marine Science,* **39**(3), 327-337.

Kyle, R., **2013**. Thirty years of monitoring traditional fish trap catches at Kosi Bay, KwaZulu-Natal, South Africa, and management implications. *African Journal of Marine Science*, **35**(1), 67-78.

Mann, B.Q., (ed.), **2013**. *Southern African Marine Linefish Species Profiles*. Special Publication, Oceanographic Research Institute, Durban, **9**, 343 pp.

Mann, B.Q. and Mann-Lang, J.B., **2020.** Trends in shore-based angling effort determined from aerial surveys – A case study from KwaZulu-Natal, South Africa. *African Journal of Marine Science.*

Mann, B.Q., Rhodes, G. and Kyle, R., **2014**. *Artisanal and subsistence fishing*. *In*: Goble, B.J., van der Elst, R.P. and Oellermann, L.K., (eds.). Ugu Lwethu – Out Coast. A profile of coastal KwaZulu-Natal. KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs and the Oceanographic Research institute, Pietermaritzburg, 110-112 pp.

McGrath, M.D., Horner, C.C.M., Brouwer, S.L., Lamberth, S.J., Mann, B.Q., Sauer, W.H.H., Erasmus, C., **1997**. An economic valuation of the South African Linefishery. *South African Journal of Marine Science,* **18**, 203-211.

Steyn, E., **2019.** *Recreational shellfish collection in KZN based on questionnaire surveys: 2015-2017.* Unpublished Report, Oceanographic Research Institute, Durban, **347**, 34.

Winker, H., Attwood, C.G. and Kerwath, S.E., **2015**. *Assessment of stock abundance of inshore fish resources included in the 'basket-of-species' to be allocated under the small-scale fisheries policy.* Linefish Scientific Working Group Unpublished Report, Department of Agriculture, Forestry and Fisheries, Cape Town, 69 pp.

7.3 RECREATIONAL FISHING

Arlinghaus, R., Cooke, S.J. and Cowx, I.G., **2010.** Providing context to the global code of practice for recreational fisheries. *Fisheries Management and Ecology,* **17,** 146-156.

Arlinghaus, R., Tillner, R. and Bork, M., **2015**. Explaining participation rates in recreational fishing across industrialised countries. *Fisheries Management and Ecology,* **22**, 45-55.

Brouwer, S.L., Mann, B.Q., Lamberth, S.J. Sauer, W.H.H. and Erasmus, C., **1997.** A survey of the South African shore angling fishery. *South African Journal of Marine Science,* **18**, 165-177.

Chale-Matsau, J.R., Govender, A. and Beckley, L.E., **1999.** Age and growth of the queen mackerel *Scomberomorus plurilineatus* from KwaZulu-Natal, South Africa. *Fisheries Research,* **44**(2), 121-127.

Cooke, S.J. and Suski, C.D., **2005.** Do we need species-specific guidelines for catch-and-release recreational angling to effectively conserve diverse fishery resources? *Biodiversity and Conservation,* **14**, 1195-1209.

Dunlop, S.W., Mann, B.Q., **2012.** An assessment of participation, catch and effort in the KwaZulu-Natal shore-based marine linefishery, with comments on management effectiveness. *African Journal of Marine Science,* **34**(4), 479-496.

Dunlop, S.W., Mann, B.Q., **2013**. An assessment of the offshore boat-based linefishery in KwaZulu-Natal, South Africa. *African Journal of Marine Science,* **35**(1), 79-97.

Everett, B.I., (ed.), **2014**. An inventory and brief description of the marine and estuarine fisheries along the KwaZulu-Natal coast. *ORI Unpublished Report 312*. Oceanographic Research Institute, Durban, 106 pp.

Garratt, P.A., **1993**. *Comparative aspects of the reproductive biology of seabreams (Pisces: Sparidae).* 247449550 clicks direct Unpublished PhD. thesis (Vol 1), Rhodes University, Grahamstown, South Africa, 175 pp.

Griffiths, M.H., **1997**. Management of South African dusky kob, *Argyrosomus japonicus* (Sciaenidae) based on per-recruit models. *South African Journal of Marine Science,* **18**, 213-228.

Griffiths, M.H., Attwood, C.G. and Thomson, R., **1999**. A new management protocol for the South African Linefishery. *In*: Mann, B.Q. (ed). Proceedings of the third Southern African Marine Linefish Symposium, Arniston, 28 April-1 May 1999. *SANCOR Occasional Report 5,* 145-156.

IOTC (Indian Ocean Tuna Commission), **2019**. Report of the 21st Session of the IOTC Working Party on Tropical Tunas. Seychelles, 21 - 26 October 2019. *IOTC–2019–WPTT21–R[E],* 146 pp.

Kramer, R.W., Mann, B.Q., Dunlop, S.W., Mann-Lang, J.B. and Robertson-Andersson, D., **2017**. Changes in recreational shore anglers' attitudes towards, and awareness of, linefish management along the KwaZulu-Natal coast, South Africa. *African Journal of Marine Science,* **39**(3), 327-337.

Lee, B., **2013.** *The biology and fishery of king mackerel, Scomberomorus commerson (Scombridae), along the southern Mozambique and KwaZulu -Natal coast*. Unpublished MSc. Dissertation, University of KwaZulu Natal, Durban, South Africa.

Maggs, J.Q., Mann, B.Q. and Cowley, P.D., **2013**. Contribution of a large no-take zone to the management of vulnerable reef fishes in the South-West Indian Ocean. *Fisheries Research,* **144**, 38-47.

Maggs, J.Q., Mann, B.Q., Potts, W. and Dunlop, S.W., **2016**. Traditional management strategies fail to arrest a decline in the catch-per-unit-effort of an iconic marine recreational fishery species with evidence of hyperstability. *Fisheries Management and Ecology,* **23**(3-4), 187-199.

Mann, B.Q. and Mann-Lang, J.B., **2020.** Trends in shore-based angling effort determined from aerial surveys – a case study from KwaZulu-Natal, South Africa. *African Journal of Marine Science,* **43** (3), 269-281.

Mann, B.Q., Fennessy, S.T., Lang, D.R. and Ogunronbi, I., **2005.** Age, growth and stock assessment of scotsman *Polysteganus praeorbitalis* and englishman *Chrysoblephus anglicus* (Pisces: Sparidae), two endemic deep-reef fishes off KwaZulu-Natal. *Oceanographic Research Institute Unpublished Report, 218,* 13 pp.

Mann, B.Q., Scott, G.M., Mann-Lang, J.B., Brouwer, S.L., Lamberth, S.J., Sauer, W.H. and Erasmus, C., **1997**. An evaluation of participation in and management of the South African spearfishery. *South African Journal of Marine Science,* **18**, 179-193.

Parker, D. and Winker, H., **2018.** *Summary of the 2017 stock assessments for the South African Linefishery and the Demersal Shark Longline Fishery.* Linefish Scientific Working Group Unpublished Report, Department of Agriculture, Forestry and Fisheries, Cape Town, 5 pp.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R. and Torres, F., **1998.** Fishing down marine food webs. *Science,* **279**(5352), 860-863.

Penney, A.J., Mann-Lang, J.B., van der Elst, R.P. and Wilke, C.D., **1999.** Long-term trends in catch and effort in the KwaZulu-Natal nearshore linefisheries. *South African Journal of Marine Science,* **21**, 51-76.

Saayman, M., Saayman, A., Zeelie, E., Potts, W., Mann, B., Weyl, O., Van der Merwe, P., Wood, A., Raemeakers, S., Cowley, P., Pledger, J., Bova, C. and Scholtz, M., **2017.** Economic significance of recreational angling in South Africa 2017. Potchefstroom: *Tourism Research in Economic Environments & Society,* 27 pp.

Sauer, W.H.H., Penney, A.J., Erasmus, C., Mann, B.Q., Brouwer, S.L., Lamberth, S.J. and Stewart, T.J., **1997.** An evaluation of attitudes and responses to monitoring and management measures for the South African boat-based linefishery. *South African Journal of Marine Science,* **18**, 147-163.

Smith, D., **2008.** *Movement, growth and stock assessment of the coastal fish Lichia amia (Teleostei: Carangidae) off the South African coast*. MSc thesis, University of KwaZulu-Natal, Durban, South Africa, 164 pp.

Steyn, E., **2019.** *Recreational shellfish collection in KZN based on questionnaire surveys: 2015-2017.* Unpublished Report, Oceanographic Research Institute, Durban, 347, 34 pp.

Steyn, E. and Schleyer, M.H., **2011.** *Assessment of management options for the East Coast rock lobster Panulirus homarus.* Unpublished Report 295, Oceanographic Research Institute, Durban. 22 pp.

Tomalin, B.J. and Kyle, R., **1998.** Subsistence and recreational mussel (*Perna perna*) collecting in KwaZulu-Natal, South Africa: Fishing mortality and precautionary management. *South African journal of Zoology,* **33**(1), 12-22.

van der Elst, R.P., **1989**. *Marine recreational angling in South Africa*. *In*: Payne, A.I.L. and Crawford R.J.M., (eds.). Oceans of life off southern Africa. Vlaeberg Publishers, Cape Town, 164-176.

van der Walt, B.A. and Govender, A., **1996.** Stock assessment of *Sarpa salpa* (Pisces: Sparidae) off the KwaZulu-Natal coast, South Africa. *South African Journal of Marine Science,* **17**, 195-204.

Winker, H., Attwood, C.G. and Kerwath, S.E., **2015.** *Assessment of stock abundance of inshore fish resources included in the 'basket-of-species' to be allocated under the small-scale fisheries policy*. Linefish Scientific Working Group Unpublished Report, Department of Agriculture, Forestry and Fisheries, Cape Town, 69 pp.

Winker, H., Kerwath, S.E. and Attwood, C.G., **2014**. Proof of concept for a novel procedure to standardise multispecies catch and effort data. *Fisheries Research,* **155,** 149-159.

7.4 NON-CONSUMPTIVE BOAT ACTIVITIES

Mann, B.Q., Khumalo, D., Daly, R., Els, M. and Mselegu, X., **2019**. *Boat Launch Site Monitoring System (BLSMS): 2018 Annual Report*. Unpublished Report, Oceanographic Research Institute, Durban, 349, 54 pp.

Mann, B.Q., Maggs, J.Q., Khumalo, M.C., Khumalo, D., Parak, O., Wood, J. and Bachoo, S., **2015**. The KwaZulu-Natal Boat Launch Site Monitoring System: A novel approach for improved management of small vessels in the coastal zone. *Ocean & Coastal Management,* **104**, 57-64.

Mann, B.Q., Pradervand, P., Maggs, J.Q. and Wintner, S., **2012**. A characterization of the paddle-ski fishery in KwaZulu-Natal, South Africa. *African Journal of Marine Science,* **34**(1), 119-130.

Penney, A.J., Mann-Lang, J.B., van der Elst, R.P. and Wilke, C.D., **1999**. Long-term trends in catch and effort in the KwaZulu-Natal nearshore linefisheries. *South African Journal of Marine Science,* **21**, 51-76.

Town and Regional Planning Commission, **1988**. *Survey of the ski-boat launching sites along the Natal coast.* Interim Policy Statement, Natal Town and Regional Planning Commission, Revision of Report 6,5.1, 116 pp.

CHAPTER 8: ECONOMIC ENVIRONMENT

8.1 PORTS AND SHIPPING

Braathen, N., (ed.), **2011.** *Environmental Impacts of International Shipping: The Role of Ports*, OECD Publishing, Paris.

DoT (Department of Transport), **2011.** *SA Maritime Transport Sector Study – Part 1: Growth of a South African Maritime Transport Industry*. www.transport.gov.za [Accessed 20 November 2020].

DoT (Department of Transport), **2017.** *Comprehensive Maritime Transport Policy (CMTP) for South Africa,* Department of Transport, Pretoria, 113 pp.

Humphreys, M., Stokenberga, A., Herrera Dappe, M., Limi, A. and Hartmann O., **2019.** *Port Development and Competition in East and Southern Africa: Prospects and Challenges.* International Bank for Reconstruction and Development / The World Bank, Washington DC.

Jones, T., **2014**. Maritime Transport and Harbours. *In:* Goble, B.J., van der Elst, R.P. and Oellermann, L.K., (eds.), *Ugu Lwethu – Our Coast. A profile of coastal KwaZulu-Natal.* KwaZulu-Natal Department of Economic Development, Tourism, and Environmental Affairs and the Oceanographic Research Institute, Pietermaritzburg, 98-101 pp.

UNCTAD (United Nations Conference on Trade and Development), **2020**. World seaborne trade. Online: UNCTAD Handbook of Statistics 2020 - World seaborne trade [Accessed 02 March 2022].

United Nations, **2019.** *Review of Maritime Transport 2019*, United Nations, New York.

8.2 TOURISM

DoT (Department of Tourism), **2017.** *National Tourism Strategy 2016 – 2026*. Department of Tourism, Pretoria, South Africa, 46 pp.

DoT (Department of Tourism), **2019.** *State of Tourism Report 2017/18.* Department of Tourism, Pretoria, South Africa, 109 pp.

Forland, E., **2012.** Tourism under global warming: Comparing Arctic summer tourists' weather preferences with regional climate statistics and projections. *Journal of Tourism management,* 1-13.

KwaZulu-Natal Tourism Authority, **2018**. *Statistics of our Tourism Sector 2018.* KwaZulu-Natal Tourism Authority, Durban, South Africa.

KwaZulu-Natal Tourism Authority, **2019**. *KwaZulu-Natal Tourism Authority Annual Report*, KwaZulu-Natal Tourism Authority, Durban, South Africa, 116 pp.

Marafa, L.M., **2008.** Integrating Sustainable Tourism Development in Coastal and Marine Zone Environment, *Open Edition Journals*, 9-10.

Seymour, J., **2006**. *Impact of 2005 Sardine Run: Top Line Summary,* KwaZulu-Natal Tourism Authority, Durban, South Africa.

TKZN (Tourism KwaZulu-Natal), **2020.** Tourism KwaZulu-Natal, Annual report 2019-2020. TKZN-Annual-report-2019-2020-1.pdf (zulu.org.za)

UNCTAD (United Nations Conference on Trade and Development), **2021**. World Investment Report. Investing in Sustainable Recovery, United Nations, Geneva 2021.

WESSA (Wildlife and Environment Society of South Africa), **2020.** *Blue flag status awarded to 64 of SA's top beaches, sustainable tourism boats and marinas.* Online: https://wessa.org.za/2019/10/25/2019-20-blue-flag-status-awarded-to-64-of-sas-top-beaches-sustainable-tourism-boats-and-marinas/ [Accessed 21 September 2020].

WTO (World Tourism Organization), **2011**. *Tourism Towards 2030 / Global Overview - Advance edition* presented at United Nations WTO 19th General Assembly - 10 October 2011, UNWTO, Madrid, 47 pp.

8.3 AQUACULTURE

Bricker, S.B., Getchis, T.L., Chadwick, C.B., Rose, C.M. and Rose, J.M., **2016.** Integration of ecosystem-based models into an existing interactive web-based tool for improved aquaculture decision-making. *Aquaculture*, **453**, 135-146.

Crass, R., **1986**. *Trout in South Africa.* MacMillian South Africa (PTY) Ltd.

DAFF (Department of Agriculture, Forestry and Fisheries), **2017**. *South Africa Aquaculture Yearbook 2016.*

DPME (Department of Planning, Monitoring and Evaluation), **2014**. *Operation Phakisa - Aquaculture.* Online:www.operationphakisa.gov.za/operations/oel/aquaculture/pages/default.aspx [Accessed 22 May 2020].

EDTEA (Department of Economic Development, Tourism and Environmental Affairs), **2018.** www.gov.za/speeches/kwazulu-natal-mission-grow-its-aquaculture-industry-20-nov-2018-0000.

Evans, L., **2009.** *Case Study: The rise and demise of the commercial shrimp farm, Amatikulu Prawns (Pty) Ltd., 1989 to 2004* (KwaZulu-Natal, South Africa). SARNISSA Project.

FAO (Food and Agriculture Organization), **1988**. *Seventh Session of the IPFC Working Party of Expects on Aquaculture*, IPFC/WPA/WPZ, RAPA/FAO, Bangkok, 1-3 pp.

FAO (Food and Agriculture Organization), **2016.** The *State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all.* Rome, 200 pp.

FAO (Food and Agriculture Organization), **2018**. *The state of world fisheries and aquaculture 2018 - Meeting the sustainable development goals.* Rome. Licence: CC BY-NC-SA 3.0 IGO.

FAO (Food and Agriculture Organization), **2019**. *Fishery and Aquaculture Statistics.* Global Aquaculture production 1950-2017 (FishStatJ), Rome.

FAO (Food and Agriculture Organization), **2020**. *Aquaculture growth potential in Africa.* World Aquaculture Performance Indicators (WAPI), Rome.

Froehlich, H.E., Gentry, R.R. and Halpern, B.S., **2017.** Conservation aquaculture: Shifting the narrative and paradigm of aquaculture's role in resource management. *Biological Conservation*, **215**, 162–168.

Hara, M., Greenberg, S., Thow, A.M., Chimatiro, S. and du Toit, A., **2017**. *Trade and investment in fish and fish products between South Africa and the rest of SADC: Implications for food and nutrition security* (Working Paper 47). Implications for Food and Nutrition Security, Cape Town.

NuLeaf Planning and Environmental, **2019.** *The proposed establishment of an Aquaculture Development Zone in Amatikulu, Kwazulu-Natal.*

TIKZN (Trade and Investment KwaZulu-Natal), **2020**. *Trade & Investment KwaZulu-Natal request proposals from service providers to develop feasibility study, business plan & conceptual designs for aquaculture development site in KwaZulu-Natal.* REFERENCE NUMBER: 3410/2020/01.

UN (United Nations), **2015**. Transforming our world: The 2030 agenda for sustainable development. UN Report #A/RES/70/1.

Viljoen, M.J., **2019.** *Determining production characteristics of dusky kob, Argyrosomus japonicus, grown in sea cages under commercial conditions in Richards Bay, South Africa.* MSc. in the Faculty of AgriSciences, Stellenbosch University.

8.4 AGRICULTURE

Agribook Digital, **2020.** *Everything you need to know about farming in South Africa.* Online: https://agribook.co.za/ [Accessed 22 September 2020].

Brand South Africa, **2016.** *SA's key economic sectors.* Online: www.brandsouthafrica.com/investments-immigration/business/investing/economic-sectors-agricultural [Accessed 21 September 2020].

Bruinsma, J., (ed.), **2003.** *World agriculture: Towards 2015/2030*, Food and Agriculture Organization, Earthscan Publications Ltd, UK, 432 pp.

Byrnes, R.M., (ed.), **1996**. *South Africa: A Country Study. Washington: GPO for the Library of Congress*, U.S. Library of Congress. Online: http://countrystudies.us/south-africa/67.htm [Accessed 20 September 2020].

Deloitte, **2016**. *KZN Agri Outlook 2016 - Building Value Chains into Africa*, Deloitte, Johannesburg, 7 pp.

DAFF (Department of Agriculture, Forestry and Fishery), **2017**. *A profile of the South African macadamia nut market value chain 2017.* Department of Agriculture, Forestry and Fishery, Pretoria, South Africa, 42 pp.

DAFF (Department of Agriculture, Forestry and Fishery), **2018.** *Economic review of South African Agriculture*, 30 pp. Compiled by the Directorate: Statistics and Economic Analysis, Private Bag X246, Pretoria 0001.

DAFF (Department of Agriculture, Forestry and Fisheries), **2019**. *South Africa Yearbook 2018/19 Agriculture*. Department of Agriculture, Forestry and Fishery, Pretoria, South Africa, 30 pp.

Farming Portal, **2020**. *South Africa's farming sectors.* Online: www.farmingportal.co.za/index.php/ farming-news/south-africa/521-south-africa-s-farming-sectors-2018 [Accessed 22 September 2020].

Goldblatt, A., **2010**. *Agriculture: Facts & Trends - South Africa.* World Wildlife Fund, 30 pp.

KZN Top Business, **2016.** KZN: *Contributing Significantly to Economic Development.* Online: KwaZulu-Natal Top Business | KZN Overview- Grant Adlam (kzntopbusiness.co.za) [Accessed 22 September 2020].

Mander, M., Ntuli, L., Diederichs, N. and Mavundla, K., **2007**. Economics of the traditional medicine trade in South Africa care delivery. *South African Health Review*, **2007**(1), 189-196.

Maree, D., **2019.** *Agricultural diversification driving economic growth in KZN*, Biz Community. Online: www.bizcommunity.com/Article/196/741/196463.html [Accessed 22 September 2020].

Ngcobo, H. and Dladla, B., **2002**. Provincial report on education and training for agriculture and rural development in Kwa-Zulu Natal. KZN Department of Agriculture.

SAMAC (Macadamias South Africa), **2018**. *Statistics on the Southern African Macadamia Industry*, SAMAC Macadamias South Africa NPC. Online: www.samac.org.za/industry-statistics/ [Accessed 22 September 2020].

SASA (South African Sugar Association), **2020**. *Socio-Economic Contribution of the South African Sugar Industry.* www.sasugarindustrydirectory.co.za/ sasi/socio-economic%20contribution%20/

Statistics SA, **2020**. *Census of commercial agriculture - KwaZulu-Natal*, Report No. 11-02-06 (2017), Statistics South Africa, Pretoria, 115 pp.

Sugden, T.**, 2014**. *Agriculture*. *In*: Goble, B.J., van der Elst R.P. and Oellermann, L.K., (eds.). *Ugu Lwethu – Our Coast: A profile of coastal KwaZulu-Natal.* Department of Economic Development Tourism and Environmental Affairs and the Oceanographic Research Institute, Pietermaritzburg, 202 pp.

Van Wyk, A., **2018.** *Earning you almost R375.000 per hectare, this must be SA's most profitable crop*, Business Insider SA 28/3/2018. Online: www.businessinsider.co.za/sas-most-profitable-crop-2018-3 [Accessed 20 September 2020].

8.5 MANUFACTURING & INDUSTRY

Department of Trade and Industry, **2011**. *Industrial Policy Action Plan 2011/12 – 2013/14.* Department of Trade and Industry, Pretoria, 178 pp.

Comrie, S. and van Rensberg, D., **2021**. Daily Maverick - All you need to know about the United Phosphorus Limited Durban warehouse. Online: www.dailymaverick.co.za [Accessed 28 March 2022].

EDTEA (Department of Economic Development, Tourism and Environmental Affairs), **2020**. *Annual Performance Plan 2019/2020 Vote 4.* KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs, Pietermaritzburg, 29 pp.

Goble, B.J. and van der Elst, R.P., **2014**. Manufacturing and Industry. *In*: Goble, B.J., van der Elst R.P. and Oellermann, L.K., (eds*.*). *Ugu Lwethu – Our Coast: A profile of coastal KwaZulu-Natal*. Department of Economic Development Tourism and Environmental Affairs and the Oceanographic Research Institute, Pietermaritzburg, 202 pp.

Gomersall, J., **2004**. The Gear legacy: Did Gear fail or move South Africa forward in development? *Development Southern Africa*, **21**, 271-288.

IDC (Industrial Development Corporation), **2020**. Region: KwaZulu-Natal. Online: www.idc.co.za/our-regions/kwazulu-natal/ [Accessed 23 November 2021].

KZN Top Business, **2016**. *KZN: Contributing Significantly to* Economic Development. KZN Top Business. Online: kzntopbusiness.co.za/site/overview [Accessed 23 November 2021].

Pouge, T., **2009**. *Wood, Paper and Pulp Sector*. *In:* Kraak, A., Sectors & Skills: The Need for Policy Alignment Edition, HSRC Press, 132-149 pp.

Provincial Planning Commission, **2019.** 2035 *Provincial Growth and Development Plan.* KZN Provincial Planning Commission, 215 pp.

SAPPI, **2021.** Saiccor Mill. Online: www.sappi.com/ saiccor-mill [Accessed 23 September 2021].

Sholtz, C., **2018.** *South African Business 2018 edition.* www.yumpu.com/en/document/view/59529666/south-african-business-2018-edition

StatsSA, **2020**. SA loses more than 600K formal sector jobs during COVID-19 lockdown. Online: www.statssa.gov.za [Accessed 28 March 2022].

TIKZN (Trade & industry KZN), **2016.** *Manufacturing Sector Overview.* Online: www.tikzn.co.za/open.php?cat=key_sectors&page=manufacturing [Accessed 23 September 2021].

Vass, J., **2005**. *The impact of HIV/AIDS on the labour market in South Africa*. Employment & Economic Policy Research Programme, HSRC. October 2005.

8.6 COMMERCIAL FISHING

Berkeley, S.A., Chapman, C. and Sogard, S., **2004.** Maternal age as a determinant of larval growth and survival in a marine fish, *Sebastes melanops*. *Ecology,* **85**, 1258-1264.

de Bruyn, P.A., **2006**. *A novel application of operational management procedures in the fisheries management of the oyster (Striostrea margaritacea) in KwaZulu-Natal, South Africa*. PhD thesis, University of KwaZulu-Natal, Durban, 276 pp.

Everett, B.I., (ed.), **2014**. *An inventory and brief description of the marine and estuarine fisheries along the KwaZulu-Natal coast.* ORI Unpublished Report 312. Oceanographic Research Institute, Durban, 106 pp.

FAO (Food and Agriculture Organization), **2021.** Indian Ocean Tuna Commission. Online: www.iotc.org [Accessed 22 November 2021].

Fennessy, S.T., **1994**. The impact of commercial prawn trawlers on linefish off the north coast of Natal, South Africa. *South African Journal of Marine Science*, **14**, 263-279.

Jordaan, G.L., Santos, J. and Groeneveld, J.C., **2018.** Effects of inconsistent reporting, regulation changes and market demand on abundance indices of sharks caught by pelagic longliners off southern Africa. *Peer J*, **6**, e5726.

Lloyd, P., Plaganyi, E.E., Weeks, S.J., Magno-Canto, M. and Plaganyi, G., **2012.** Ocean warming alters species abundance patterns and increases species diversity in an African sub-tropical reef-fish community. *Fisheries Oceanography*, **21**(1): 78-94.

Maggs, J., Parker, D., Kerwath, S., Attwood, C., da Silva, C. and Winker, H., **2017**. *The 2017 assessment of Slinger (Chrysoblephus puniceus) for the South African linefishery*. Unpublished Report, Department of Agriculture, Forestry and Fisheries, 27 pp.

Parker, D., Winker, H., da Silva, C., Mketsu, Q. and Kerwath, S., **2019**. *South African National Report to the Scientific Committee of the Indian Ocean Tuna Commission, 2019*. IOTC–2019–SC22-NR26. Department of Environment, Forestry and Fisheries, 43 pp.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R. and Torres, F., **1998.** Fishing down marine food webs. *Science*, **279**(5352), 860-863.

Penney, A. J., Mann-Lang, J.B., van der Elst, R.P. and Wilke, C.G., **1999**. Long-term trends in catch and effort in the KwaZulu-Natal nearshore linefisheries, *South African Journal of Marine Science,* **21**(1), 51-76.

Ryan, P.G., Keith, D.G. and Kroese, M., **2002.** Seabird bycatch by tuna longline fisheries off South Africa, 1998-2000. *African Journal of Marine Science*, **24**, 103-110.

Shapiro, D.Y., **1984**. *Sex reversal and sociodemographic process in coral reef fishes. In:* Potts, G.W. and Wootton, R.J., (eds.). *Fish reproduction. Strategies and* tactics. Academic Press, London, England, 103-118 pp.

Steyn, E., Montoya-Moya, P. and Schleyer, M.H., **2010**. *A stock assessment of the oyster, Striostrea margaritacea, on the KwaZulu-Natal South Coast with recommendations regarding rezoning of the fishery.* Oceanographic Research Institute, Durban. ORI Unpublished Report 289, 13 pp.

Van der Lingen, D., Coetzee, J.C. and Hutchings, L., **2010**. Overview of the KwaZulu-Natal sardine run. *African Journal of Marine Science*, **32**(2), 271-277.

8.7 COASTAL DUNE MINING

Cloete, J. and Marais, L., **2013**. Labour, Migration, Settlement and mine closure in South Africa. *Geography*, **98**, 77–84.

CSIR (Council of Scientific and Industrial Research), **2019**. A CSIR perspective on South Africa's post-mining landscape. CSIR Report No.: stelgen16928, ISBN: 978-0-7988-5641-6, CSIR, Pretoria.

Department of Transport, **2020**. KwaZulu-Natal Freight Transport Data Bank. Online: www.kzntransport.gov.za/public_trans/freight_databank/kzn/industries/mining_quarrying/index_xml.html [Accessed 23 September 2021].

Dlamini, L.Z. and Xulu S., **2019**. Monitoring Mining Disturbance and Restoration over RBM Site in South Africa Using LandTrendr Algorithm and Landsat Data. *Sustainability*, **11**(24), 1-16.

DMR (Department of Mineral Resources), **2010**. Value Chain System of South Africa's Heavy Minerals Industry. REPORT R84 /2010. Department of Mineral Resources, Pretoria, 19 pp.

Mining Weekly, **2022**. Mining can be a catalyst for growth in 2022. Online: https://www.miningweekly.com/article/mining-can-be-a-catalyst-for-growth-in-2022-2022-01-14/rep_id:3650 [Accessed 2 March 2022].

Gesch, D.B., **2005.** *Analysis of multi-temporal geospatial data sets to assess the landscape effects of surface mining.* In Proceedings of the National Meeting of the American Society of Mining and Reclamation, Lexington, USA, **19**(23), 415-432.

Global Africa, **2017**. *Contributors to the KwaZulu-Natal mining sector - The rich mineral sands of northern KwaZulu-Natal underpin the province's mining sector.* Online: Contributors to the KwaZulu-Natal mining sector | Global Africa Network [Accessed 2 March 2022].

Global Africa Network, **2017**. Contributors to the KwaZulu-Natal mining sector. Online: https://www.globalafricanetwork.com/company-news/contributors-to-the-kwazulu-natal-mining-sector/ [Accessed 2 March 2022].

Lubke, R.A., Avis, A.M. and Moll, J.B., **1996**. Post-mining rehabilitation of coastal sand dunes in Zululand, South Africa. *Landscape and Urban Planning,* **34**, 335-345.

Mentis, M.T. and Ellery, W.N., **1998**. Environmental effects of mining coastal dunes: Conjectures and refutations. *South Afr J Sci*, **94**, 215-222.

Oellermann, L.K., **2014**. Minerals and Mining. *In*: Goble, B.J., van der Elst, R.P. and Oellermann, L.K., (eds.). *Ugu Lwethu – Our Coast. A Profile of coastal KwaZulu-Natal*. KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs and the Oceanographic Research Institute, Pietermaritzburg, 202 pp.

Ott, T., **2017.** Finding the interface between mining, people, and biodiversity: A case study at Richards Bay Minerals. *J.S. Afr. Inst. Min. Metall,* **117**, 1-5.

Rossmin mining, **2021**. About Rossmin Mining. Online https://rossmin.co.za/about.html [Accessed 2 March 2022].

Swart, E., **2003.** The South African legislative framework for mine closure. *J. S. Afr. Inst. Min. Metall*, **103**, 489-492.

TIKZN (Trade and Investment KwaZulu-Natal), **2016**. Mining and beneficiation overview. Online: www.tikzn.co.za [Accessed 2 March 2022].

Williams, G.E. and Steenkamp, J.D., **2006**. *Heavy Minerals Processing at Richards Bay Minerals; South African Pyrometallurgy*. *In*: Jones, R.T., (ed.). South African Institute of Mining and Metallurgy, Johannesburg, South Africa.

8.8 SAND MINING

Ahmed, N., Anh, L.H. and Schneider, P., **2020**. *A DPSIR Assessment on Ecosystem Services Challenges in the Mekong Delta, Vietnam: Coping with the Impacts of Sand Mining Sustainability*, **12**(22): 9323.

Amponsah-Dacosta, F. and Mathada, H., **2017**. Study of Sand Mining and Related Environmental Problems along the Nzhelele River in Limpopo Province of South Africa. *Mine Water and Circular Economy*. 13th International Mine Water Associations Congress, Finland, 1259-1266.

Bendixen, M., Best, J., Hackney, C. and Iversen, L. L., **2019**. Time is running out for sand. *Nature*, **571**(7763), 29-31.

Bredin, I., Myeza, N. and Tshabalala, G., **2019**. *The uMngeni Sand Mining Project: Situation Analysis & Institutional and Regulatory Framework Assessment.* Report by the Institute of Natural Resources (INR) in association with the Duzi uMngeni Conservation Trust (DUCT) for the South African National Biodiversity.

Chamber of Mines of South Africa, **2017**. *Facts and Figures 2016.*

Chaussard, E. and Kerosky, S., **2016**. Characterization of black sand mining activities and their environmental impacts in the philippines using remote sensing. *Remote Sensing*, **8**(2).

Chevallier, R., **2014**. *Illegal Sand Mining in South Africa*. Governance of Africa's Resources Programme Policy Briefing No. 116, South African Institute of International Affairs. https://saiia.org.za/ research/illegal-sand-mining-in-south-africa/

Cooper, J., Wright, I. and Mason, T., **1999**. Geomorphology and sedimentology. *In*: Allanson, B.R. and Baird, D., (eds.). *Estuaries of South Africa*. Cambridge University Press.

Corbella, S. and Stretch, D.D., **2012**. Decadal trends in beach morphology on the east coast of South Africa and likely causative factors. *Natural Hazards and Earth System Science*, **12**(8), 2515-2527.

de Lange, W., Nahman, A. and Theron, A., **2008**. *External costs of sand mining in rivers: Evidence from South Africa.* CSIR Unpublished Report.

Demetriades, N.T., **2007**. *An inventory of sandmining operations in KwaZulu-Natal estuaries: Thukela to uMtamvuna.* Investigational report prepared by Marine and Estuarine Research for Coastwatch KZN, Ezemvelo KZN Wildlife and the Environmental Management Department of eThekwini Municipality.

Duan, H., Cao, Z., Shen, M., Liu, D. and Xiao, Q., **2019**. Detection of illicit sand mining and the associated environmental effects in China's fourth largest freshwater lake using daytime and nighttime satellite images. *Science of the Total Environment*, **647**, 606-618.

Freedman, J.A., Carline, R.F. and Stauffer, J.R., **2013**. Gravel dredging alters diversity and structure of riverine fish assemblages. *Freshwater Biology*, **58**, 261-274.

Gondo, T., Mathada, H. and Amponsah-Dacosta, F., **2019**. Regulatory and policy implications of sand mining along shallow waters of Njelele River in South Africa. *Jàmbá Journal of Disaster Risk Studies*, **11**(3), 1-12.

Heath, R., Moffett, M. and Banister, S., **2004**. *Water related impacts of small-scale mining*. WRC Report 1150/1/04.

Kędzior, R., Skalski, T. and Radecki-Pawlik, A., **2016**. The effect of channel restoration on ground beetle communities in the floodplain of a channelized mountain stream. *Periodicum Biologorum*, **118**(3), 171-184.

Koehnken, L. and Rintoul, M., **2018**. *Impacts of Sand Mining on Ecosystem Structure, Process and Biodiversity in Rivers.* WWF.

Koehnken, L., Rintoul, M.S., Goichot, M., Tickner, D., Loftus, A.C. and Acreman, M.C., **2020**. Impacts of riverine sand mining on freshwater ecosystems: A review of the scientific evidence and guidance for future research. *River Research and Applications,* December 2019, 1-9.

Kondolf, G. M., **1994**. Geomorphic and environmental effects of instream gravel mining. *Landscape and Urban Planning*, **28**(2–3), 225-243.

KwaZulu-Natal Provincial Government, **2019/2020**. *Socio-economic Review and Outlook*. ISBN: 1-920041-43-45.

Latapie, A., Camenen, B., Rodrigues, S., Paquier, A., Bouchard, J.P. and Moatar, F., **2014**. Assessing channel response of a long river influenced by human disturbance. *Catena*, **121**, 1-12.

Leal Filho, W., Hunt, J., Lingos, A., Platje, J., Vieira, L.W., Will, M. and Gavriletea, M.D., **2021**. The unsustainable use of sand: Reporting on a global problem. *Sustainability*, **13**, 3356.

Le Bot, S., Lafite, R., Fournier, M., Baltzer, A. and Desprez, M., **2010**. Morphological and sedimentary impacts and recovery on a mixed sandy to pebbly seabed exposed to marine aggregate extraction (Eastern English Channel, France). *Estuarine, Coastal and Shelf Science*, **89**(3), 221-233.

Mineral Council of South Africa, **2010**. *Facts and Figures*, 2010 Edition.

Mineral Council of South Africa, **2019**. *Facts and Figures*, 2018 Edition (September Issue).

Peduzzi, P., **2014**. *Sand, rarer than one thinks*. Article reproduced from United Nations Environment Programme (UNEP) Global Environmental Alert Service (GEAS). Environmental Development, **11**, 208-218.

Pitchaiah, P.S., **2017**. Impacts of Sand Mining on Environment – A Review. SSRG International *Journal of Geo informatics and Geological Science,* **4**(1), 1-5.

PWC, **2016**. *SA construction 4th edition* (November Issue).

Torres, A., Liu, J., Brandt, J. and Lear, K., **2017.** The high cost sand mining extracts from coastal ecosystems. Oceans Deeply, *The New Humanitarian* (September 19 Issue). https://deeply.thenewhumanitarian.org/oceans/articles/2017/09/19/the-high-cost-sand-mining-extracts-from-coastal-ecosystems.

UNEP (United Nations Environment Programme), **2019**. *Sand and Sustainability: Finding New Solutions for Environmental Governance of Global Sand Resources*. GRID-Geneva, United Nations Environment Programme, Geneva, Switzerland. https://wedocs.unep.org/handle/20.500.11822/28163

Van Niekerk, L., Adams, J., Lamberth, S., MacKay, C., Taljaard, S., Turpie, J., Weerts, S. and Raimondo, D., **2019**. *South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm*. CSIR report number: CSIR/SPLA/EM/EXP/ 2019/0062/A. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A.

Van Niekerk, L. and Turpie, J., (eds.), **2012.** *South African National Biodiversity Assessment 2011: Technical Report. Volume 3: Estuary Component*. CSIR Report No. CSIR/NRE/ECOS/ER/2011/0045/B (Vol. 3).

8.9 OFFSHORE MINING

Ahnert, A. and Borowski, C., **2000.** Environmental risk assessment of anthropogenic activity in the deep-sea. *Journal of Aquatic Ecosystem Stress and Recovery*, **7**(4), 299-315.

Biccard, A., Gihwala K, Clark BM, Mostert B, Brown E, Hutchings K, Massie V and Melidonis M., **2018.** *Desktop study of the potential impacts of marine mining on marine ecosystems and marine biota in South Africa – Final report.* Report prepared by Anchor Research & Monitoring (Pty) Ltd for Council for Geoscience. Report no. 1795/1.

Boetius, A. and Haeckel, M., **2018**. Mind the seafloor. *Science*, **359**(6371), 34-6.

Bollmann, M., **2010.** *World ocean review: Living with the oceans.* Maribus and Kiel Marine Sciences, 236 pp.

Burd, B.J., **2002**. Evaluation of mine tailing's effects on a benthic marine infaunal community over 29 years. *Marine Environmental Research*, **53**, 481-519.

Essink, K., **1999.** Ecological effects of dumping of dredged sediments; options for management. *Journal of Coastal Conservation,* **5**, 12.

Fennessy, S.T., Roberts M.J. and Barlow, R.G., **2016**. An editorial synthesis of the ACEP project: Ecosystem Processes in the KwaZulu-Natal Bight. *African Journal of Marine Science,* **38**(1), S217-S223.

German, C.R., Casciotti, K.A., Dutay, J.C., Heimbürger, L.E., Jenkins, W.J., Mills, R.A., Obata, H., Schlitzer, R., Tagliabue, A., Turner, D.R. and Whitby, H., **2016.** Hydrothermal impacts on trace element and isotope ocean biogeochemistry. *Phil. Trans. R. Soc. A*, **374**(2081), 20160035.

Hall, S.J., **1994**. Physical disturbance and marine benthic communities: Life in unconsolidated sediments. *Oceanography and Marine Biology: An Annual Review*, **32**, 179-239.

Harris, J.M., Livingstone, T., Lombard, A.T., Lagabrielle, E., Haupt, P., Sink, K., Schleyer, M. and Mann, B.Q., **2012.** *Coastal and Marine Biodiversity Plan for KwaZulu-Natal. Spatial priorities for the conservation of coastal and marine biodiversity in KwaZulu-Natal.* Ezemvelo KZN Wildlife Scientific Services Technical Report.

Hawkins, A.D., Pembroke, A.E. and Popper, A.N., **2015**. Information gaps in understanding the effects of noise on fishes and invertebrates. *Reviews in Fish Biology and Fisheries*, **251**, 39-64.

Koper, R.P and Plön, S., **2012**. *The potential impacts of anthropogenic noise on marine animals and recommendations for research in South Africa.* EWT Research & Technical Paper No. 1. Endangered Wildlife Trust, South Africa, 118 pp.

Levin, L.A., Mengerink, K., Gjerde, K.M., Rowden, A.A., Van Dover, C.L., Clark, M.R., Ramirez-Llodra, E., Currie, B., Smith, C.R., Sato, K.N. and Gallo, N., **2016**. Defining "serious harm" to the marine environment in the context of deep-seabed mining. *Marine Policy*, **74**, 245-59.

Majiedt, P.A., Sink, K.J., Reed, J., Franken, M., Holness, S., Adams, L., Perscke, M., Miza, S., Currie, J. and Dunga, V.L., **2019.** *Pressures on the Marine Environment. In*: Sink, K.J., Majiedt, P.A., van der Bank, M.G., Harris, L., Atkinson, L., Kirkmanm S. and Karenyi, N., (eds.). *National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria.

Parsons, T.R., Kessler T.A. and Guanguo, L., **1986a**. An ecosystem model analysis of the effect of mine tailings on the euphotic zone of a pelagic ecosystem. *Acta Oceanol. Sin,* **5**, 425-436.

Rona, P.A., **2008**. The changing vision of marine minerals. *Ore Geology Reviews*, **33**(3-4), 618-666.

Schleyer M.H. and Porter S.N., **2018**. Drivers of soft and stony coral community distribution on the high-latitude coral reefs of South Africa. *Advances in Marine Biology*, **80**, 1-56.

Sink, K.J., Van der Bank, M.G., Majiedt, P.A., Harris, L., Atkinson, L., Kirkman, S. and Karenyi, N., **2019**. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm.* South African National Biodiversity Institute, Pretoria, South Africa.

8.10 OIL AND GAS EXPLORATION

Atkinson, L. and Sink, K., **2008.** *Offshore Marine Protected Areas: User profiles support document*. SANBI Biodiversity Series 10.

Attwood, C., Moloney, C., Stenton-Dozey, J., Jackson, L., Heydorn, A. and Probyn, T., **2000.** *Conservation of Marine Biodiversity in South Africa*. Marine Biodiversity Status Report. Pretoria, National Research Foundation, 68–83 pp.

Bhattacharya, M. and Duval, G., **2016**. A snapshot of the geotectonics and petroleum geology of the Durban and Zululand Basins, offshore South Africa. *First Break*, **3412**, 45-51 pp.

Cordes, E.E., Jones, D.O., Schlacher, T.A., Amon, D.J, Bernardino, A.F., Brooke, S., Carney, R., DeLeo, D.M., Dunlop, K.M., Escobar-Briones, E.G., Gates, A.R., Génio, L., Gobin, J., Henry, L.A., Herrera, S., Hoyt, S., Joye, M., Kark, S., Mestre, N.C., Metaxas, A. Pfeifer, S., Sink, K., Sweetman, A.K. and Witte, U., **2016**. Environmental impacts of the deep-water oil and gas industry: a review to guide management strategies. *Frontiers in Environmental Science*, **4**, 1-25.

CCA & CMS (Crowther, Campbell & Associates cc and Centre for Marine Studies), **2001.** *Generic Environmental Management Programme Reports for Oil and Gas Prospecting off the Coast of South Africa.* Prepared for Petroleum Agency SA, October 2001.

CoastKZN, **2020.** *Documenting seismic surveys' effect on* marine life. Online: www.coastkzn.co.za/ documenting-seismic-surveys-effect-on-marine-life [Accessed 2 May 2020].

Grasso, M., **2019**. Oily politics: A critical assessment of the oil and gas industry's contribution to climate change. *Energy Research & Social Science*, **50**, 106-115.

Hawkins, A.D., Pembroke, A.E. and Popper, A.N., **2015**. Information gaps in understanding the effects of noise on fishes and invertebrates. *Reviews in Fish Biology and Fisheries*, **251**, 39-64.

Majiedt, P.A., Sink, K.J., Reed, J., Franken, M., Holness, S., Adams, L., Perscke, M., Miza, S., Currie, J. and Dunga, V.L., **2019.** *Pressures on the Marine Environment*. *In:* Sink, K.J., Majiedt, P.A., van der Bank, M.G., Harris, L., Atkinson, L., Kirkman, S. and Karenyi, N., (eds.). National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm, South African National Biodiversity Institute, Pretoria.

Petroleum Agency SA, **2013**. *Petroleum Agency SA: Explore South Africa*. Online: www.petroleumagencysa.com [Accessed 20 August 2022].

Richmond, M.D., **2016**. Oil, gas and renewable energy. *In:* Paula, J., (ed.). *The Regional State of the Coast Report: Western Indian Ocean.* UNEP and WIOMSA, Nairobi, Kenya. Western Indian Ocean, 342-359 pp.

Sink, K.J., Atkinson, L.J., Kerwath, S. and Samaai, T., **2010.** *Assessment of offshore benthic biodiversity on the Agulhas Bank and the potential role of petroleum infrastructure in offshore spatial management*. Report prepared for WWF South Africa and PetroSA through a SANBI initiative, 77 pp.

Smith, C.R., Levin, L.A., Koslow, A., Tyler, P.A. and Glover, A.G., **2008**. *The near future of the deep seafloor ecosystems. In*: Polunin N., (ed.). Aquatic ecosystems: trends and global prospects. Cambridge University Press, 334-349 pp.

United States Department of the Interior, **2007**. Notice to Lessees and Operators NTL of federal oil, gas, and sulphur leases in the outer continental shelf, Gulf of Mexico OCS Region: Implementation of Seismic Survey Mitigation Measures and Protected Species Observer Program. NTL No. 2007-G02.

CHAPTER 9: GOVERNANCE ENVIRONMENT

9.1 COASTAL MANAGEMENT

Goble, B.J., Hill, T.R. and Phillips, M.R., **2017**. An Assessment of Integrated Coastal Management Governance and Implementation Using the DPSIR Framework: KwaZulu-Natal, South Africa. *Coastal Management*, **45**(2), 107-124.

Sowman, M. and Malan, N., **2018**. Review of progress with integrated coastal management in South Africa since the advent of democracy. *African Journal of Marine Science*, April 2018.

Van der Elst, R.P. and Goble, B., **2014**. The Coastal Economy. *In*: Goble, B.J., van der Elst, R.P. and Oellermann, L.K., (eds.). *Ugu Lwethu – Our Coast. A profile of coastal KwaZulu-Natal*. KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs and the Oceanographic Research institute, Pietermaritzburg, 110-112 pp.

9.2 MARINE PROTECTED AREAS

Attwood, C.G., Mann, B.Q., Beaumont, J. and Harris, J.M., **1997a**. Review of the state of marine protected areas in South Africa. *South African Journal of Marine Science*, **18**, 341-367.

Attwood, C.G., Harris, J.M. and Williams, A.J., **1997b.** International experience of marine protected areas and their relevance to South Africa. *South African Journal of Marine Science*, **18**, 311-332.

Dames, V., Bernard, A., Floros, C., Mann, B.Q., Speed, C., Maggs, J.Q., Laing, S., Meekan, M. and Olbers, J., **2020**. Zonation and reef size significantly influence fish population structure in an established marine protected area, iSimangaliso Wetland Park, South Africa. *Ocean and Coastal Management*, **185**, 1-12.

Edgar, G.J., Stuart-Smith, R.D., Willis, T.J., Kininmonth, S., Baker, S.C., Banks, S., Barrett, N.S., Becerro, M.A., Bernard, A.T. and Berkhout, J., **2014**. Global conservation outcomes depend on marine protected areas with five key features. *Nature*, **506**(7487), 216.

Floros, C., Schleyer, M.H. and Maggs, J.Q., **2013**. Fish as indicators of fishing and diving pressure on high-latitude coral reefs. *Ocean and Coastal management*, **84**, 130-139.

Garratt, P.A., **1993**. Slinger - the final analysis? *In:* Beckley, L.E. and van der Elst, R.P., (eds.). *Fish, Fishers and Fisheries: Proceedings of the Second South African Marine Linefish Symposium*, 23-24 October 1992, Durban. Special Publication, Oceanographic Research Institute, Durban, **2**, 28-31

Harris, J., Livingstone, T., Lombard, A., Lagabrielle, E., Haupt, P., Sink, K., Schleyer, M. and Mann, B., **2012.** *Coastal and Marine Biodiversity Plan for KwaZulu-Natal Spatial priorities for the conservation of coastal and marine biodiversity in KwaZulu-Natal. Durban, South Africa*: Ezemvelo KZN Wildlife Scientific Services, 137 pp.

Harrison, T.D. and Whitfield, A.K., **2006**. Application of a multimetric fish index to assess the environmental condition of South African estuaries. *Estuaries and Coasts*, **29**, 1108-1120.

Lagabrielle, E., Lombard, A.T., Harris, J.M. and Livingstone, T.C., **2018**. Multi-scale multi-level marine spatial planning: A novel methodological approach applied in South Africa. *PLoS One*, **13**(7), 1-29.

Livingstone, T., Harris, J., Lombard, A., Smit, A. and Schoeman, D., **2018**. Classification of marine bioregions on the east coast of South Africa. *African Journal of Marine Science*, **40**(1), 51-65.

Lombard, A.T. Durbach, I., Harris, J.M., Mann-Lang, J.B., Mann, B.Q., Branch, G.M. and Attwood, C.G., **2020**. South Africa's Tsitsikamma Marine Protected Area – winners and losers. *In*: Humphreys, J. and Clark, R.W.E., (eds.). Marine Protected Areas: Science, Policy and Management. *Elsevier,* 237-260.

Mann, B.Q., Cowley, P.D. and Kyle, R., **2016a**. Estimating the optimum size for inshore no-take areas based on movement patterns of surf-zone fishes and recommendations for rezoning of a World Heritage Site in South Africa. *Ocean & Coastal Management*, **125**, 8-19.

Mann, B.Q., Harris, J. and Livingstone, T., **2014**. Marine Protected Areas. Management of the coastal and marine environment. *In*: Goble, B.J., van der Elst, R.P. and Oellermann, L.K., (eds.). *Ugu Lwethu - Our Coast. A profile of coastal KwaZulu-Natal.* KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs and the Oceanographic Research Institute, Pietermaritzburg, 174-176 pp.

Mann, B.Q., Taylor, R. and Densham, D., **1998.** A synthesis of the current status of marine and estuarine protected areas along the KwaZulu-Natal coast. *Lammergeyer*, **45**, 48-64.

Mann, B.Q., Winker, H., Maggs, J.Q. and Porter, S., **2016b**. Monitoring the recovery of a previously exploited surf-zone fish community in the St Lucia Marine Reserve using a no-take sanctuary area as a benchmark. *African Journal of Marine Science*, **38**(3), 423-441.

Nel, R., Punt, A. and Hughes, G.R., **2013**. Are Coastal Protected Areas Always Effective in Achieving Population Recovery for Nesting Sea Turtles? *PLos ONE*, ***8***(5).

O'Leary, B.C., Winther-Janson, M., Bainbridge, J.M., Aitken, J., Hawking, J.P. and Roberts, C.M., **2016**. Effective coverage targets for ocean protection. *Conservation Letters,* **9**(6), 398-404.

Pomeroy, R.S., Parks, J.E. and Watson, L.M., **2004**. *How is your MPA doing? A guidebook of natural and social indicators for evaluating MPA management effectiveness*. IUCN Gland Switzerland and Cambridge UK, 216 pp.

Roberts, C.M., O'Leary, B.C., McCauley, D.J., Cuy, P.M., Duarte, C.M., Lubchenco, J., Pauly, D., Sáenz-Arroyo, A., Sumaila, U.R., Wilson, R.W., Worm, B. and Castilla J.C., **2017**. Marine reserves can mitigate and promote adaptation to climate change. *PNAS,* **114**, 6167-6175.

RSA, **2019**. *Government notices declaring new Marine Protected Areas in South Africa*. Department of Environmental Affairs, Government Gazette No 42478, 1-83.

Schleyer, M.H., **2000**. *South African coral communities. In*: McClanahan, T., Sheppard, C. and Obura, D., (eds.). Coral Reefs of the Indian Ocean: Their Ecology and Conservation. Oxford University Press, New York, 83-105 pp.

Sink, K.J., Sibanda, S.M., Fielding, P., Skowno, A.L., Franken, M., Harris, L.R., Adams, R. and Beleta, T., **2019**. *Ecosystem Protection Level*. *In*: Sink, K.J., van der Bank, M.G., Majiedt, P.A., Harris, L.R., Atkinson, L.J., Kirkman, S.P. and Karenyi, N., (eds.). South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm. South African National Biodiversity Institute, Pretoria, South Africa.

Whitfield, A.K., **1998**. *Biology and ecology of fishes in Southern African estuaries*. Ichthyological Monographs of the J.L.B. Smith Institute of Ichthyology, No. 2, 223 pp.

Whitfield, A.K., Attwood, C.G., Cowley, P.D., Lamberth, S.J. and Mann, B.Q., **2020**. No-take Estuarine Protected Areas – the missing armour for the conservation of fishes. *Koedoe*, **62**(1).

KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs
Sub-directorate: Coastal and Biodiversity Management
Private Bag X9152
Pietermaritzburg, 3200
South Africa
Telephone: (+27-33) 264 2500
Website: www.kznedtea.gov.za