Final Summary Report 2011

Offshore Marine Protected Area Project

Systematic planning to identify focus areas for offshore biodiversity protection in South Africa

December 2011

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Recommended citation: Sink KJ, Attwood CG, Lombard AT, Grantham H, Leslie R, Samaai T, Kerwath S, Majiedt P, Fairweather T, Hutchings L, van der Lingen C, Atkinson LJ, Wilkinson S, Holness S, Wolf T. 2011. Spatial planning to identify focus areas for offshore biodiversity protection in South Africa. Final Report for the Offshore Marine Protected Area Project. Cape Town: South African National Biodiversity Institute.

Acknowledgements

The majority of funding for this project was provided through the Greentrust (a partnership between WWF and Nedbank). Additional funds for project co-ordination were provided by SANBI. The African Coelacanth Ecosystem Program assisted with funding for Dr Hedley Grantham's participation in planning and for the development of pelagic bioregions and habitats led by Dr Erwann Lagabrielle. We are grateful to Professor Hugh Possingham of the University of Queensland for additional funding for Hedley, for technical support and for his insights on the use of cost data. We thank and acknowledge Dr Jean Harris and Tamsyn Moss from Ezemvelo KZN Wildlife as well as their collaborators, who pioneered marine bioregionalisation efforts in South Africa.

The Department of Agriculture, Forestry & Fisheries (DAFF) provided data for fisheries effort, catch and bycatch data and data to support ecosystem based management of fisheries. We thank Capfish for their excellent service in mapping. Several scientists at DAFF are acknowledged for valuable input at workshops and meetings in terms of the project approach, sourcing and interpreting data and discussions about planning results. Peter Simms is acknowledged for sharing his extensive experience and for his vision and his sustained interest in this project. We thank Andy Cockcroft, Janet Coetzee, Rob Cooper, Rob Crawford, Charlene da Silva, Steve Lamberth, Marek Lipinski, Herman Oosthuizen, Kim Prochazka, Rob Tarr and Dawit Yemane as well as all members and participants of relevant demersal, small pelagic, linefish and ecosystem approach to fisheries management working groups. Diedre Williams and Morne Koen from the Department of Minerals are thanked for provision of information about mining license holders in the northern and western Cape. We thank Lebeau Labuschagne for project assistance and insights into marine mining. We are grateful to Lesley Roos from De Beers for her inputs and data verification where appropriate. Andrea Pulfrich shared her experience and helped to provide data for the diamond mining sector. Current information about petroleum activities were provided by Stephen Mills at the Petroleum Agency South Africa (PASA) and we thank Nthageni Nwendamutswu for his participation and collaboration. We thank Jessica Courtoreille and Sumaya Arendse from PetroSA for further information and collaboration. Wellheads were mapped from positions reported in the Annual summary of South African Notices to Mariners (SANHO 2009). We also acknowledge Ian Mclachlan from PASA for sharing his extensive experience.

We thank all the scientists that contributed to our understanding of offshore biodiversity pattern and process including many of the scientists already acknowledged as well as Eric Anderson, Phil Heemstra, Louise Lange, Khara Shine, Malcome Smale, Len Compagno, Butch Hulley, Tim McClurg, Alan Connell, Les Underhill and Mike Roberts. We also thank George Branch, John Field, John Rogers, Charlie Giffiths and Lynne Shannon of the University of Cape Town for advice, input and workshop participation. We thank Awie Badenhorst for his assistance and insight on small pelagic fisheries. Doug Butterworth is acknowledged for discussions and advice that helped to strengthen this project. We are very grateful to Liz Hoensen and Wayne Florence at Iziko for access to and aid with the invertebrate collection at the South African Museum and their input to the project. Original turtle home range data was acquired from Paolo Luschi, University of Pisa and Mike Meyer, Department of Environmental Affairs and this data was processed at Nelson Mandela Metropolitan University. We thank Ronel Nel and Linda Harris and Lorien Pichegru for inputs and discussions about turtles and seabirds. The Percy FitzPatrick Institute of African Ornithology and the Centre National de la Recherche Scientifique (CNRS) is acknowledged for provision of gannet and penguin tracking data. Samantha Petersen and Sean Fennessey provided guidance on use of bycatch data for the large pelagic and crustacean trawl fisheries respectively. We thank Melanie Smith for sharing her work on hake lifecycles and the South African Deep Sea Trawl Industry Association for provision of data on the distribution of spawning and large hake. Dave Japp of Capfish is acknowledged for his valuable expertise and advice, data, comments and ongoing project collaboration. We thank and acknowledge the many fisheries, mining, petroleum and shipping stakeholders for their contributions, attendance at workshops and vigorous discussions.

We acknowledge and are indebted to our colleagues from WWF South Africa including Deon Nel, Peter Chadwick, Jaco Barendse, Aaniyah Omardien, Samantha Petersen and Nicola Oakes. Cloverley Lawrence from the SANBI Marine Program helped to collate and manage data, assisted with workshops and is acknowledged for project support. Audrey Lombard and Molly Wekwete are acknowledged for the help in sustaining and supporting the project team during times of intense analysis.

Executive summary

Only 0.4% of South Africa's mainland marine territory is protected within Marine Protected Areas (MPAs) and most offshore habitat types are unprotected. The offshore expansion of South Africa's MPA network is a national priority. A collaborative five-year Offshore Marine Protected Area project was undertaken to support the identification of a network of potential offshore spatial management measures including MPAs. The network aims to represent offshore biodiversity, protect vulnerable marine ecosystems, contribute to fisheries sustainability, support the management of bycatch, and provide for research and monitoring. The implementation of offshore spatial management measures can secure remaining healthy offshore habitats, prevent further habitat damage, support stock recovery, and the sustainability of our fisheries and advance integrated ecosystem-based management of South Africa's marine territory.

Key elements of the planning approach included

- systematic biodiversity planning based on best available scientific and socio-economic research
- integrated spatial planning with spatial data for all sectors,
- collaboration among government departments,
- application of other international and local experience in MPA design and spatial planning and
- stakeholder involvement in the planning and implementation process.

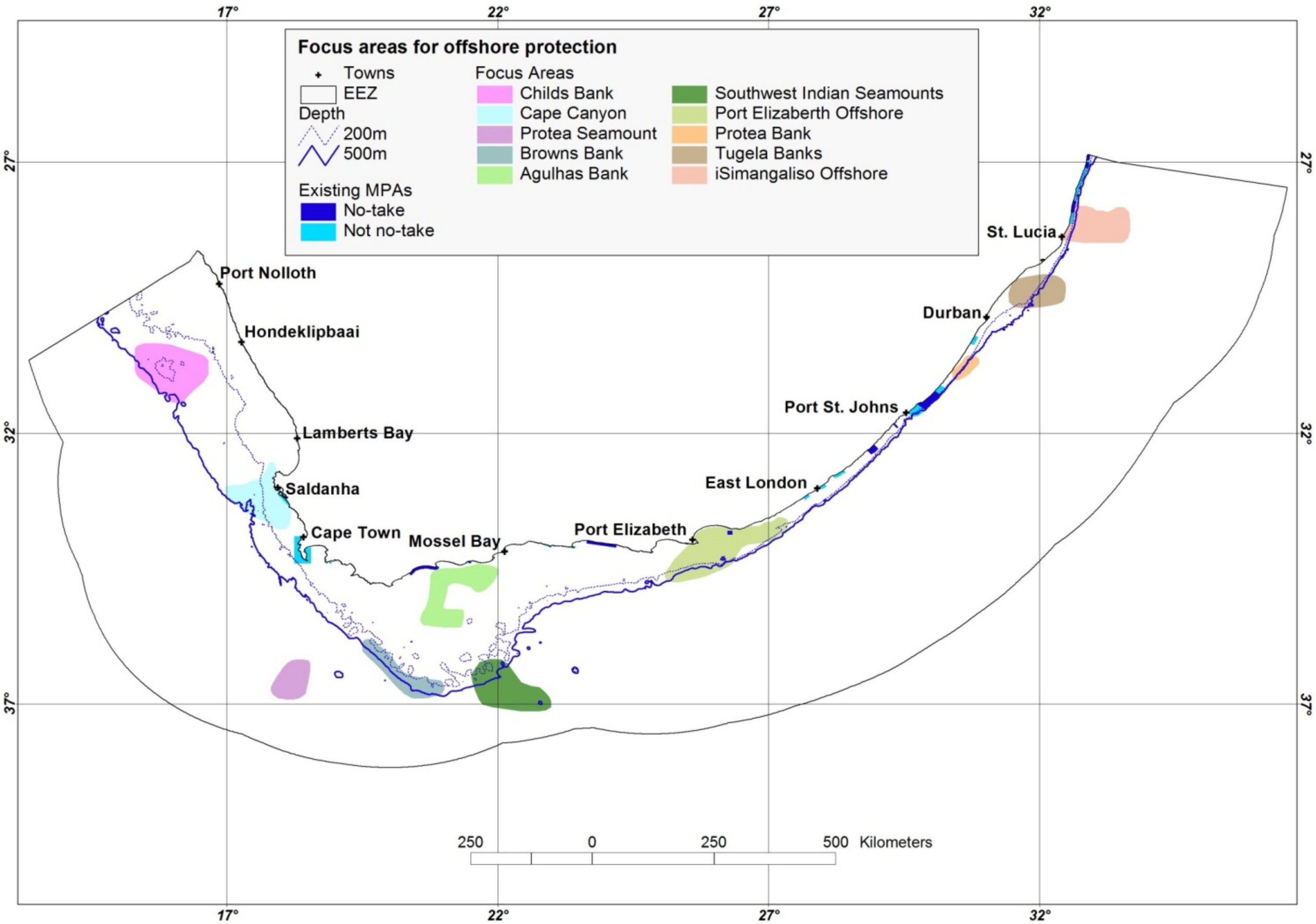
This was achieved by undertaking background research; collating substantial amounts of spatial data; engaging with relevant industries, scientists and government departments and undertaking systematic biodiversity planning analyses. Systematic planning allowed for the consideration of appropriate trade-offs among the interests of biodiversity and all relevant user groups. This approach allowed for the identification of a spatially efficient network of focus areas for offshore protection that could meet multiple objectives with minimum cost to industry. This report provides an overview of the project and further details on the key activities, events and products for each of four project phases. These include (1) project initiation, (2) data collation, research and review, (3) analyses and review and (4) final analyses and identification of focus areas. The implementation phase will constitute the final project phase.

The Offshore MPA project covered the national area from the 30 m depth contour to the current 200 nm limit of the EEZ of South Africa. The project aimed to identify focus areas for offshore protection over the next five years. The planning framework included 15 534 planning units of approximately 72 km^2 each, as well as data for 557 biodiversity, fisheries and industry features. Biodiversity pattern data including benthic and pelagic habitats, important areas for threatened species and fisheries data (including data to reflect spawning, size structure and bycatch) constituted the biodiversity input data. Spatial data on "costs" (activities not compatible with offshore protection) were used to minimise overlap between proposed focus areas for offshore protection and existing use of the offshore environment by a range of industry sectors. Cost data represented the intensity of industry activity, such as fisheries, mining and petroleum activities, in a particular area. Systematic biodiversity planning was conducted using Marxan to identify focus areas for offshore protection with the least impact on existing offshore industries.

A number of planning scenarios were analysed to identify important areas for different objectives (such as seabed protection, protection of threatened species or sector-specific bycatch reduction) and to allow for the use of different cost data layers that accounted for the appropriate offshore

industries that would be impacted under different scenarios. The results from these analyses and an integrated analysis were used to identify a final set of ten focus areas (see map overleaf) for offshore protection. The integrated analysis covered all objectives and biodiversity data and used a general cumulative cost layer that included cost data for all offshore sectors. This was the most appropriate analysis to support the identification of a set of focus areas but exploration of a range of scenarios for different objectives enabled the interpretation of the complex results from the integrated analysis. The integrated analysis was used to develop a first set of priority areas that comprised large, unfragmented areas of high importance suitable for spatial management. These areas were identified by applying a size and selection frequency threshold. Additional smaller areas that were important in the results of either the integrated or individual analyses, but were not captured in these seven areas, were added, resulting in ten final focus areas.

Focus areas are geographic areas with the highest priority for the implementation of offshore spatial management and are similar to the 42 focus areas for land-based protected area expansion as identified by the National Protected Area Expansion Strategy. The focus areas do not constitute proposed boundaries of spatial management measures but represent those areas where the most offshore biodiversity targets can be met with the least impact on offshore industries. Focus areas include the key features or processes that should be protected but do not account for the practical aspects of implementation. Appropriate spatial management measures and sensible proposed boundaries for each focus area must now be determined through finer-scale interrogation of spatial data and further stakeholder consultation. For each of the focus areas, the objectives and important implementation considerations, including key stakeholders, are specified. Rather than implementing MPAs or other spatial management measures one by one, it is recommended that a combined set (i.e. a network) of offshore MPAs and other spatial management measures be implemented simultaneously. This would enable fast tracking the expansion of South Africa’s MPA network, minimising cumulative impacts on industry through ad-hoc implementation of individual spatial management measures, and achieving a spatially efficient network that meets multiple objectives.



The ten focus areas for offshore biodiversity protection through MPAs or other types of spatial management.

Table showing focus areas for offshore biodiversity protection including key objectives, key stakeholders and management considerations.

Focal Area Name	Objectives	Key stakeholders	Potential spatial management measures & other considerations
Childs Bank	• Offshore habitat representation • Benthic protection (submarine bank, shelf, shelf edge and cold water corals) • Bycatch management (offshore trawl) • Fisheries management (demersal trawl)	Offshore trawl fishery Demersal longline fishery Petroleum Mining	Experimental closure for benthic fisheries along the shelf (linked to the SADSTIA proposed trawl closure committed as part of eco-certification conditions) is recommended. Full seabed protection is advised for the Child's Bank submarine feature and it is suggested that this is effected prior to implementation of the closure so as not to shift effort onto this potential vulnerable marine ecosystem. iBhubesi reef is also recommended as a seabed protection zone and further engagement with the petroleum sector is needed in this regard. The broader focus area is important for large pelagic fishing, seabed protection and support for the management of demersal resources. It may not be necessary to exclude pelagic fisheries from this area.
Cape Canyon	• Offshore habitat representation • Pelagic habitats and processes • Benthic protection (canyon) • Threatened species • Fisheries sustainability	Offshore trawl fishery Demersal longline fishery Small pelagic Petroleum Mining	A zoned MPA including no-take areas, seabed protection zones and zones to minimise user conflict could help achieve multiple objectives in this area. The existing MPAs (Langebaan, Sixteen Mile Beach, Marcus Island, Malgas Island and, Jutten Island) in the area should be considered for consolidation, extension or re-zoning to resolve existing resource conflicts, protect threatened species in core areas and minimise stakeholder impacts. This area is important for small pelagic fisheries who are interested in negotiation to achieve increased protection of core seabird habitat in return for access to part of the Sixteen mile beach MPA.
Protea Seamount	• Offshore habitat representation • Benthic protection (seamount)	Large pelagic Mining	Two seamounts in this area should be included within a zoned MPA that includes a no-take area and a benthic protection zone. Fishing could be excluded from the seamount where lowest effort has been exerted. A portion of the Ferro-manganese nodule habitat must be included in the MPA.
Browns Bank	• Offshore habitat representation • Benthic protection • Fisheries sustainability (demersal trawl & longlining) • Bycatch management (offshore trawl)	Offshore trawl fishery Demersal longline fishery Demersal shark South coast rock lobster	Sector specific Fishery management Areas, seabed protection zones or MPAs can be considered in this area. The Browns Bank area is an important spawning area for hake and data suggests that large hake frequent this area. As such a small closed area, including the more vulnerable hard ground habitat, could support the sustainability of the hake fisheries. There are hard grounds in this focus area which should receive formal protection (effected in legislation) from fishing and mining. Activities that affect the seabed should be prevented from extending into deeper water along this shelf edge area.
Agulhas Bank	• Offshore habitat representation • Benthic protection (deep reefs) • Bycatch management (inshore trawl) • Fisheries sustainability (linefish, hake) • Threatened species (linefish)	Inshore trawl Linefish Demersal shark South coast rock lobster Petroleum	A zoned MPA is recommended in this area to represent poorly protected habitats (especially mud and gravel habitats), protect vulnerable marine ecosystems (deep reefs, hard grounds) and support fisheries sustainability. This could include or supplement independent spatial management aimed at supporting bycatch management for the inshore trawl sector. A network of linked (but not necessarily contiguous) spatial management measures across the bank may be most appropriate in this focus area. Key features for inclusion include the Alphard Banks, the 45 Mile Bank, unrepresented gravel and mud habitats and different fish communities that are caught by the inshore trawl sector.
Southwest Indian Seamounts	• Offshore habitat representation • Benthic protection (seamount, shelf edge) • Fisheries sustainability (small pelagic species) • Bycatch reduction (large	Offshore trawl Large pelagic	A fully protected or zoned MPA is suggested to achieve the multiple objectives for this area. Very rough ground and strong currents already offer some protection to this area which has lower cost than many other shelf edge areas. Unprotected habitats of very limited spatial extent should be considered for inclusion (e.g. shelf edge gravels). Two separate management areas or a large single zoned area could be considered.

Focal Area Name	Objectives	Key stakeholders	Potential spatial management measures & other considerations
	pelagic)		
Offshore Port Elizabeth	• Offshore benthic habitat representation • Benthic protection (cold water corals, canyon, shelf edge, deep reefs) • Fisheries sustainability (kingklip, hake, linefish, squid) • Bycatch management (inshore and offshore trawl) • Threatened species (seabirds)	Inshore trawl fishery Offshore trawl fishery Midwater trawl fishery Linefishery Demersal longline fishery Demersal shark fishery Large pelagic fishery South coast rock lobster fishery Petroleum	Seabed Protection zones, Fishery Management Areas and expansion of existing or proposed Marine Protected Areas should all be considered in this complex area. There are offshore features in this area that have few alternative options for conservation which is why this area is still selected despite relatively high cost values in this area. Existing planning for the proposed Addo MPA and the existing seasonal kingklip closure should also be considered in the development of offshore spatial management measures in this area and a suite of smaller appropriately zoned areas across this focus area could be appropriate.
Protea Bank	• Offshore benthic habitat representation • Pelagic habitats and processes representation • Benthic protection (cold water corals, canyon, shelf edge, deep reefs) • Fisheries sustainability (linefish) • Threatened species (linefish)	Linefishery Recreational fishers Scuba divers Large pelagic fishery (if offshore of 20 nm)	A zoned Marine Protected Area should be considered in this area which also has potential to provide for non-consumptive resource use. This focus area was also identified by fine-scale planning conducted in KwaZulu-Natal through the SeaPlan project. The presence of 4 submarine canyons, deep reefs and 7cold water coral records highlight the need for effective seabed protection in this area although there is evidence that this area is important for pelagic processes (high frequency of fronts) and sharks. This area could contribute to reef types that are currently underprotected in the bioregion and could help recovery of overexploited linefish. Conflict between divers and fishers needs to be addressed but there is currently some voluntary effort to stop fishing in some areas.
Tugela Banks	• Offshore habitat representation • Benthic protection (cold water corals, canyon, shelf edge, deep reefs) • Bycatch management (crustacean trawl) • Threatened species (turtles, linefish)	Crustacean trawl fishery Linefishery Large pelagic Petroleum (new leases) Mining	A zoned Marine Protected Area and industry –specific fisheries or bycatch management areas should be considered for implementation in this area. Unprotected pelagic and seabed habitats (such as Natal shelf muds and gravels and submarine canyons) warrant protection in this area which has complex sedimentary patterns and complex oceanography. This area is highly productive and serves a nursery area for many species. This focus area was also identified by fine-scale planning conducted in KwaZulu-Natal through the SeaPlan project led by Ezemvelo KZN Wildlife.
iSimangaliso Offshore	• Offshore benthic habitat representation • Pelagic habitats and processes representation • Benthic protection (canyons, corals) • Bycatch management (crustacean trawl) • Fisheries sustainability (linefish) • Threatened species (turtles, linefish)	Crustacean trawl fishery Linefishery Large pelagic fishery (if extends beyond 20 nm) Recreational fishers	Southern and offshore expansion of the existing Marine Protected Area and World Heritage Site with appropriate zonation is recommended in this area. Large pelagic fishing is not permitted within 20 nm of the coastline and costs are low within this zone of the focus area. This focus area was also identified by fine-scale planning conducted in KwaZulu-Natal (SeaPlan project). This area is important for threatened species, particularly turtles and linefish. Entire canyons and cold water coral records offshore of the current MPA must be included.

Acronyms

BMAs	Bycatch Management Areas
BOFFFF	Big Old Fat Fecund Female Fish
BPZs	Benthic Protection Zones
CSIR	Council for Scientific and Industrial Research
DEAT	Department of Environmental Affairs & Tourism
EEZ	Exclusive Economic Zone
FMAs	Fishery Management Areas
GEBCO	General Bathymetric Chart of the Oceans
KZN	Kwa-Zulu Natal
MPA	Marine Protected Areas
NPAES	National Protected Area Expansion Strategy
NSBA	National Spatial Biodiversity Assessment
SANBI	South African National Biodiversity Institute
VME	Vulnerable Marine Ecosystems
WWF	Worldwide Fund for Nature

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Introduction

South Africa's first National Spatial Biodiversity Assessment (Lombard *et al.* 2004, Driver *et al.* 2005) exposed the low protection levels of offshore ecosystems and biodiversity, with less than 0.5 % of South Africa's Exclusive Economic Zone (EEZ) represented in the Marine Protected Area (MPA) network. The Offshore Marine Protected Area (MPA) project was developed to address the inshore bias in South Africa's protected area system, support ecosystem based management and spatial planning in the offshore environment and identify a potential network of offshore MPAs or other types of effective spatial management (Sink and Attwood 2008).

South Africa has committed to a representative MPA network (Government of South Africa 2010) and it is envisaged that offshore MPAs and other forms of effective spatial management can play a role in addressing many of the offshore biodiversity challenges in South Africa. These include the maintenance of seabed (benthic) habitats and the protection of vulnerable marine ecosystems (Shannon *et al.* 2006, Sink and Samaai 2009, Atkinson 2010), protection of threatened species and mitigation of incidental mortality (Crawford *et al.* 1999, Kemper *et al.* 2007, Pichegru *et al.* 2009, Petersen *et al.* 2009a,b,c and d), protection of unmanaged bycatch species (Attwood and Petersen 2010, Lombard *et al.* 2010) and the provision of reference areas for research (Attwood *et al.* 2000, Shannon *et al.* 2006, Atkinson 2010). Fisheries benefits from offshore MPAs are more controversial (Sink and Attwood 2010 and references therein) but offshore MPAs may be able to contribute to the recovery of some resources and play a role in the sustainability of others.

The Offshore MPA project was a five year project that was initiated in October 2006 and culminated in October 2011 with the identification of ten focus areas for offshore protection. The project included several phases (Table 1) with various key events and products characterising each phase. A multi-sectoral stakeholder workshop was held at the outset of the offshore MPA project to develop agreed objectives and an approach for the identification of a potential offshore MPA network. A detailed description of the rationale, objectives and proposed approach for the establishment of a representative system of offshore MPAs for the South African Exclusive Economic Zone (EEZ) and territorial waters is published in Sink and Attwood (2008) but key aspects are also included in this report. Detailed background research was a key element in most phases of this project. This included scientific research to support project objectives (Sink and Attwood 2010), facilitate mapping of biodiversity features (Sink and Samaai 2009) and their underlying processes (Lagabrielle 2009), research to understand offshore industries and other sectors (Atkinson and Sink 2008), investigation of obstacles and opportunities in terms of previous efforts to proclaim offshore MPAs (Sink 2008), a legal review (Moolla and Currie 2007) and research to support best practice, practical and effective design (Sink and Attwood 2010) and compliance (Kroese 2009,) with any recommended spatial management measures. Stakeholder engagement was a key element in all phases of this project. This included one-on-one engagement with individual sectors including individual companies, rights holders and government departments and their staff and engagement across sectors. Such engagement centred on the communication of project objectives and the proposed approach and dialogue aimed at understanding and resolving industry concerns. The implementation of offshore spatial management measures can be considered as the final project phase

Table 1: Overview of different project phases including key activities, events and products.

Project phase (timelines)	Project activities	Key events (date)	Products
Project initiation (October 2006-September 2007)	• Background research (biodiversity, oceanography, fisheries and MPA science considerations, legal review, investigation of obstacles to offshore MPA establishment, research to understand stakeholders, impacts of offshore activities, existing governance frameworks and key considerations). • Scientific workshops and meetings to discuss objectives, data and planning approach. • Stakeholder engagement (with individual sectors and across sectors, including individual businesses and broad business associations) to communicate project objectives, proposed approach and understand industry considerations and concerns	Multi-sectoral workshop to discuss and develop agreed project objectives and approach (22 June 2007) Scientific workshop datasets (5 June 2008)	• Report on South African law pertaining to marine protected area declaration and management (Moolla and Currie 2007) • Workshop reports (Sink 2010) • Report on constraints and opportunities for the proclamation of offshore Marine Protected Areas in South Africa (Sink 2008) • Offshore user profiles (Atkinson and Sink (2008) • Guidelines for Offshore Marine Protected Areas in South Africa (Sink and Attwood 2008)
Data collation, additional research and review of data inputs and targets (October 2007-October 2009)	• Scientific meetings and research to support mapping of biodiversity features and fisheries data • Ongoing stakeholder engagement to produce maps of industry activity • Research of case studies to assess potential effect of Offshore MPAs and identify key lessons from elsewhere • Research and engagement to support target setting • Research to support effective compliance	Open day for all sectors to view maps and agree on targets for use in analyses (1 October 2009)	• Pelagic bioregions report (Lagabrielle 2009) • Final maps of all input layers (biodiversity and industry data) and agreed targets for use in planning analyses • Review of case studies to guide the establishment of an Offshore Marine Protected Area Network for South Africa (Sink and Attwood 2010). • Report to support the development of compliance strategies for offshore Marine Protected Areas (Kroese 2009)
Analyses and review (October 2009-March 2010)	• Development of spatial planning framework • Systematic planning analyses • Discussion and review of results	Stakeholder workshop to review planning results and identify concerns (11 March 2010)	• Offshore systematic biodiversity planning framework and spatial layers • Draft Offshore MPA project report showing interim planning results (Sink *et al.* 2010). • Offshore Marine Protected Area Stakeholder Workshop Report (Sink 2010) • Identified stakeholder concerns
Final analyses and identification of focus areas (April 2010 – December 2011)	• Targeted stakeholder meetings to address concerns raised at March 2010 stakeholder workshop • Revised systematic planning analyses and planning team meetings to identify focus areas • Project reporting	-	• Maps showing systematic planning results • Focus areas for offshore spatial management • Final project report (December 2010)

Study Area

The study area for the Offshore MPA project extended from the 30 m depth contour to the current 200 nm limit of the EEZ of South Africa. A systematic conservation plan for the Price Edward Islands (Lombard *et al.* 2007) identified priority areas for protection in the EEZ around South Africa's island territory in the sub-Antarctic.

Objectives and planning approach

The objectives of offshore spatial management measures including MPAs and the proposed planning approach were discussed, debated, refined and eventually agreed upon at a multi-sector stakeholder workshop in the first year of the project (Sink and Atwood 2008).

The overall goal of the Offshore MPA project is the establishment of an ecologically representative network of effective spatial management measures including MPAs. The more specific objectives of this proposed network include

- to protect representative examples of all marine habitat types in all bioregions of South Africa
- to contribute to the long term persistence of offshore biodiversity and its underlying processes,
- to contribute to fisheries sustainability and ecosystem based management of resources,
- to provide undisturbed areas for scientific study and long term monitoring,
- to advance integrated spatial planning and management arrangements for the EEZ, and
- to promote appropriate non-consumptive use of the offshore marine environment.

The Offshore MPA project aimed to support the implementation of the National Protected Area Expansion Strategy (Government of South Africa 2010). The project aimed to identify focus areas for offshore protection over the next 10 years.

Key elements of the planning approach included:

- systematic planning based on best available scientific and socio-economic research,
- integrated spatial planning framework with shared spatial data among sectors,
- collaboration between and within government departments,
- application of other experience in MPA design and spatial planning,
- stakeholder involvement in the planning and implementation process,
- consideration of appropriate tradeoffs among the interests of biodiversity and different user groups,
- raising awareness of potential MPA benefits, design principles and supporting science,
- identifying and addressing implementation and management concerns including compliance and monitoring for Offshore MPAs, and
- ongoing alignment with policy & legislation.

Systematic biodiversity planning

Systematic biodiversity planning, also known as systematic conservation planning, allows for an integrated approach that facilitates the consideration of multiple data sets in a transparent process to identify priority areas for spatial biodiversity management (Margules & Pressey 2000). The aim is to identify potential areas that meet a pre-defined set of biodiversity objectives (expressed as quantitative targets) usually at minimum economic cost. Much of the science has focused on methods to identify areas where objectives can be achieved with minimum impact to industry (Pressey 1999, Ball & Possingham 2000, Possingham *et al.* 2000, Watts *et al.* 2009).

The South African EEZ provides considerable economic opportunities and supports many commercial activities. This project reviewed existing activities in our EEZ to provide profiles for various offshore sectors (Atkinson and Sink 2008). These include petroleum, diamond mining, fishing, maritime transport, waste disposal, submarine communications, science and marine defense sectors. We collated data covering all sectors to reflect areas of importance to offshore industries as far as possible and have explicitly considered most economic sectors in our plan. Spatial data on "costs" (activities not compatible with offshore protection) were used to minimise overlap between proposed focus areas for offshore protection and existing use of the offshore environment by a range of industry sectors. Cost data represent the intensity of industry activity, such as fisheries, mining, petroleum or shipping, in a particular area. We also engaged all relevant government departments as well as industry stakeholders through meetings, workshops and an open day held in October 2009. The purpose of the open day was to present all data sets and maps and identify concerns prior to spatial analyses (Table 1).

Principles for Offshore MPA network planning

Six categories of principles were developed to address the different objectives for a proposed Offshore MPA network. These principles drew from the technical advice on the establishment of a network of Marine Protected Areas published by the Convention on Biological Diversity (Secretariat of the Convention on Biological Diversity 2004), from the Guidelines for Offshore Marine Protected Areas in South Africa (Sink and Attwood 2008) and from publications that recommend spatial management as a component of the implementation of the Ecosystem Approach to Fisheries Management (Cochrane 2004, Shannon *et al.* 2006, Petersen *et al.* 2009a,b and d, Atkinson 2010, Attwood and Petersen 2010, Lombard *et al.* 2010). These principles were operationalised through quantitative targets and design considerations used in a planning framework.

The six key principles on which the planning for offshore spatial management was based are:

1. *Representation of biodiversity pattern* – targets to protect a percentage of biogeographic regions, depth zones and specific habitat types to ensure the proposed offshore MPA network is representative. Targets were higher for habitats likely to support Vulnerable Marine Ecosystems (VMEs) while lower targets were set for recently defined pelagic "habitats" due to greater uncertainty in our understanding of how well these habitats represent pelagic biodiversity.

2. *Protection of threatened species* - considerations to protect areas of importance for threatened species. This includes breeding and foraging areas.

3. *Supporting fisheries sustainability* – targets that contribute to fisheries sustainability for target species e.g. maintenance of size and age structure, protection of nursery grounds and spawning areas.

4. *Mitigation of fisheries bycatch and incidental mortality* – targets or design considerations to minimise bycatch and incidental mortality of non-target species. In this sense, bycatch refers to species that are not managed through quotas.

5. *Industry considerations* – cost layers and design considerations to minimize the impact of biodiversity management on industry or other sectors. Examples include identifying priorities further away from ports, avoiding active mining areas and selecting outside of fishing areas or in areas of low fishing effort where possible.

6. *MPA viability and adequacy* – design considerations that relate to the size, spacing, shape and orientation of potential spatial management interventions. This category includes practical aspects needed to constrain the design into an implementation framework e.g. alignment with other spatial grids and ensuring compatibility with vessel monitoring systems. This principle is more pertinent to the last phase of this project that needs to identify proposed boundaries within each of the focus areas identified.

The role of MPAs and other types of spatial management

The National Protected Area Expansion Strategy (Government of South Africa 2010) defines Protected Areas as “areas of land or sea that are protected by law and managed mainly for biodiversity conservation”. This is the broad definition used by the Offshore MPA planning team and biodiversity conservation is considered to include habitat and species representation and protection. An important aspect of biodiversity conservation includes objectives that are also pertinent to fisheries management such as the protection of vulnerable habitats, the protection of spawning or nursery areas, maintenance of age and size structure and genetic diversity as well as the management of bycatch. Protected areas recognised in the National Environmental Management: Protected Areas Act (Act 57 of 2003) are considered formal protected areas in the NPAES, this includes MPAs proclaimed through South Africa’s Marine Living Resources Act. Although the Marine Living Resources Act implies that MPAs should be no-take, in reality most MPAs are zoned. In this report, Offshore MPAs are interpreted more broadly than MPAs as declared by the MLRA. Offshore MPAs could include declared MPAs and their existing different types of zones (such as no-take and limited use zones), new types of zones such as seabed protection zones, Fishery Management Areas and other types of spatial management that can provide adequate protection to some components of marine biodiversity. South Africa’s Marine Living Resources Act accommodates the declaration of Fishery Management Areas that could include permanent, long term or seasonal closures to protect nursery areas or spawning aggregations. Fishery Management Areas could also include areas declared for the purpose of bycatch management and such areas could be permanent or temporary closures that are triggered when bycatch limits are reached or time-area closures to protect certain species during specific periods. The inclusion of broader fishery management objectives along with other biodiversity objectives can lead to a more spatially efficient network of areas than if these objectives were not integrated.

The Offshore MPA project aimed to identify focus areas for offshore spatial management to meet a range of different biodiversity and fishery management objectives. Priority areas for different types of objectives were explored and it is recognised that protection may be apportioned between different types of spatial management including different zones of MPAs but also other types of spatial management. For example, seabed protection could be achieved within both no-take and seabed protection zones of an MPA or even within a Fishery Management Area. It is important to distinguish between areas protected by legislation versus those that may be less formally protected through current management (e.g. through permit conditions) . Unless long-term security is associated with such areas, they cannot be considered a strong form of protection (Government of South Africa 2010). It is for this reason that it is recommended that protection measures should be affected in legislation such as through declared zoned MPAs or Fishery Management Areas. This would afford greater security and long term protection and such areas should be considered as contributing to the protected area objectives of South Africa. It is recognized that an experimental approach may be the best approach in the initial phases to allow the efficacy of any implemented spatial management to be assessed and to guide the further development of a network of effective spatial management measures in the offshore environment.

Planning methods

Planning steps

The basic steps undertaken in this systematic planning initiative are outlined in Figure 1. The plan relies on maps of both biodiversity features or processes and industry activity. The plan also requires targets that quantitatively express a region's biodiversity or conservation goals. These targets typically include goals for representation as well as persistence and define how much of each biodiversity pattern (e.g. habitat types or species), or biodiversity processes (e.g. spawning areas), should be included under spatial management. Once biodiversity patterns and processes have been mapped, the study area is subdivided into planning units. The contribution of each planning unit to the quantitative targets is then calculated. The constraints to the plan are generally referred to as costs. Cost data reflect the cost or impact to industry and are needed to minimize the impact of proposed spatial management areas on offshore users. As with the biodiversity data, cost data are assigned to each planning unit and then an efficient and practical spatial arrangement of planning units is identified to meet all the targets with the least cost. Various software systems are available to perform these calculations, for example C-Plan and Marxan (Pressey 1999, Ball & Possingham 2000, Possingham *et al.* 2000, Game and Grantham 2008) and Marxan with zones (Watts *et al.* 2009). Software outputs show which planning units should be considered for spatial management although actual boundaries are often different from this because the software outputs need to be constrained into a practical implementation framework.

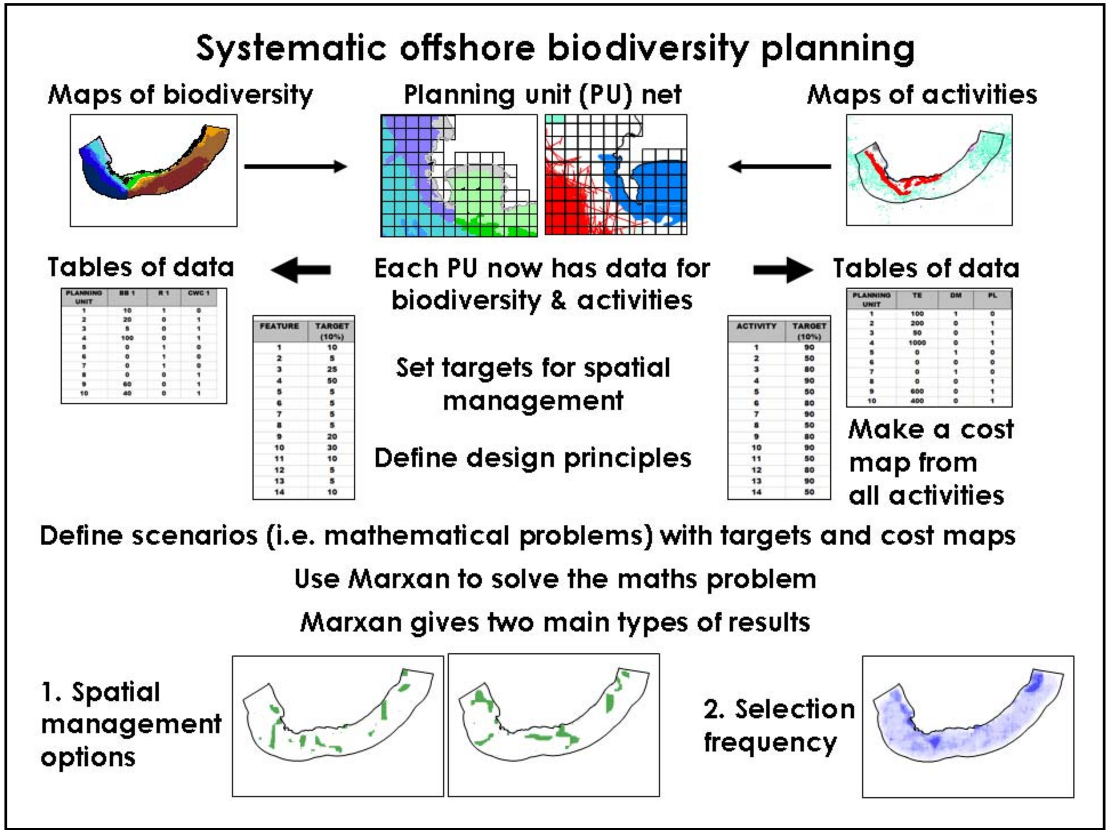


Figure 1: A summary of the basic systematic planning steps used in this study.

Planning units

A planning unit size of 5x5 minutes (or nautical miles) i.e. approximately 72 km^2 was used in this study. This planning unit size aligns with the smallest grid size used in research at the time of project initiation. A total of 15 534 planning units including data for 557 biodiversity, fisheries and industry features were included in the planning framework. Biodiversity pattern data included benthic and pelagic habitats, threatened species and fisheries data to reflect spawning, size structure and bycatch. The cost data used in the Offshore MPA project were data to minimize the impact of proposed spatial management areas on different industry sectors. Cost data represent the intensity of industry activity and a range of cost data layers were compiled for this project. Some cost layers reflected the importance to a single sector and the cumulative cost layer accounted for the cumulative importance to fisheries, mining, petroleum and shipping industries. Cost data were treated similarly to biodiversity data: they were subdivided by the planning units and a cost value was assigned to each planning unit.

Planning software

The software used for his study was Marxan (Possingham *et al.* 2000, Game & Grantham 2008) although we also experimented with Marxan with zones (Watts *et al.* 2009). These programs allow multiple objectives and constraints to be factored into the spatial planning framework. Analyses were aimed at avoiding marine industries and the clustering of potential spatial management solutions into compact areas while trying to meet biodiversity targets (Figure 1). Marxan with zones allowed for the exploration of different solutions for different types of zones (using different cost layers) although the very large data sets and substantial numbers of zones used in this project could not be analysed in a single integrated analysis with this software, limiting its application in planning. A number of planning scenarios were used to support the identification of focus areas for offshore spatial management (Table 2).

Marxan identifies areas by minimizing a multivariate objective function (see Possingham *et al.* 2000 and Game and Grantham 2008 for more technical details on the algorithm and software). The objective function is a combination of the total cost of selection, a penalty for any of the targets that are not met and the total sum of boundary lengths in the solution, multiplied by a modifier. The selection algorithm used in this software is simulated annealing (Possingham *et al.* 2000). This objective function is designed so that the lower the value the better. Marxan analyses were run 1000 times for each scenario analysed for this project. This allowed for ‘the ‘selection frequency’ and the most efficient solution’ to be calculated for each scenario (see Box 1 for How to interpret the maps in this report). The ‘selection frequency’ solution shows the number of times a particular planning unit was selected across all runs and provides an indication of biodiversity conservation importance. The ‘most efficient solution’ is the solution that best achieves the objective function over all runs. As Marxan provides only a near-optimal solution, a range of different solutions are usually provided by the runs. For example if a planning unit has a selection frequency of 80, then it was selected by 800 of 1000 runs. Other planning units might also be important but there is more flexibility where targets can be achieved.

The objective function in Marxan:

$$\overbrace{\sum_{PUs} Cost}^{1} + \underbrace{BLM \sum_{PUs} Boundary}_{3} + \overbrace{\sum_{ConValue} SPF \times Penalty}^{2} + \underbrace{CostThresholdPenalty(t)}_{4}$$

where

1. The total cost of the solution
2. The penalty for not adequately meeting quantitative targets
3. The total solution boundary length, multiplied by a modifier
4. The penalty for exceeding a preset cost threshold (which was not used in our analysis but is an option for solving a different type of problem).

Input data

Spatial data used in the Offshore MPA project included both biodiversity pattern and process data (including data to support fisheries management), maps to reflect existing spatial management measures and cost data. Appendix 1 details the data source and targets for each data layer or feature included in the spatial planning framework.

Biodiversity pattern

Planning for a representative offshore MPA network required improved biodiversity data for the South African EEZ. The offshore MPA team met with experts to refine data collated during the 2004 National Spatial Biodiversity Assessment (Lombard *et al.* 2004), revise broad biogeographic and depth patterns and improve offshore habitat data (Sink 2010). In addition, further work was undertaken to identify vulnerable marine ecosystems (Sink and Samaai 2009) using guidelines developed by the Food and Agriculture Organisation (FAO 2009). A pelagic bioregionalisation exercise was undertaken to plan for the inclusion of different pelagic ecosystems (Lagabrielle 2009).

Benthic biodiversity

The bathymetry data used in the 2004 National Spatial Biodiversity Assessment (Lombard *et al.* 2004) was updated with new data from the General Bathymetric Chart of the Oceans (GEBCO) in 2009. GEBCO is a continuous ocean bathymetric model largely generated by combining quality-controlled ship depth soundings, with predicted depths between the sounding points guided by satellite-derived gravity data. The bioregions and biozones from the 2004 NSBA (Lombard *et al.* 2004) were updated using improved bathymetric information and expert recommendations about finer-scale biodiversity patterns on the shelf and shelf edge. In addition, new research in progress has revealed new information about benthic fish and invertebrate communities. Some areas, previously considered to be different, were shown to be similar and some previous areas of difference were therefore no longer considered valid. For example, although the inshore and inner shelf of the previous Namaqua and south-western Cape bioregions are still considered distinct, the outer shelf of the west coast is now considered to be a single biozone, the southern Benguela outer shelf, as opposed to the previous Namaqua and southwestern Cape subphotic biozones. This pattern is reflected in demersal fish assemblages as well as benthic invertebrates (Shine 2007, Louise Lange, University of Cape Town pers. comm.).

The offshore MPA project recognised six benthic bioregions, the Southern Benguela, Agulhas, Natal, Delagoa, Southeast Atlantic and Southwest Indian (Figure 3). There are 20 benthic biozones (Figure 4) that nest within these bioregions and each biozone is considered to support distinct species assemblages that need to be included in a representative MPA network. The Southern Benguela, Agulhas, Natal and Delagoa bioregions include the coast, continental shelves and shelf break whereas the more offshore Southeast Atlantic and Southwest Indian bioregions include the slope and upper basins. The inshore (supratidal, intertidal and shallow subtidal) components of the bioregions are outside of the primary planning area of this project. On the west coast and the Agulhas Bank, the continental shelf was classified into inner and outer shelf areas separating at 150 m on the west coast and 100 m on the south coast. This was based on expert workshop discussions as well as the published literature (Roel 1987, Smale *et al.* 1993). The narrow shelf in the Natal and Delagoa bioregions and the lack of evidence for finer scale pattern within shelf communities there, led to single shelf biozones in these bioregions (Figure 3).

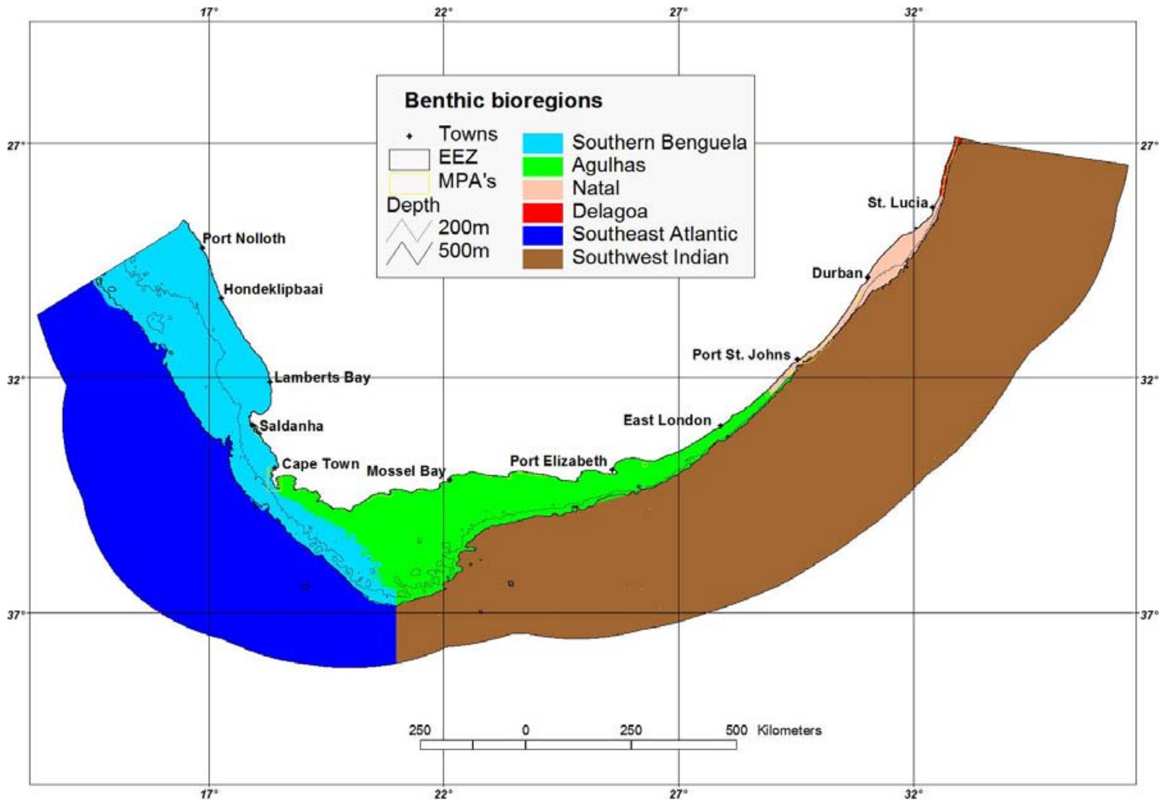


Figure 2: The benthic bioregions used for planning for a representative offshore MPA network for South Africa.

The shelf edge zone includes the shelf break, a distinct habitat that warrants explicit consideration in MPA planning because there are differences in the composition and abundance of species between these zones (e.g. commercial target species such as hake and bycatch species such as rattails). In the Southern Benguela bioregion, the shelf edge extends from the 350m depth contour or the shelf break line (whichever is shallowest), to the 500m depth contour or the shelf break line (whichever is deepest). In the Agulhas, Natal and Delagoa bioregions, the shelf edge extends from the shelf break line to the 500m depth contour. However, in a few places the shelf is extremely steep and the 500m depth contour lies shallower than the shelf break line. In these cases, there is no shelf edge habitat (such as at the southern tip and eastern edge of the Agulhas Bank and near Port St Johns). This complexity is the result both of the shelf break being defined by angle rather than depth contour and that the shelf break line being less accurate than the depth contours. The shelf break line consequently weaves over both the 350 and 500m contour lines.

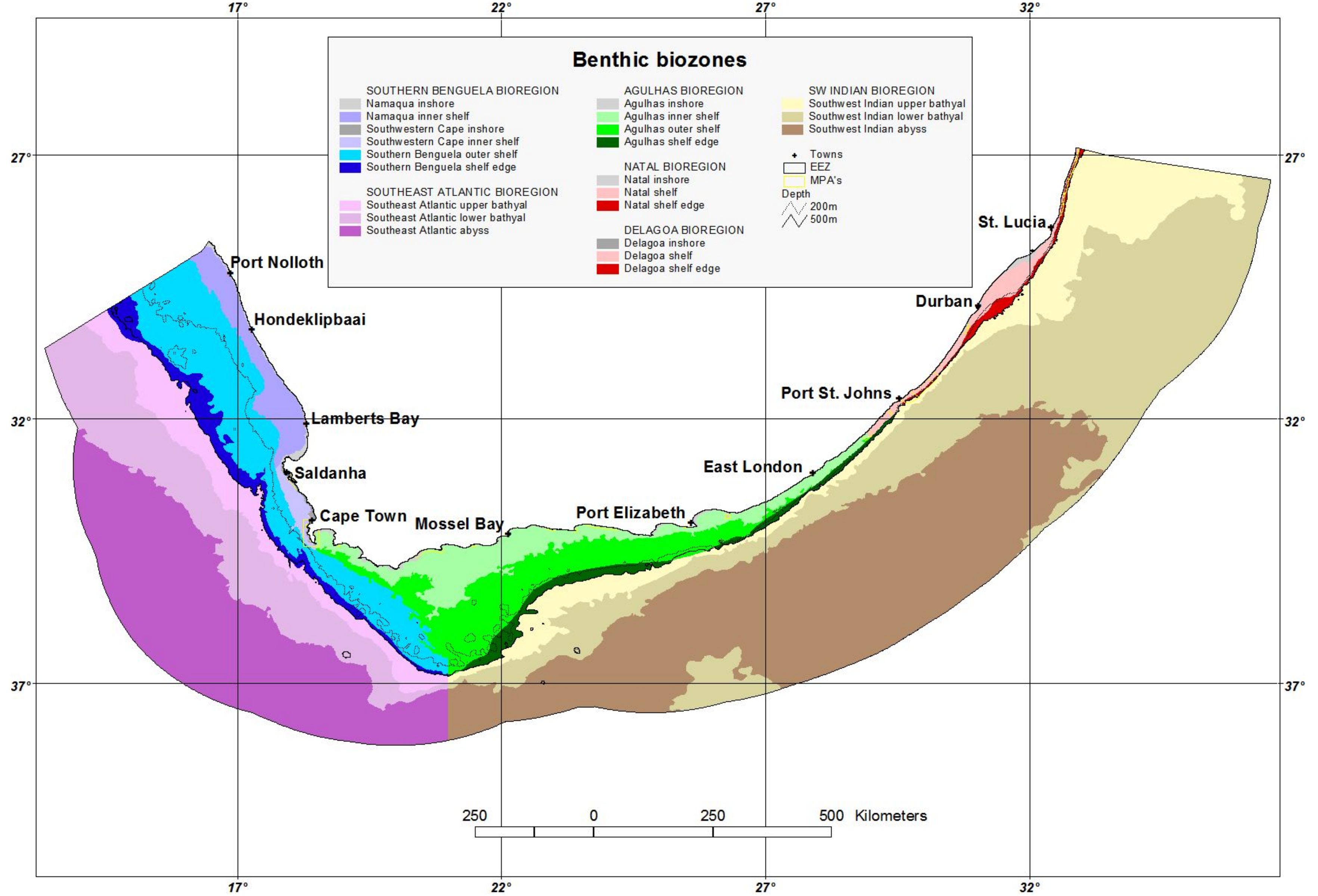


Figure 3: The benthic biozones used for planning for a representative offshore MPA network for South Africa

The continental slope was subdivided into two zones, the upper and lower bathyal. The upper bathyal extends from the deeper boundary of the shelf edge to the 1800 m depth contour. The lower bathyal in each bioregion extends from 1800 m to the 3500 m bathymetric contour. The abyss is defined as the area below 3500 m.

The offshore geology and sediment type maps were refined by classifying different seabed geological types (Dingle *et al.* 1987) or sediment types by bioregion or biozone, depending on expert advice. A total of 22 geological seabed types and 30 sediment types were considered during planning. For example, two different types of ferro-manganese deposits were classified, Atlantic and Southwest Indian as this geological seabed type is expected to support different fauna in different bioregions. Similarly, 5 different types of mud were considered as experts suggest that fauna inhabiting muddy sediments are different in different bioregions. Low oxygen areas were mapped and targeted as these habitat types may support unique biodiversity.

A further potentially distinct habitat type that warrants representation in an offshore MPA network is a habitat forming sponge of the genus *Suberites*. We mapped data from demersal research trawls (Africana and Fridtjof Nansen) to identify dense areas where large volumes (100-1 555 kg per trawl) were collected in demersal research trawls for this species. Although this sponge has been identified as a potential invasive species (Uriz 1985), this is considered unlikely and large volumes of sponges were documented along the west coast during the first trawls in these areas (Gilchrist 1921). Current thinking by sponge systemetists is that the *Suberites* from southern Africa's west coast is a distinct species that varies from *Suberites tylobtusa* from the Red Sea (Toufiek Samaai, Department of Environment pers. comm.).

Potentially vulnerable marine ecosystems (FAO 2009) that were explicitly considered in planning include the shelf break, seamounts, submarine canyons, hard grounds, submarine banks, deep reefs and cold water coral reefs or species records of reef building cold water corals (Figure 4). The shelf break, defined by the line of greatest change in slope angle between the continental shelf and ocean basins (using the Lombard *et al.* 2004 line) was also classified by bioregion with the Benguela, Agulhas, Natal and Delagoa shelf break considered as distinct features. Images acquired by submersible and remotely operated vehicle (ROV) from three bioregions (Delagoa, Agulhas and Benguela) has shown distinct fauna on the shelf edge in different bioregions (Sink and Samaai 2009). Two types of seamounts were recognised, Atlantic and Southwest Indian Ocean, as seamounts in these different bioregions were considered likely to support different fauna. Submarine canyons were also classified according to the updated bioregions following the approach of Lombard *et al.* 2004.

Hard grounds and deep reefs were classified by biozone because of the high biodiversity and variability in rocky areas and hard grounds within different biogeographic regions and depth zones as recognised by experts engaging in offshore research (Sink, Samaai, Leslie, Kerwath, Atkinson and Attwood). Deep reef data was acquired from SANBI's Reef Atlas Project and linefish scientists from the Department of Agriculture, Forestry & Fisheries. The latter include research position and linefish species richness data (corrected for sampling effort) from the National Marine Linefish System (commercial, boat-based data from 2003-2009 i.e. since medium term rights were instituted). Areas of high linefish species richness were considered as potential reef areas in each bioregion and were used during planning. Only one submarine bank, Child's Bank, is known from South Africa and there is one reported cold water coral reef, Ibhubesi reef, off the west coast. In addition, national museum records for three species of reef-building cold water corals, *Lophelia pertusa, Goniochorella dumosa* and *Solensmilia variabilis* (Sink and Samaai 2009) were included in the planning analyses. Records for the latter two species were classified by bioregion but species records data for *L. pertusa* has only been recorded in one bioregion.

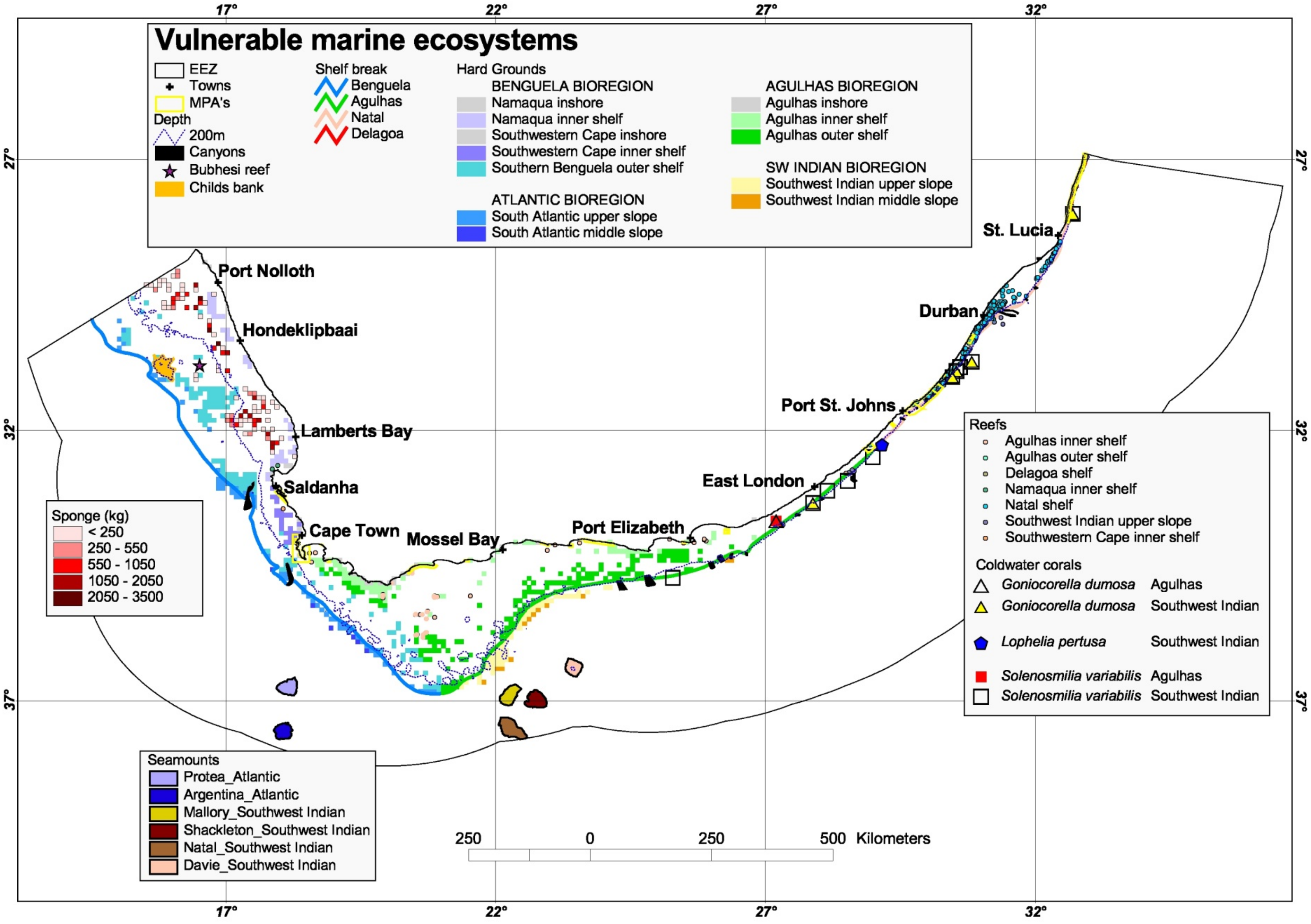


Figure 4: Potential Vulnerable Marine Ecosystems in the South African offshore environment.

Pelagic biodiversity

A pelagic bioregionalisation exercise was undertaken to support MPA planning for pelagic biodiversity and resources (Lagabrielle 2009). Three pelagic bioregions, 7 pelagic biozones and 16 pelagic "habitats" were mapped hierarchically by cluster analysis (Figure 9). The bioregions separate primarily on the basis of productivity and temperature. The Benguela pelagic bioregion (A) is the only one to occur in the high productivity cluster while two bioregions, the temperate Atlantic and Indian Ocean (B) and the warm Indian and Agulhas pelagic bioregions (C), occur within a low productivity cluster. Pelagic biozones separate on the basis of the mean, maximum and standard deviation (variability) in productivity, sea surface temperature and chlorophyll. Pelagic habitats separate on the basis of these same variables as well as the distribution of cyclonic and anti-cyclonic eddies, sea surface temperature fronts and chlorophyll fronts.

Table 2: Key characteristics of the 16 pelagic "habitats" recognised within the South African EEZ. Note that descriptions of key characteristics are within a South African and not a global context.

Pelagic habitat	Key characteristics
Aa1	Very high productivity, high chlorophyll and very cold water (SST mean = 15.2°C) over the shallow gradually sloping shelf of the upwelling centre of the Benguela current in the south Atlantic ocean.
Ab1	High productivity and high but highly variable chlorophyll and cold water (SST mean 16.6°C) due to upwelling over the deeper gradually sloping Benguela shelf area of the south Atlantic ocean. Very high occurrence of chlorophyll fronts.
Ab2	Medium - high productivity and very high variability in productivity, medium-high chlorophyll and very high variability in chlorophyll over the shallow gently sloping Agulhas Bank. Moderate Indian Ocean temperatures that are highly variable (SST mean = 19.1 °C).
Ab3	Medium productivity, cold to moderate Atlantic temperatures (SST mean=18.3°C) moderate chlorophyll related to the eastern limit of the Benguela upwelling on the outer shelf. Relatively frequent chlorophyll fronts occur in this bioregion.
Bc1	Moderate temperature (SST mean = 21.8°C), low productivity, frequent sea surface temperature fronts in the Open Indian Ocean.
Bc2	Moderate temperature (SST mean = 20.5°C) with moderate variability in the Indian Ocean Abyss. Medium frequency of eddies. Agulhas retroflection and transition toward the Southern Ocean.
Bb1	Atlantic Ocean abyss, consistently low productivity and temperature (SST mean 18.7C°), low frequency of SSF fronts
Bb2	Consistently low productivity, chlorophyll and temperature (SST mean = 18.5°C) Atlantic open ocean transition toward the Benguela upwelling region.
Ba2	Cool (SST = 19.4°C) Indian and Atlantic ocean steep slope or abyss with high frequency of eddies, medium frequency of SST fronts, Agulhas retroflection transition to the Southern Ocean.
Ba1	Cold (SST mean 17.8°C) Atlantic Ocean abyss with consistently low chlorophyll and medium frequency of eddies.
Ca1	Warm (SST mean = 24.1°C) Indian ocean abyss with very low chlorophyll, productivity and frequency of chlorophyll fronts.
Ca2	Consistently warm (SST mean 23.5°C) Indian ocean water with low variability in temperature and very low frequency of chlorophyll fronts.
Cb1	Very warm (SST mean = 24.9°C) stable Indian Ocean shelf ecosystem with low frequencies of eddies and SST fronts.
Cb2	Warm (SST mean = 23.5°C) core of the Agulhas current along the steep slope of the eastern continental shelf. High variability in primary productivity and chlorophyll with moderate to high chlorophyll values.
Cb3	Cool (SST mean = 21.2°C) Indian Ocean water with high productivity and high but variable chlorophyll, associated with very frequent SST and chlorophyll fronts.
Cb4	Moderate (SST mean = 22.2°C) Indian Ocean water with frequent SST and chlorophyll fronts associated with the steep outer shelf

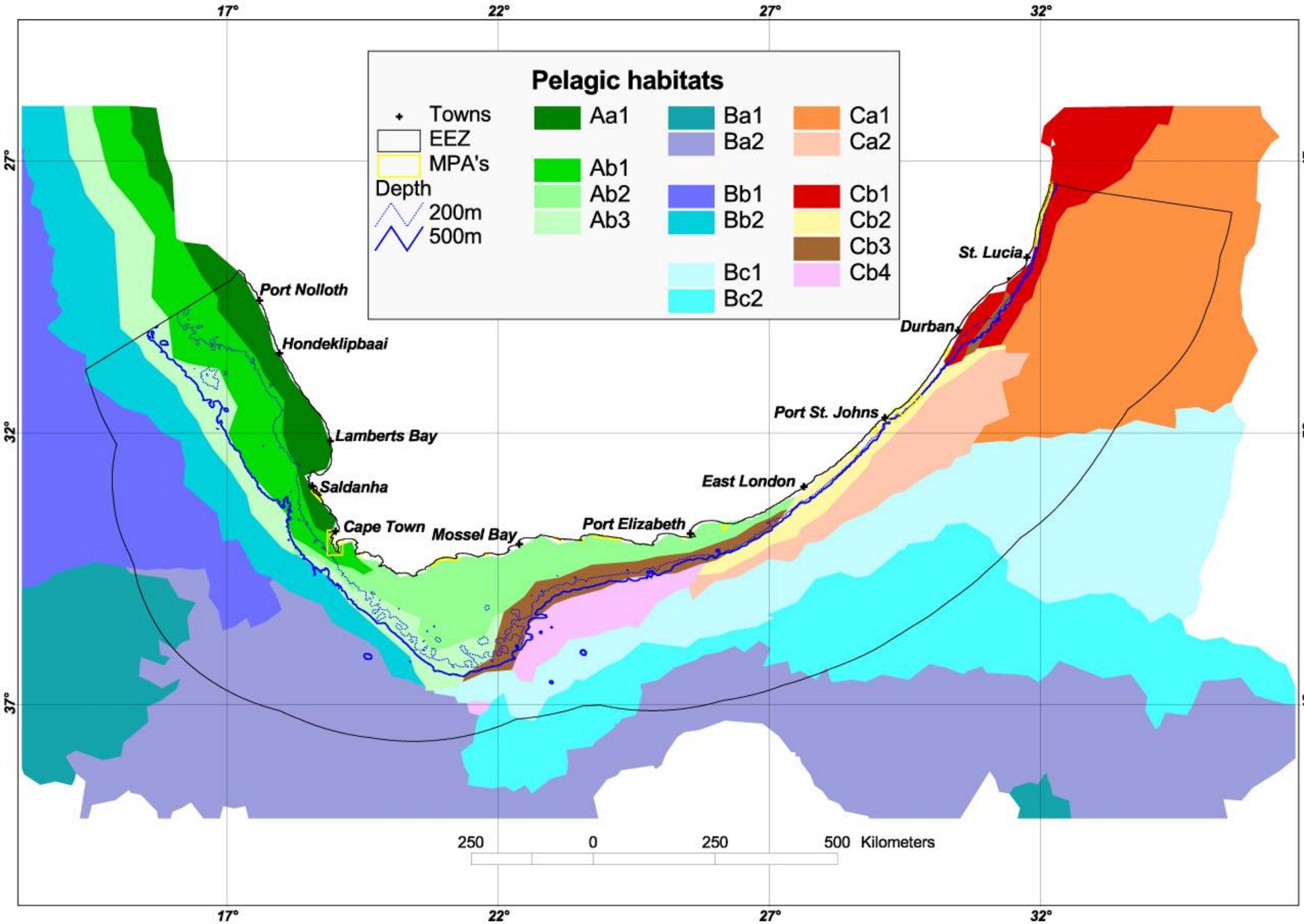


Figure 5: Pelagic "habitats" as classified by Lagabrielle (2009). These "habitats" represent areas of the ocean with distinct oceanographic and physical characteristics such as productivity, sea surface temperature, chlorophyll, bathymetry, slope and the frequency of eddies, sea surface temperature fronts and chlorophyll fronts. The classification does not capture three-dimensional aspects of the water column.

Retention

One of the data layers included in initial analyses was data that reflects results from a Lagrangian particle-tracking model that simulated oceanographic conditions to predict areas of retention. Although retention data was initially included in planning analyses, this resulted in a strong bias in selected priority areas towards areas of high retention (Sink *et al.* 2010 Offshore MPA project draft report). Retention data was excluded from the final analyses presented in this report because of stakeholder feedback that it is more important to consider pathways of successful transport (such as the pathways described by Hutchings *et al.* 2002) rather than retention when planning for MPAs and other types of spatial management. Also, export of eggs, larvae and fish from MPAs or Fishery Management areas may be a key objective if such areas are to contribute to fisheries sustainability and it was therefore considered inappropriate to bias the spatial management network to areas of high retention.

Threatened species

Planning accounted for threatened seabirds, turtles and linefish species of conservation concern. Home range data for leatherback turtles was provided through a collaborative satellite tracking project led by the Department of Environment. The primary area of utilisation for this endangered species in South Africa is on the north east coast adjacent to the nesting beaches protected within the existing St Lucia and Maputaland MPAs within the iSimangaliso Wetland Park World Heritage site. These MPAs only extend 3 nm offshore whereas the turtles spend a substantial amount of time further offshore. Foraging areas of Cape cormorants and Bank cormorants and the African penguin were mapped based on expert knowledge. And additional foraging range data for Cape gannets and penguins was acquired from the Percy FitzPatrick Institute of African Ornithology, University of Cape Town. Distribution maps of linefish species or groups of species that are of conservation concern were prepared from data provided by the Department of Agriculture, Forestry & Fisheries, based on catch information. Data was corrected for effort and log transformed. The groups were selected based on the results of a prioritisation exercise (Lamberth and Joubert, in prep.) and the data were extracted from the National Marine Linefish System for the years 2003-2009. Linefish of conservation concern that are not also listed as priority fisheries species by Lamberth and Joubert (in prep.) were considered as threatened species. This includes all rockcods, scotsman, false englishman, seventy four, king soldier and dane.

Fisheries sustainability

The only spatial data available for spawning and/or nursery areas was for squid *Loligo reynaudi*, sardines *Sardinops sagax*, anchovy *Engraulis encrasicolus* and the two hake species *Merluccius capensis* and *M. paradoxus*. Data reflecting the known positions of squid nests and catch data for squid eggs in demersal research trawls was included to plan for benthic protection of squid spawning areas. In addition, data reflecting the density of large fish was available for sardines, anchovy and the two hake species. These data were taken into account as a result of evidence that larger fish contribute more eggs that survive better than smaller fish (Beckley and van der Lingen 1999, Berkeley 2004, Field *et al.* 2008). This is commonly referred to as the big old fat fecund female fish (or BOFFFF) hypothesis). Although the spawning areas described by Hutchings *et al.* (2002) were also mapped, the coarse nature of the schematics produced in that publication led experts to recommend that such areas are not targeted in the plan.

A catch layer was developed for conservation priority linefish species that are also priority species for fisheries based on commercial catch data extracted from the National Maine Linefish System. The total individual catch of slinger, dageraad, red stumpnose, englishman, red steenbras, kob species, poenskop, geelbek and 'redfish' for each planning unit was mapped to account for the explicit consideration of these groups in offshore MPA planning. Data was corrected for effort and log transformed. Spatial spawning and nursery area information were not available but catch data were used to reflect abundance and to attempt to improve the sustainability of this sector, which was declared in a state of emergency in 2000.

Bycatch

Bycatch data was acquired for four fisheries sectors, namely; the inshore and offshore demersal trawl sectors, the crustacean trawl fishery in KwaZulu-Natal and the large pelagic fishery. Data for the inshore trawl sector was extracted from the observer program through a related project (Attwood and Petersen 2010). Observer data was acquired from the Department of Agriculture, Forestry & Fisheries and Capfish for the crustacean trawl, offshore trawl and large pelagic sectors. Additional data reflecting the abundance of key bycatch species (kingklip and monk) was obtained from the government demersal research trawl database. In addition, commercial catch records were used to examine the distribution of bycatch species for all the demersal trawl fisheries sectors.

Existing spatial management

A new map reflecting current spatial management was compiled in 2009, updating the MPA map produced by Lomabard *et al.* (2004) with new proclaimed and proposed MPAs and other spatial management measures. The only new MPA declared since 2004 is the Still Bay MPA. In addition, the seasonal kingklip closure, all trawl exclusion areas and experimental small pelagic exclusion areas (Dassen Island, Riy Banks and St Croix) were mapped from 2008 permit conditions and included in the planning framework (Figure 6). The inshore and offshore trawl footprint areas, as mapped by the South African hake trawl industry as a contribution to eco-certification (Wilkinson and Japp 2008) were also included in the planning database.

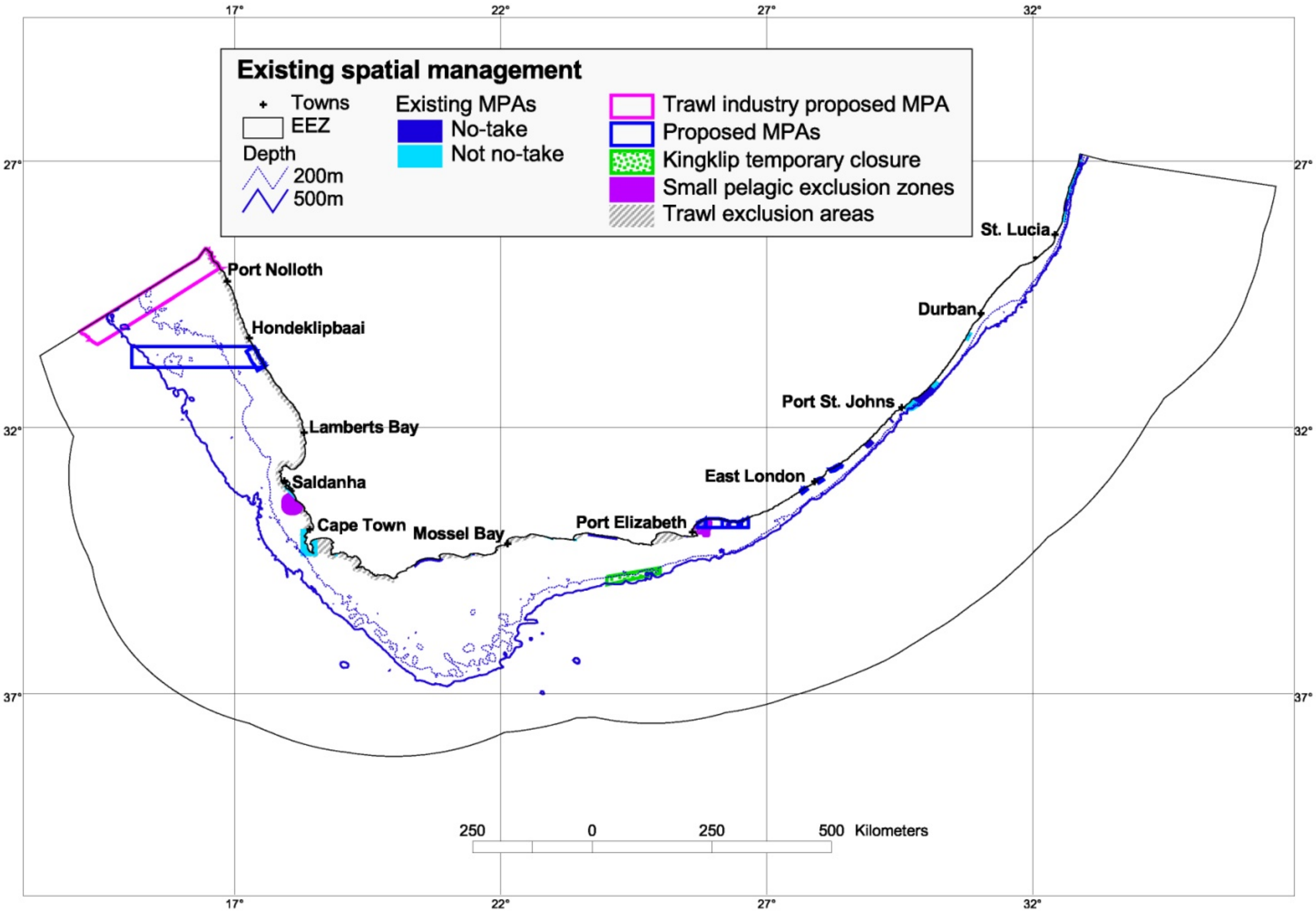


Figure 6: Map of proclaimed MPAs, proposed MPAs (formally proposed in government gazette and industry proposed alternative), exclusion areas and temporary fishery closures in the South African mainland EEZ. Cost data reflecting commercial activities.

As planning aimed to minimise the impact of potential spatial management areas on offshore industry and other sectors, spatial mapping was undertaken to reflect fisheries effort (or catch where effort data is not appropriate) for 11 fisheries sectors, areas of activity in the petroleum and diamond mining industries, shipping intensity, submarine cables and navy activity (see Appendix 1 Industry Activity). Fisheries tracks to support finer scale planning, particularly during the implementation phase, was also collected and mapped where feasible (e.g. trawl tracks, long line sets). The underlying data from these maps was incorporated into various “cost metrics” and GIS cost layers (maps reflecting different cost metrics). Multiple cost layers were developed to allow for different scenarios to account for the different industries or sectors that would be affected in planning for different objectives (see Table 3). For example, in a scenario to identify seabed protection priorities, pelagic activities that do not affect the benthic habitat were not considered as these stakeholders may not be excluded from areas where the only objective is protection of the seafloor. Nine different cost layers were developed to support planning for this project. These included four cost layers involving multiple sectors (1, 2, 3 and 7) and five industry specific cost layers to explore industry-specific management interventions.

The nine cost layers produced during this project are listed below.

1) General costs - cumulative effort (or catch where no effort data exists) and use data from all industries and sectors.
2) Benthic costs - including data from all industries and sectors that impact the seabed and that are likely to be excluded from any spatial management aimed at protecting the seabed, benthic resources or eggs that are attached to the seabed.
3) Pelagic costs - including data from all pelagic industries and sectors (i.e. shipping and pelagic fisheries). This cost layer was not actually used in any planning scenario as no form of spatial management was envisaged that would only impact pelagic industries.
4) Small pelagic fishery costs - industry specific cost layer reflecting relative catch for this sector across the planning area
5) Inshore trawl fishery costs - industry specific cost layer reflecting relative effort for this fishery (hours trawled) across the planning area
6) Offshore trawl fishery costs - industry specific cost layer reflecting relative effort (hours trawled) for this fishery across the planning area
7) Demersal trawl fishery costs - industry specific cost layer reflecting relative effort for both the inshore and offshore trawl sectors (hours trawled) across the planning area
8) Crustacean trawl fishery cost - industry specific cost layer reflecting relative effort for this fishery (hours trawled) across the planning area
9) Large pelagic fishery costs - industry specific cost layer reflecting relative effort (cumulative number of hooks) for this fishery across the planning area

Fishery sector specific cost metrics were the most simple to calculate and involved assigning effort data across planning units based on spatially referenced effort or catch (small pelagic fishery) data. The most comprehensive cost metric, the general cost layer, included all sectors i.e. all commercial fisheries, oil and gas leases, diamond and other mineral leases and shipping lanes. The cost metrics involving multiple sectors were calculated based on the following principles: Each industry sector was given equal weighting, for example each fishery and each mining sector. If a sector consisted of several subsectors, this was weighted according to the importance of that subsector, based on expert opinion. For example in the small pelagic fishery, there are three target species; red eye, anchovy and sardine, and the assigned weighting used 10/40/60 according to the estimated relative importance of each of these three species to the overall fishery as agreed by industry stakeholders (considering the value of catch species and the past, current and projected total allowable catches). For the mining and petroleum sectors, different types of leases were weighted with production or active mining areas reflecting greater cost than exploration or prospecting areas. For the petroleum sector, technical co-operation leases (an agreement specifying desk-top analyses to support future prospecting applications) were weighted much lower than areas with actual exploration rights (where drilling for prospecting purposes takes place).The cost value for each industry in a planning unit was therefore based on its relative importance to that industry. Each cost value was standardised by dividing the value by the summed value (across all planning units).

An example of the cost equation used to calculate the general cost metric is shown below.

General costs = Crustacean trawl effort (hours) + demersal inshore trawl effort (hours) + Demersal offshore trawl effort (hours) + Midwater trawl effort (hours) + Commercial linefish effort (no. of boat days) + Hake longline effort (total hooks) + Shark directed longline effort (hooks) + Sharknets (no.) + (0.6*Tuna pole (Albacore) + 0.4*Tuna pole (Yellowfin)) + Large pelagics effort (Hook no.) + (0.5* Small pelagics: Pilchard Catch + 0.4* Small pelagics: Anchovy Catch + 0.1* Small pelagics: Redeye Catch) + South coast Rock lobster effort (total traps) + West coast Rock lobsters Effort (total traps) + Squid Effort + (0.66*Diamond mining Lease type: Mining + 0.17*Diamond mining Lease type: Prospecting + 0.17*Other minerals Lease type: Application) + (0.3*Petroleum lease status: Exploration + 0.6*Petroleum lease status: Production + 0.1*Petroleum lease status: Tech Co-op Permit) + Petroleum Oil and gas wellheads + Shipping intensity

The general cost metric was used to determine where all types of offshore spatial management should be considered in an integrated analysis. This cost layer should also be used to guide the placement of highly protected areas (such as no-take zones of MPAs), as these types of spatial management impact on all sectors and therefore the importance to all industries must be considered. A benthic (seabed) protection zone would only exclude benthic industries and therefore a separate cost map (or GIS layer) was developed to reflect areas of importance for all sectors that may need to be excluded from benthic protection zones. Pelagic fisheries and shipping were not included in the benthic cost metric. Industry specific cost metrics were developed for scenarios that aimed to support fisheries or bycatch management for specific sectors. These included data from only the individual fisheries sector or sectors (e.g. both inshore and offshore trawl were included in an analysis to support fisheries management in demersal trawl fisheries).

The benthic, pelagic and general cost layers produced for systematic planning for offshore spatial management are shown in Figures 7-9. These maps reflect the cumulative importance of different sectors within South Africa's EEZ. Darker areas represent areas of greater relative importance to industry, i.e. higher cost to industry in terms of the implementation of spatial management types that exclude industry activity. Areas of higher industry importance were avoided as far as possible in identifying potential areas for spatial management whereas the less important areas were favoured in identifying areas for potential MPAs and other types of spatial management. Figure 7 represents industry importance for activities that affect the seabed (i.e. industries that may impact seabed habitat structure and demersal fish and invertebrate communities) and that need to be considered in planning for seabed protection. This includes all types of demersal trawling, trap fisheries, shark nets, line fishing, diamond mining and petroleum activities. The darker planning units in Figure 7 are areas that were avoided as far as possible in selecting potential areas for seabed protection. These industry sectors should be excluded from areas where the management objectives include seabed protection. This could include MPAs or seabed or benthic protection zones in MPAs or Fishery Management Areas. Figure 7 reflects a general pattern of higher industry activity on the continental shelf, a concentration on the shelf edge and reduced activity in less industrialised areas along the south east coast (former Transkei). The area of high benthic cost between Cape Town and Saldanha is caused by a combination of linefishing and west coast rock lobster fishing. Industries with a smaller spatial extent, such as the crustacean trawl fishery in KwaZulu-Natal, fall within only a few planning units and thus the relative contribution of each planning unit to the total industry is quite high – this results in high importance to industry (dark colours) within these planning units, even if no other industry is present.

Areas of relative overall importance for pelagic activities are shown in Figure 8. This includes all pelagic fisheries, shark nets, squid fishing and shipping but excludes includes all types of trawling, trap fisheries, line fishing, diamond mining and petroleum activities. Hotspots of pelagic activity include the shelf edge on the west and south coasts, the shelf between Lambert’s Bay and Cape Agulhas, the area offshore of Mossel Bay and the area off Port Elizabeth. The area between Lamberts Bay and Cape Town has high cost for pelagic activities due to the importance of this area to the small pelagic fishery and the shipping industry. The area from Lamberts Bay to Gansbaai has relatively high pelagic cost all the way out to the shelf break. The relatively small area of influence of the shark nets in KwaZulu-Natal drive high pelagic costs in the inshore areas there.

Areas of relative overall importance for all industry activities (general costs) are shown in Figure 9. This map includes both benthic and pelagic costs and therefore the combined relative importance to industries that depend on both benthis and pelagic habitats and resources. The general cost map reflects relatively high cost along the coast and continental shelf for most of South Africa. Cost is greater closer to Cape Town, Port Elizabeth and Durban. There are fewer industry activities further offshore with benthic activity seldom extending below the upper bathyal zone. Some demersal trawling does take place in the upper bathyal and there is increasing interest in petroleum activities in deeper water with technical co-operation permits contributing to moderate cost values in deep areas off Cape Town and Port Elizabeth. Areas that are diamond prospecting areas as well as under application for prospecting for heavy minerals, gold and sapphires (two darker strips north of Lamberts Bay) also have higher cost values. Cost maps reflect lower industry activity offshore from the former Transkei area although there is an area of higher cost off Port St Johns due to large pelagic fishing. Higher relative costs in the Durban bight show the importance of this area of wider shelf to fisheries in the area.

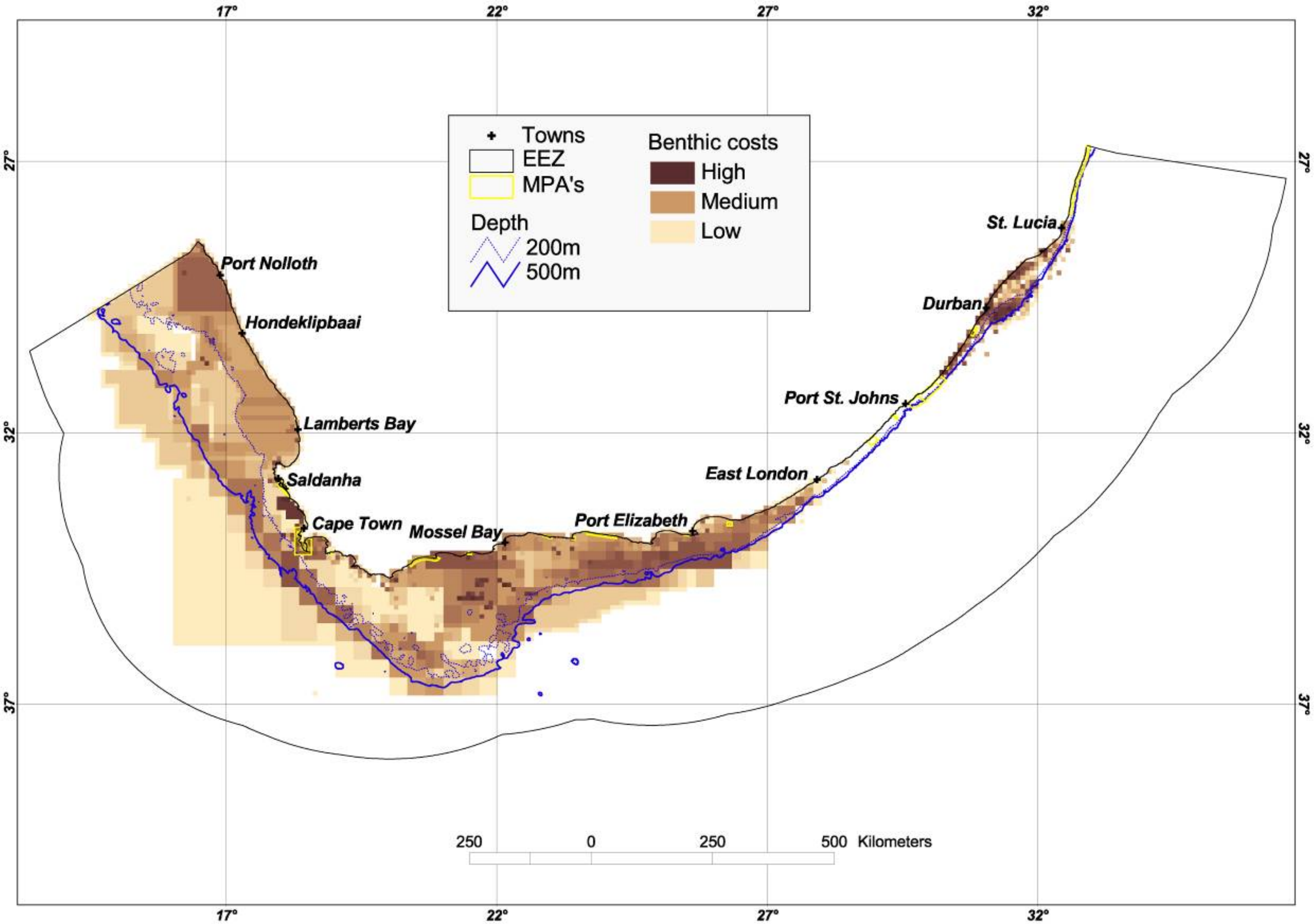


Figure 7: Areas that we attempted to avoid in assessing potential priority areas for seabed protection. Darker areas reflect greater importance to industry and therefore a higher "cost metric" and were more strongly avoided.

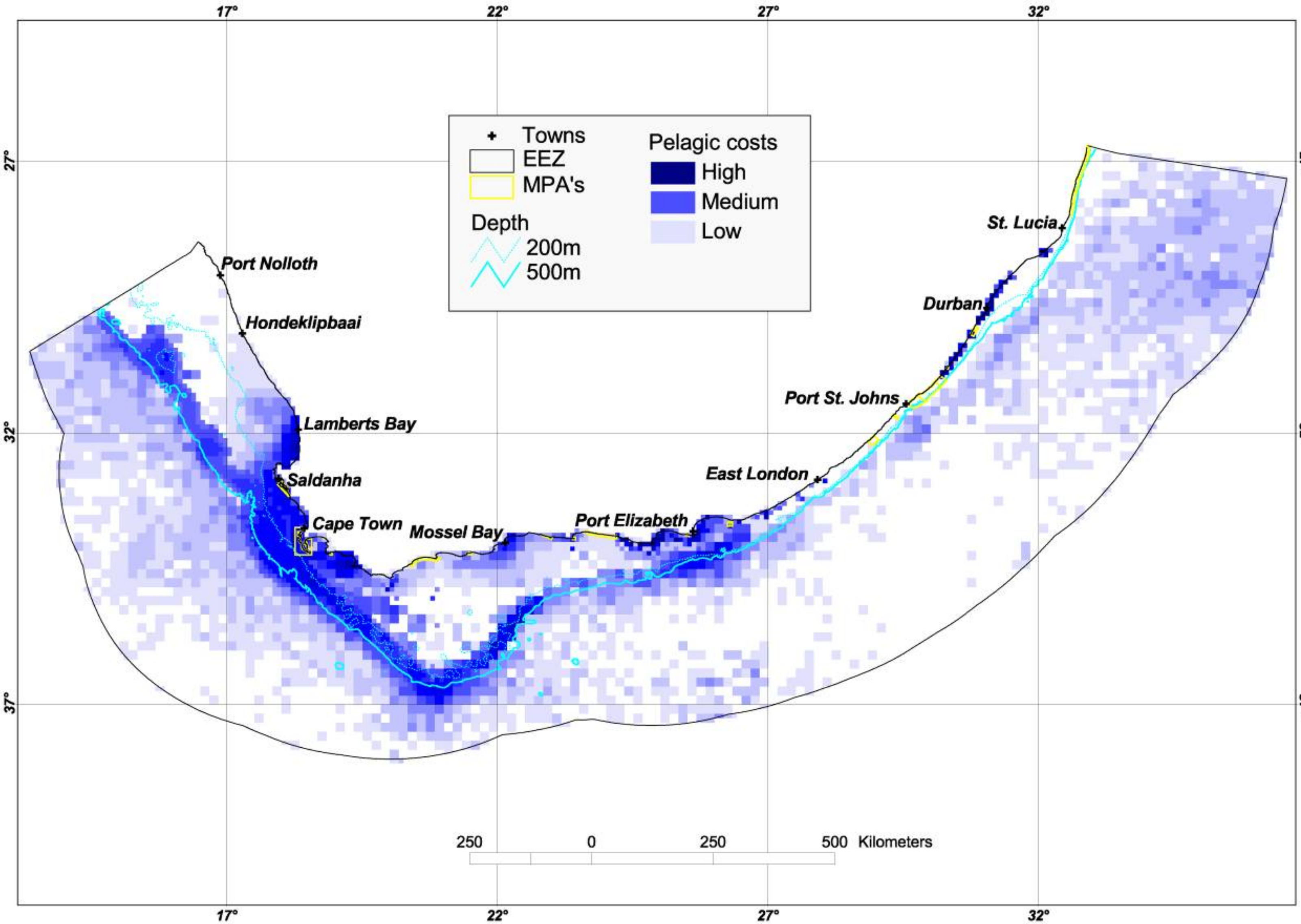


Figure 8: Areas of importance to industries that utilise pelagic resources or impact on the pelagic environment as measured by a "cost metric" that can be used to avoid industry activity when planning for MPAs or other types of spatial management.

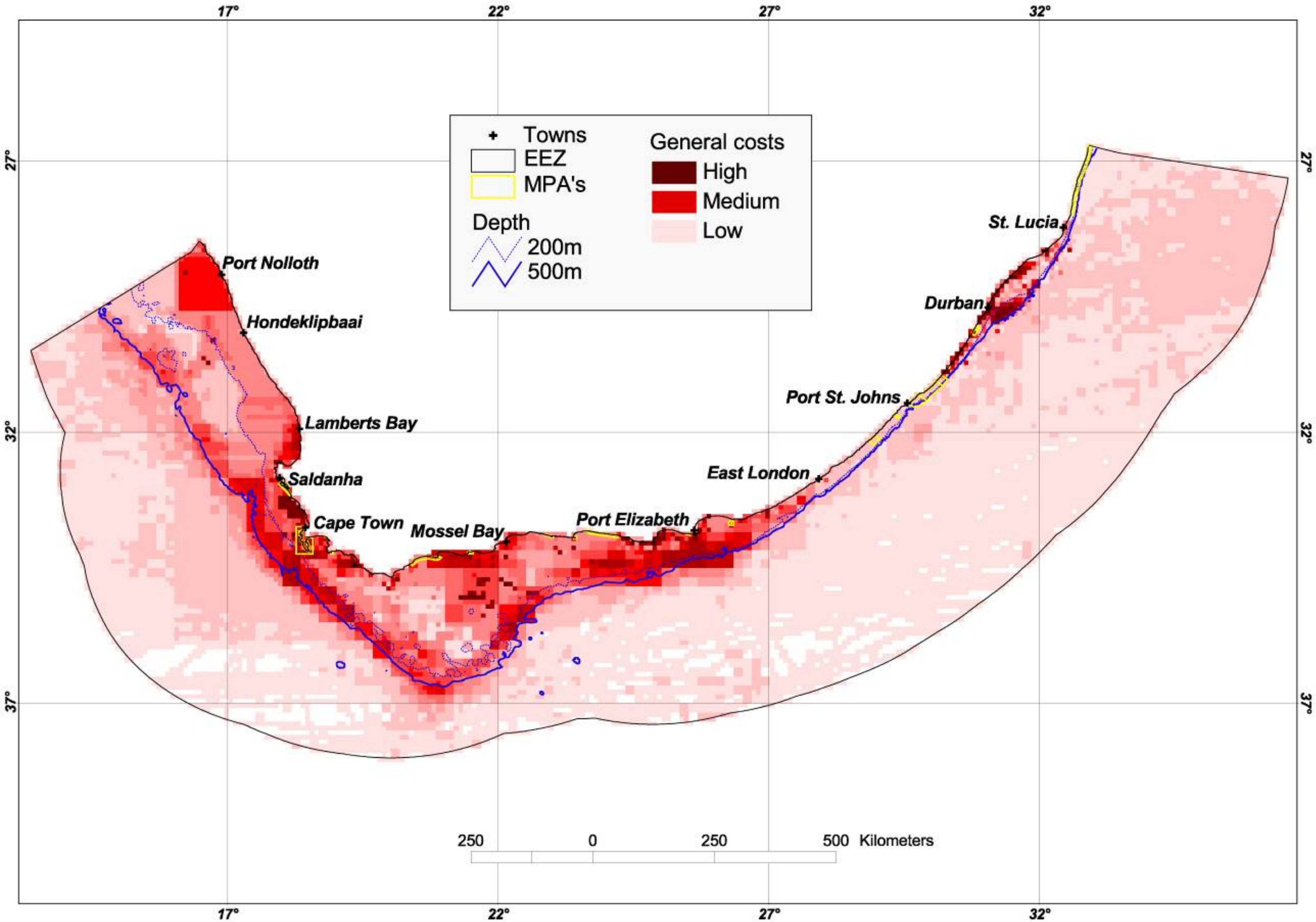


Figure 9: The general "cost metric" used to minimise the impact of potential spatial biodiversity or fishery management measures on South African offshore industries. Darker areas have higher relative "cost" for implementation of spatial management and were avoided as far as possible.

Targets

The National Protected Area Expansion Strategy (Government of South Africa 2010) sets five-year and twenty-year targets for expanding protected areas. These are time-bound protected area targets that, in the case of marine ecosystems, are acknowledged as not being based on ecological thresholds. The NPAES set a 20 year target of 15% of South Africa's EEZ for protection in no-take MPAs, and an additional 5 % target was set for multiple-use MPAs. The Offshore MPA project did not set any overall protected area targets (i.e. programmatic targets for how much of the study area should be formally protected), as was agreed during a stakeholder workshop held at the project outset. The Offshore MPA project does however provide guidance on spatial priorities for offshore MPA expansion, to inform the implementation of the NPAES and any offshore MPAs that may be established will contribute to the NPAES protected area targets.

As the offshore MPA project employed a systematic planning approach, quantitative biodiversity and industry targets were needed to undertake analyses to identify potential priority areas to achieve project objectives. Numerical biodiversity and industry targets were developed in consultation with several experts in a transparent process, were verified by the Department of Agriculture, Forestry & Fisheries' EAF working group and were discussed and agreed upon (at least for initial use) at the Offshore MPA project open day. Biodiversity targets used in the plan range from 5-50% for different habitat types with a base target of 5% for pelagic features and 10% for benthic features (see Table 3 and Appendix 1). Biodiversity targets in excess of 10% were set for potential vulnerable marine ecosystems such as cold water coral reefs, seamounts and hard ("untrawlable") grounds and to protect important areas for threatened species. The targets should be viewed as starting points to help identify potential priority areas for the protection of offshore biodiversity and not as absolute numbers.

The base target for pelagic features and biozones was 5%. A target of at least 10% was set for all benthic biozones and features including geological seabed types, sediment types and the shelf edge. Higher targets were set for vulnerable marine ecosystems (VMEs). A 20 % target was set for submarine canyons and a 30% target was set for seamounts, hard grounds, cold water coral reefs and carbonate mounds. A 10% target was set for deep reef positions and areas of high linefish species richness and a 10% target was set for reef data provided by SANBI's collaborative Reef Atlas Project. A 50 % target was set for species records of reef-building cold water corals. Although a target of 30% of carbonate mounds and cold water coral reefs was set, only one example of each is currently known, Child's Bank and Ibhubesi reef, respectively, meaning that these features played a key role in driving benthic protection priorities. Benthic protection targets were set for squid eggs and nests. A 10% target was set for squid nests and for benthic protection for squid eggs using data that reflects the volume and frequency of eggs caught in demersal research trawls.

Planning accounted for threatened seabirds and turtles. A 30% target was set to protect the important areas for leatherback turtles in South Africa. Targets of 10, 20 and 30% were used for foraging areas of threatened seabirds, including Cape and Bank cormorants, Cape gannets and the African penguin. This allowed for the effect of increasing targets to be explored. A 30% target was set for linefish of conservation concern.

Fisheries management targets were set for the protection of spawning and nursery areas of sardine, anchovy and hakes *Merluccius capensis* and *M. paradoxus*. A 10% target was set for nursery and spawning areas and a 5% target was set for large fish (sardine, anchovy and hake) to bias the selection in areas of consistently higher relative abundance.

For the inshore demersal trawl sector, the Offshore MPA project collaborated with a more detailed and comprehensive project that aimed to assess the bycatch for this sector (Attwood and Petersen 2010) and identify potential closed areas to reduce bycatch in this fishery (Lombard *et al.* 2010). Targets were set for 27 nominal species of bycatch, based on CPUE data from the observer program. Targets were only set for species with a mean CPUE above 0.1 Kg/hr. Pelagic species such as mackerel were excluded. The bycatch target was to reduce bycatch in all species by at least 20% (using CPUE values), while preferentially selecting gridcells with a small mean size of four species of bycatch (Carpenter, Geelbek, Panga and Silver kob), and one target species (shallow-water hake). Further scenarios explored the use of targets for reducing the commercial catch of kob, panga and skates but there was less confidence in this data and data was only available for a few species. For the offshore demersal trawl sector, targets were based on industry catch data and observer catch data for kingklip and demersal research trawl data reflecting the relative abundance of key bycatch species. These included kingklip, monk, skates and panga. For the crustacean trawl fishery, targets were set to reduce the bycatch of all kobs and grunter.

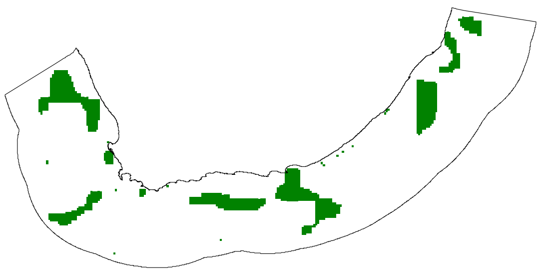
Planning scenarios

A range of planning scenarios were developed to identify focus areas for offshore protection with the least cost to industry. More than 100 different planning scenarios were explored during the analyses but the results from 9 key scenarios are presented here (Table 3). A scenario is a particular problem formulation which is a combination of biodiversity, and or industry targets that were used to explore potential options for offshore spatial management using a specific cost layer. Scenarios include analyses to examine all biodiversity priorities simultaneously, analyses to determine potential priority areas for benthic and pelagic protection and a range of sector-specific analyses exploring areas where spawning or nursery grounds can be protected and bycatch reduced. Some scenarios included industry targets to help spread the impact equitably among sectors and among rights holders for sectors where different rights holders operate in spatially fixed delineated areas (such as diamond mining and petroleum). Such analyses included multiple zones in Marzone but the results from these analyses were less useful as they did not account for multiple cost layers and only industry or protection zones could be considered in any one analysis. Marxan with zones was however useful in exploring tradeoffs between biodiversity and industry targets.

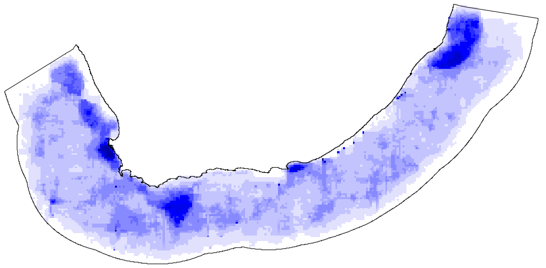
Table 3: Overview of planning scenarios included in this report. These scenarios enable us to identify different priority areas for different types of objectives. Zonation is not considered in these scenarios and it is important to note that targets and different objectives could be apportioned between different types of spatial management and different zones.

Scenario name	Overview of targets used (range of biodiversity target %)	Cost layer	Results figure
Seabed protection	All seabed protection targets for representivity (10%) and habitat protection (10-50% targets). This includes targets for protection of squid nests and important areas for linefish sustainability.	Benthic	Fig 10
Pelagic biodiversity	All targets for pelagic features and processes (5%).	General	Fig 11
Threatened species	Targets to protect important areas for threatened species (10, 20 & 30% targets)	General	Fig 12,13
Small pelagic fisheries sustainability	Targets to support fisheries sustainability including spawning (10%) and large fish (5%).	Small pelagic	Fig 14
Demersal trawl fisheries sustainability	Targets to support fisheries sustainability including spawning (10%), nursery areas (10%) and large fish (5%) for Cape Hakes *Merluccius capensis* and *M. paradoxus*.	Industry specific (Demersal trawl)	Fig 15, 16
Inshore trawl bycatch management	Targets to reduce the bycatch of 27 species (20%). One analysis (Figure 18) used a 2o minute planning grid and included size structure targets for 5 species.	Industry specific (Inshore trawl)	Fig 17, 18
Offshore trawl bycatch management	Targets to reduce bycatch of kinglip, monk, skate and panga (10-20%)	Industry specific (Offshore trawl)	Fig 19
Crustacean trawl bycatch management	Targets to reduce bycatch of kobs and grunter (20%)	Industry specific (Crustacean trawl)	Fig 20
Integrated analysis	All targets for all objectives including minimising and spreading impact on industry	General	Fig 21

Box 1: How to interpret the maps showing planning results in this report:



Most Efficient Solution



Selection Frequency

The conservation planning software produces two types of spatial outputs that provide information about different aspects of the planning scenario results. The first is a number of individual solutions including a “most efficient solution” that is identified by the software. The software is designed to provide many alternative solutions to the problem but the most efficient solution is the one that minimises the objective function (equation) i.e. achieves the most targets, avoids industry the best and maximises compactness (by minimising the boundary length). This map shows the minimum amount of area required to meet the targets specified in wach analysis. The other output is the specified selection frequency. Selection frequency is the number of times a planning unit is selected across all the solutions. This report displays the selection frequency in all cases and the most efficient solution in a few cases. The selection frequency provides an indication of particularly important (darker coloured) areas. Areas that have low selection frequency might still be important for achieving targets but there is likely to be flexibility in where targets can be achieved. Frequently selected areas are selected more often because there are fewer places where these targets can be achieved. Less frequently selected (lighter) areas have fewer constraints as there are more options and more flexibility for meeting targets for these features. Note that the maps in this report display selection frequency in three categories (high, medium and low). The same range of selection frequency categories (i.e cut-offs) were not used in the result maps for each analysis but rather natural breaks in the data were used to show planning units that had relatively high, medium or low selection frequency in each analysis. This means that the categories of selection frequency across different scenarios or analyses may not be equivalent and that the three categories are relative to each other for the analysis concerned but not across analyses. For some analyses, some cells were selected in every run (i.e. 100% selection frequency) whereas in other analyses, the maximum selection frequency may be much lower. The Offshore MPA project relied heavily on selection frequencies to determine important areas for protection. The targets used in the analyses were time-bound i.e. aimed at identifying the most important first set of offshore areas in the next five years rather than absolute values that specify the total amount of protection required into perpetuity. The most efficient solution (or “best” solution as termed by Marxan) is only displayed to provide an idea of the size and configuration of potential spatial management areas that may be required to achieve the specified targets in any given scenario. Figure 13 demonstrates the effect of increasing target size on the most efficient solution and on selection frequency.

Seabed protection

The analysis to identify priority areas for seabed protection indicated several areas with very high selection frequencies (80-100%) (darker areas in Figure 10). These areas are important to protect because they have fewer options to meet biodiversity targets (i.e. they contain biodiversity that is not known to occur anywhere else). Planning units with 100% selection frequency comprise those that include some of South Africa's only known submarine bank Childs Bank (also known as the "karbonkel"), a deep water coral reef on the west coast known as Ibhubesi reef and a planning unit off Port Alfred that includes a deep reef and records of two species of reef building cold water corals. Other areas with high selection frequency include the head of the Cape Canyon and Cape Valley off Cape Columbine and Cape Point respectively (note that the selection of these features is not clearly visible at the broad scale of the map), hard grounds in the inner Agulhas shelf, deep reefs on the Agulhas Bank, cold water coral records and deep reefs and submarine canyons along the south and east coast. Hard grounds and deep reefs contribute strongly to areas of higher selection frequency on the west and south coasts. Darker areas close to Saldanha Bay are selected to meet targets for low oxygen areas and hard grounds in that area. Of the two Benguela canyons, the Cape Canyon off Cape Columbine point had slightly higher selection frequency (53%) than the Cape Valley (off Cape Point 48%). In the Atlantic abyss, the area with highest selection frequency includes Protea seamount and an area with ferro-manganese deposits. Of the southwest Indian seamounts, Mallory (61%) and Davie (58%) were selected more frequently.

Lower costs drive higher selection frequencies on the south-eastern edge of the Agulhas Bank (Figure 10). The area off Cape Agulhas has higher selection frequency due to the presence of hard grounds and numerous geological and sediment types, enabling many targets to be met in a small area. The Tsitsikamma canyon drives a higher selection frequency just offshore of the current Tsitsikamma MPA. The darker area on the KwaZulu Natal south coast is driven by the presence of many targeted features (biozones, rare sediment types/geology, shelf edge, submarine canyon, cold water corals and deep reefs) in one area (the area between Umzumbe and Shelley Beach). Similarly, the area north of Durban (including offshore of Tugela mouth) is selected because of geological and sediment types of restricted distribution and the presence of submarine canyons. Lower relative costs (i.e. important to industries that depend on or impact the seabed) in these areas also contribute to their higher selection frequency.

Pelagic biodiversity

The scenario aimed at identifying broad pelagic priorities for potential spatial management included targets for pelagic bioregions and features as well as some benthic features (such as the shelf edge, canyons, seamounts and reefs) due to their perceived role in pelagic processes (Figure 11). Targets for threatened species that depend on pelagic ecosystems, fisheries management targets for small pelagic fisheries and bycatch management targets for the large pelagic fishery were not included in the analysis for which results are shown in Figure 11. Only one planning unit, off Port Alfred, had a selection frequency of 100% where deep reef, two pelagic habitat types and high frequencies of SST and chlorophyll fronts drive selection in this small area. One planning unit off Dassen Island had a very high selection frequency (93%) driven mostly by the presence of a known reef in this area where very limited reef data is available. Planning units with a selection frequency of 60-70% included two in the vicinity of Protea Banks off Shelley Beach in KwaZulu-Natal where canyons, deep reefs and frequent fronts drive selection there. Submarine canyons off Saldanha, Port Elizabeth and the south coast of KwaZulu-Natal led to high (45-50%) selection frequencies in the results from this analysis. The few areas with high selection frequency are related to seabed features of very limited extent that drive selection. Larger diffuse areas of moderate selection frequency are a result of the proximity of many pelagic habitats and features in these areas in combination with the clumping (minimising the boundary length) component of the algorithm. When other pelagic objectives (such as pelagic fisheries management and seabird protection objectives were included in analyses (results not shown) areas of high selection frequency that were driven principally by threatened species resulting in a similar result to that shown in Figure 12.

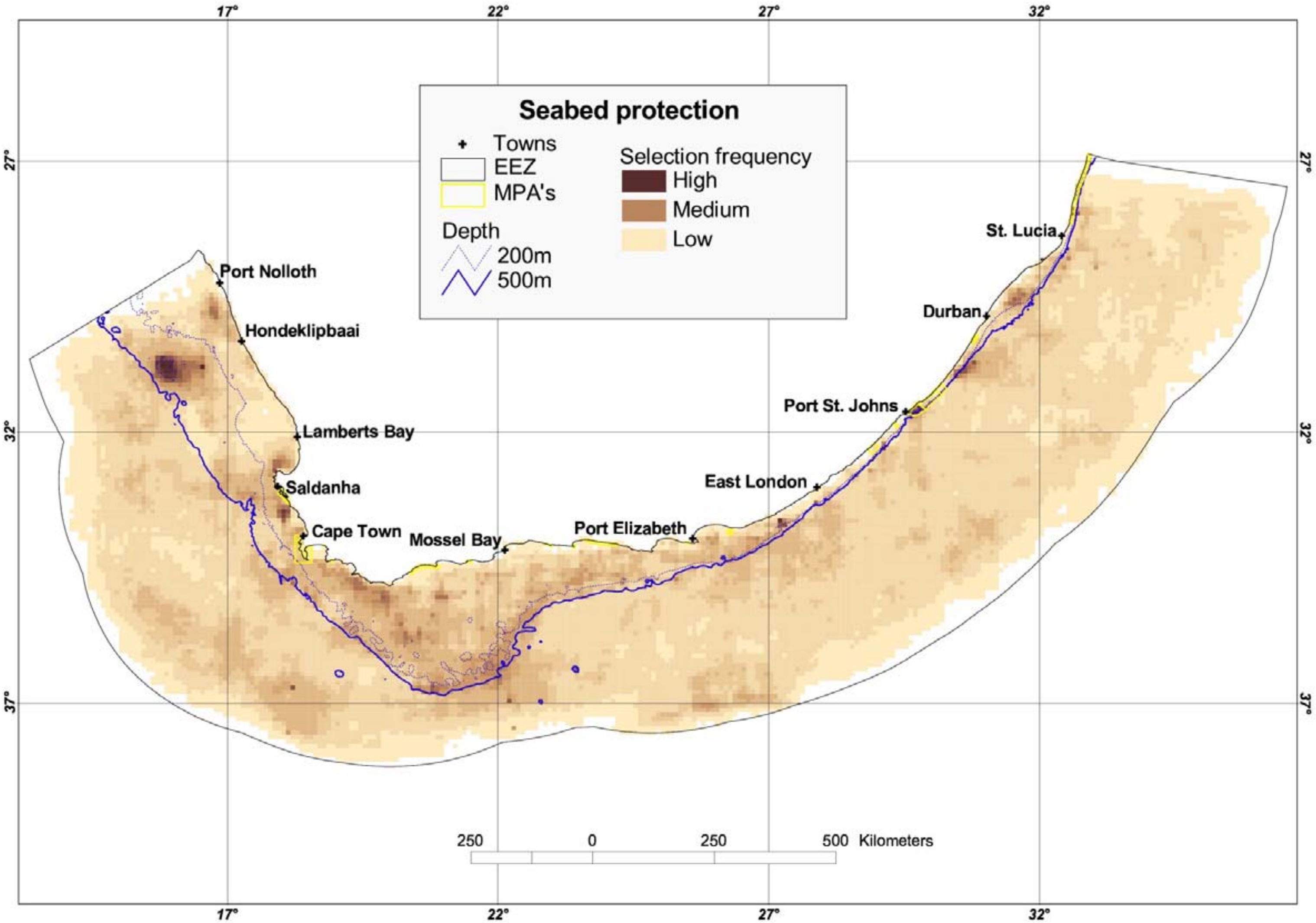


Figure 10: Priority areas for seabed protection in the offshore environment.

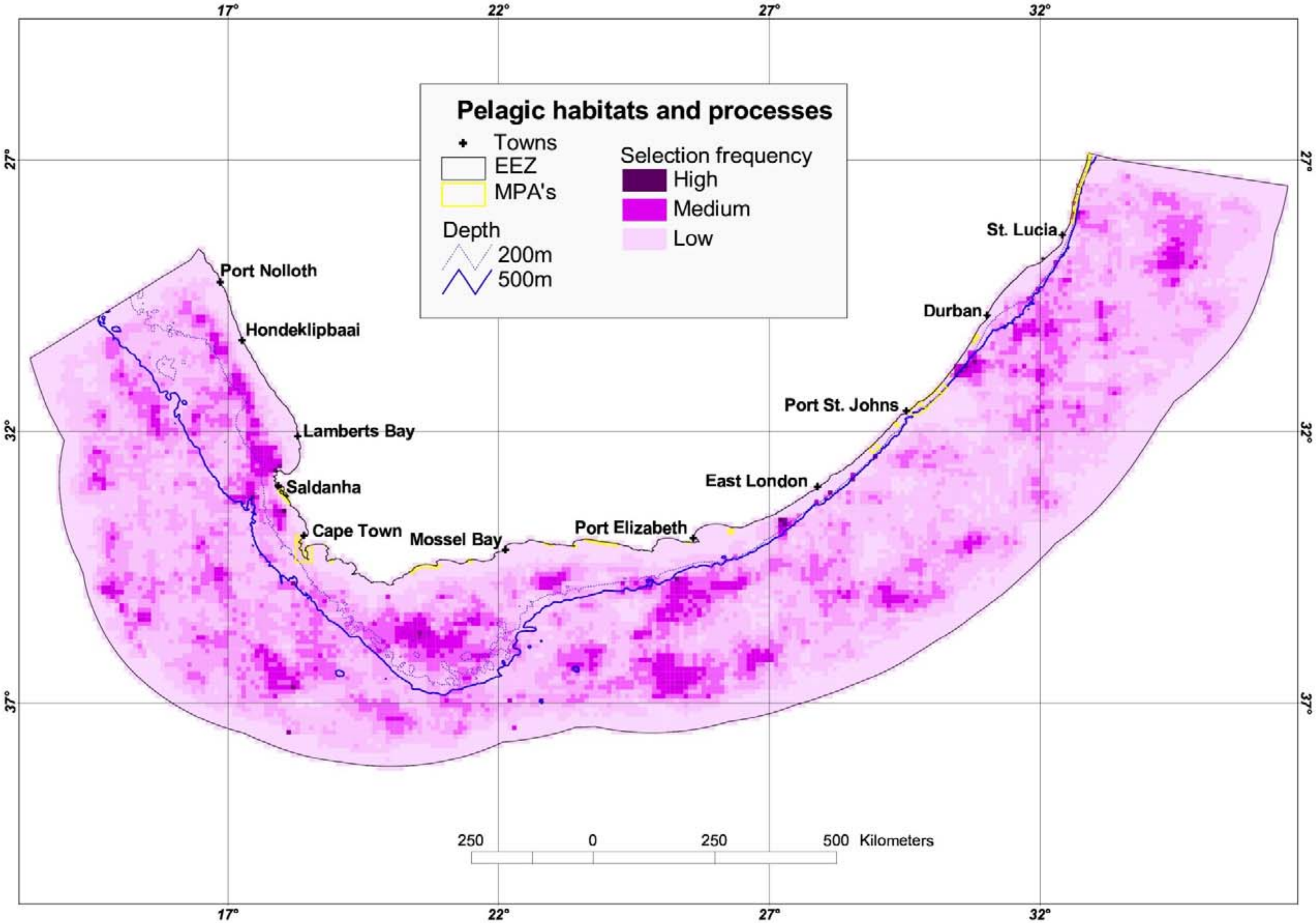


Figure 11: Potential priority areas for representing pelagic biodiversity and processes in South Africa

Threatened species priorities

Potential priority areas for conserving threatened species are shown in Figure 12. Key areas of importance include the area between Cape Town and Saldanna Bay, an area off Port Elizabeth and the area off St Lucia in northern Kwazulu-Natal. The area off St Lucia was selected because it is an important area for leatherback turtles which nest on adjacent beaches and forage offshore with tracking data reflecting turtle habitat use well beyond the 3 nautical mile boundary of the existing St Lucia and Maputaland MPAs. Threatened seabirds drive the remaining areas although linefish of conservation concern also contribute to these results.

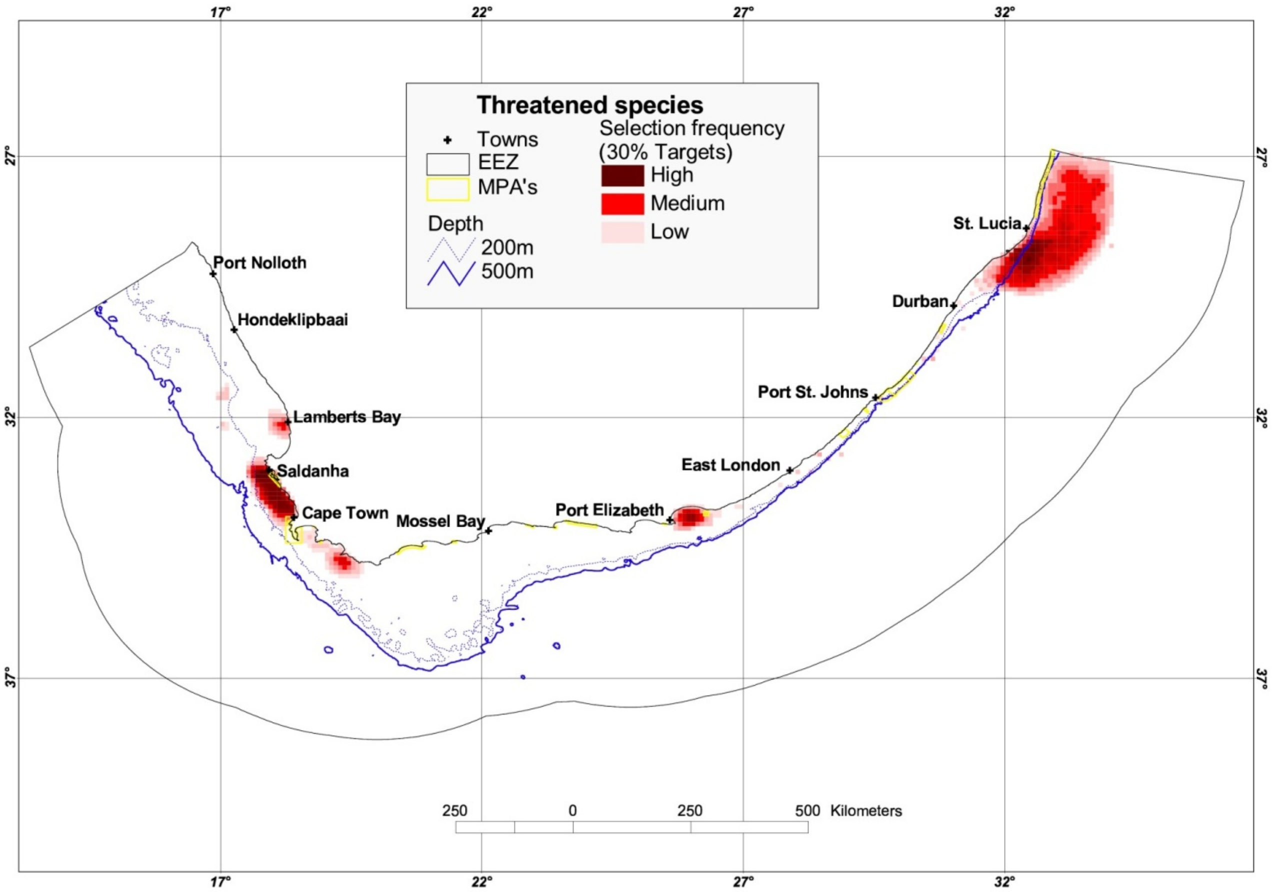
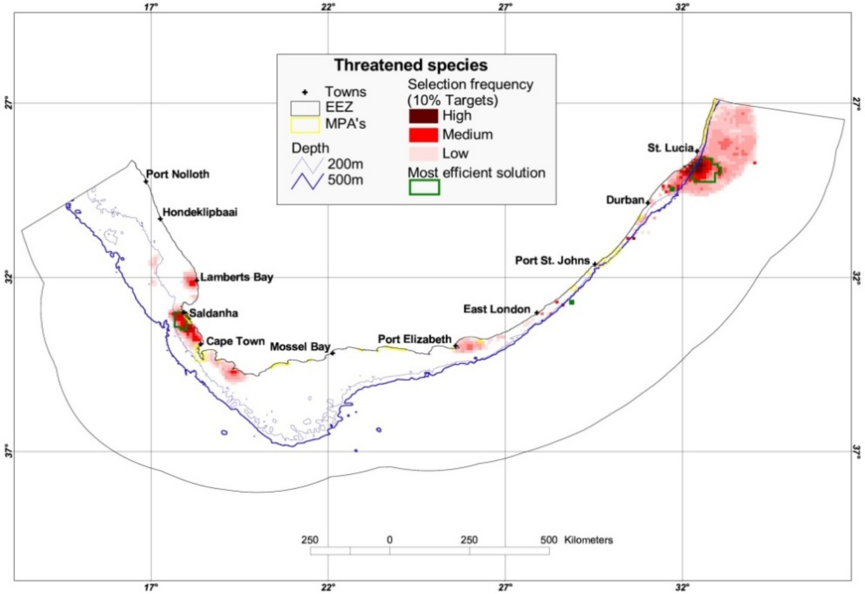
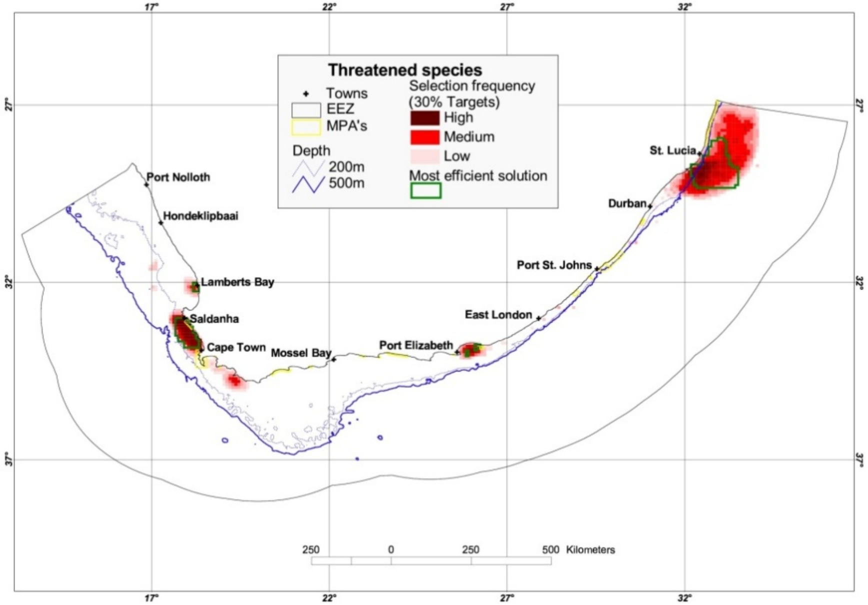


Figure 12: Priority areas for protecting important areas for threatened coastal seabirds and leatherback turtles in South Africa.

The relatively limited spatial extent of the important areas for these threatened species lead to relatively high selection frequencies in this analysis, although no planning units had selection frequencies exceeding 83%. The highest selection frequencies that emerged from this scenario were in planning units offshore of the northern part of the Sixteen Mile Beach MPA south of Saldahna, followed by the area south of St Lucia (driven by turtle habitat use and linefish) (Figure 12). Off Saldahna and Lamberts Bay, threatened seabird foraging areas for four species (African penguins, Cape Gannets, Bank and Cape cormorants) resulted in the high selection frequencies there. Similarly, the high selection frequency off Port Elizabeth (with colonies of African penguins, Cape Gannets and Cape cormorants) and the moderate frequencies off Betty's Bay on the south coast (with a colony of African penguins) is driven by the foraging area of the relevant threatened seabird species.

Note that although increased targets increases the size of the most efficient solution (Figure 13), the same key areas emerge in all analyses regardless of target size. This reflects the fact that the targets serve to guide the selection of the most suitable areas for target achievement without needing to precisely specify the total amount of a feature required for protection. In the Offshore MPA project, and in this report, targets should not be viewed as absolute values that specify the total amount of protection required in perpetuity, but rather as input values to help identify potential priority areas to start meeting offshore biodiversity targets now. This is appropriate in the offshore environment where current protection levels are very far below any target likely to be determined on ecological grounds. Most offshore features targeted in these systematic planning analyses currently have zero or below 1% protection whereas targets of at least 10% and with targets of 30% or more justified in some plans (Porter *et al.* 2011). Ecologically determined biodiversity targets are still under development for marine species and ecosystems in South Africa. The Offshore MPA project aims to identify important areas for the next five years, recognising that more research is needed to support the development of targets that specify the total amount of marine biodiversity features (or other sustainability thresholds) required for protection into perpetuity.





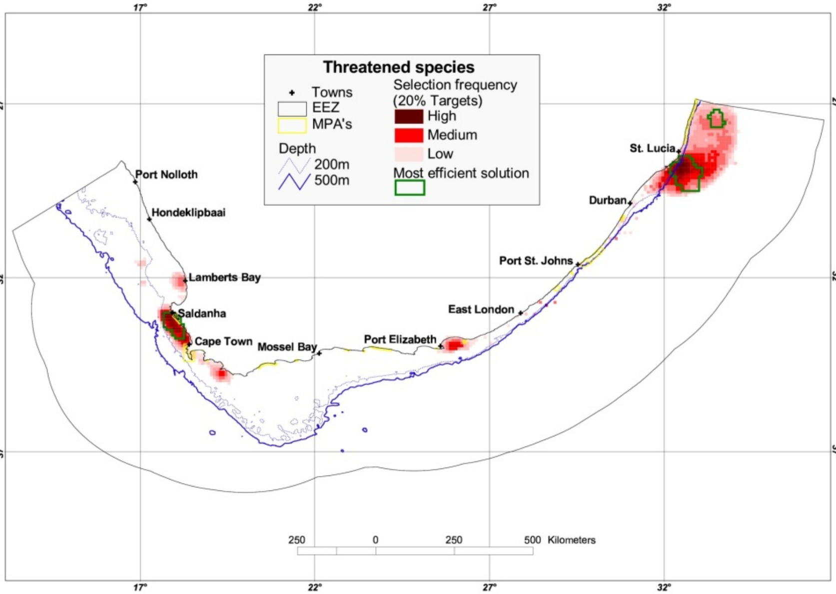


Figure 13: Results from analyses with increasing targets for important areas for threatened seabirds and turtles in South Africa. Targets of 10, 20 and 30% were included in analyses to assess the difference in selection frequency as well as the size of the area selected to meet different targets (most efficient solution). Although the size of the most efficient solution changes, the same areas emerge as priority areas for protecting these species indicating that these analyses are appropriate for identifying important areas for protection now without needing to know the precise amount of protection (target) required into perpetuity.

Supporting Fishery Sustainability

Scenarios to explore potential priority areas for supporting fisheries sustainability through protection of spawning and/or nursery areas and considering the maintenance of size structure were explored for the demersal and small pelagic fishery sectors. Although linefish sustainability was considered, a dedicated linefish scenario was not explored due to the lack of spatially referenced size and breeding data for key species in the linefish sector. Rather, linefish sustainability targets were included in the analyses for benthic protection and threatened species.

Small pelagic fishery sustainability

Several scenarios were examined to explore potential priority areas for the small pelagic fishery. Where threatened seabirds were also included in targets (results not shown), the high targets (30% foraging area) and limited spatial extent of foraging areas for these species drove the results with a very similar picture emerging as that of the threatened species priorities (Figures 12 and 13). Scenarios using only fishery management targets (10% target for areas of high egg density for sardine and anchovy and 5% for areas with a higher relative abundance of large fish) were preferable to identify potential areas for contributing to the sustainability of target species (Figure 14). Selection frequencies from this analysis did not exceed 32% indicating substantial flexibility in achieving targets for this analysis. The planning units of highest selection frequency were on the south eastern edge of the Agulhas Bank where there is relatively low cost, higher sardine and anchovy egg densities and more larger fish. These same patterns drive high selection frequency north of Cape canyon off Cape Columbine (just north of Saldanha). We experimented to assess whether inclusion of a 5% target for large fish required any additional area and found that this was not the case. These potential fishery management areas effectively avoid areas of high industry importance for this sector.

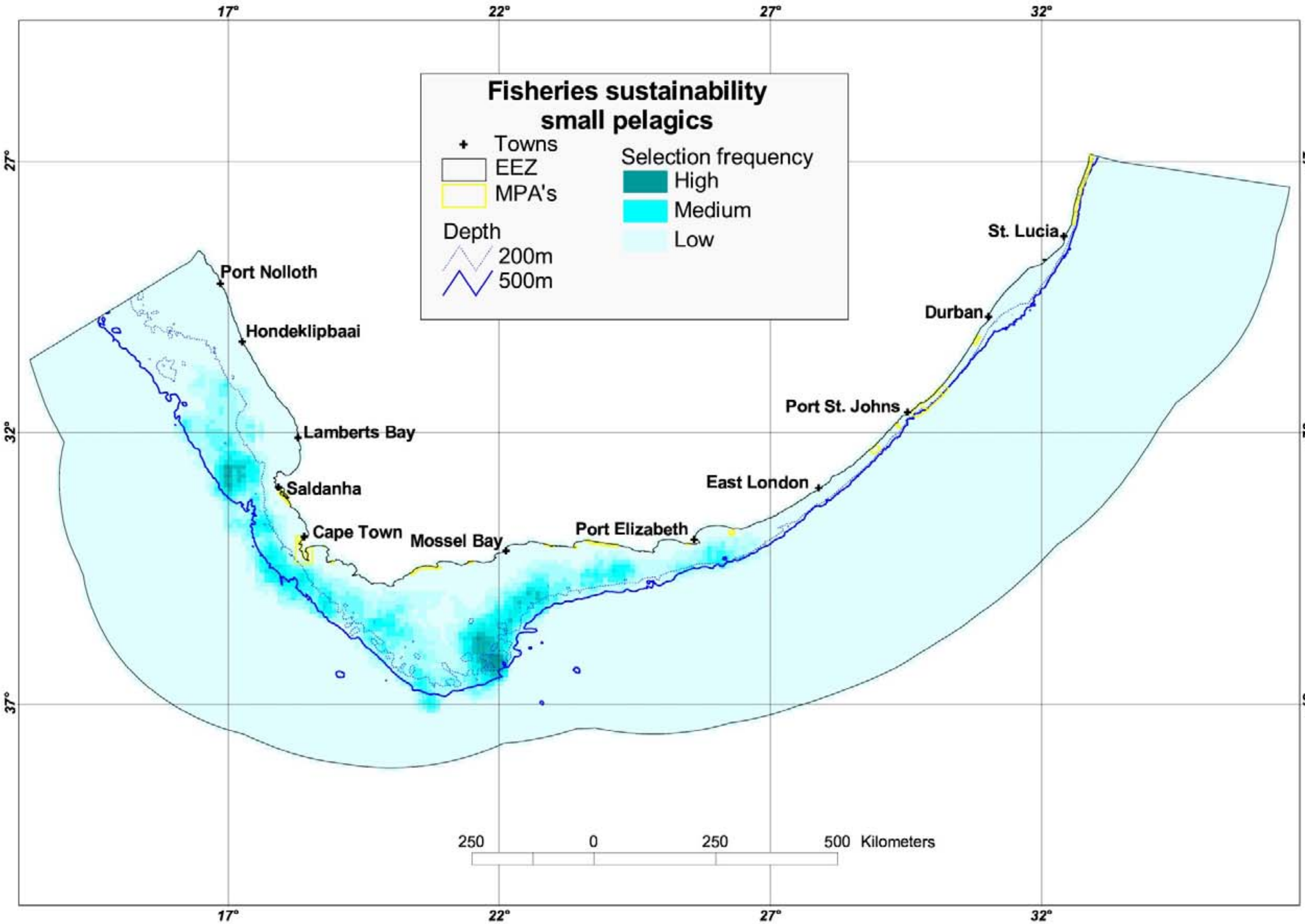


Figure 14: Potential priority areas for protecting spawning areas and maintaining size structure for sardine and anchovy. Areas of high selection frequency include areas of high densities of pilchard and anchovy eggs as well as higher relative abundance of large fish. For sardines, it is estimated that there is a 50-70% increase in spawning for every 1 cm increase in adult fish length. Larger sardines also spawn over a longer spawning season than smaller ones.

Hake trawl fishery sustainability

Fishery management targets for *Merluccius capensis* and *M. paradoxus* included protection of 10% of the nursery area for both species, 10% of the known spawning area and a 5% target for large fish. We experimented by running scenarios with various permutations to investigate results for *M. capensis* and *M. paradoxus* independently and combined. Setting targets for the two species separately resulted in slightly different areas although the same areas were sometimes selected (Figure 15) than when targets for both species were included in a single analysis (Figure16). In all three analyses there was flexibility in where targets could be reached as revealed by the relatively low selection frequency values (ranging from 0-26% (*M. Paradoxus*), 0-34 (*M. capensis)* and 0-30% for both species). The analysis that included targets for both species simultaneously (Figure 16) was able to meet targets more effectively with less overall area required than that specified by the most efficient solution for each species combined. Areas with highest selection frequencies include a shelf area (50-100 m depth range) between Port Nolloth and Hondeklipbaai, an area of shelf and shelf edge off Lamberts Bay, an area around the Cape Canyon off Saldanha and an area off the existing De Hoop MPA. We tested whether the inclusion of a target for large fish (5%) resulted in additional area and this was indeed the case with an additional 40 planning units required for the most efficient solution. However, as with the range of targets explored for threatened species (Figure 13), increasing targets did not change the core areas identified but rather the total amount of area selected within the most efficient solution.

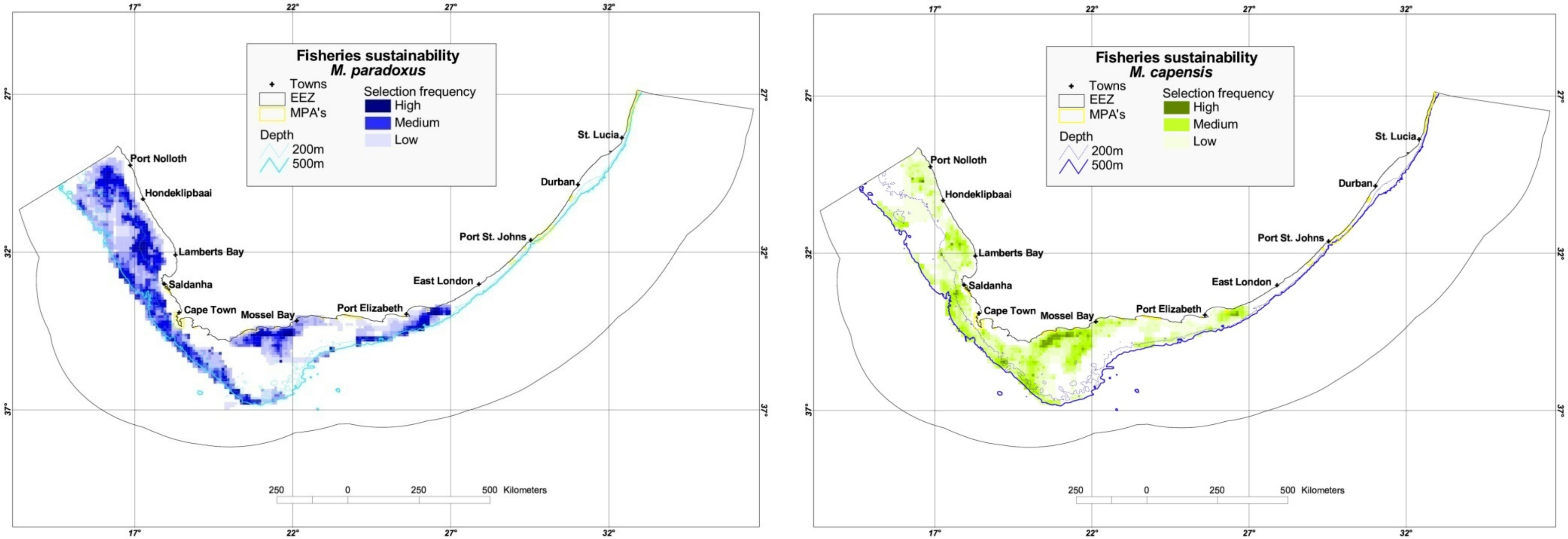


Figure 15: Potential priority areas for protecting spawning areas and maintaining size structure for hake *Merluccius capensis* and *M. paradoxus*

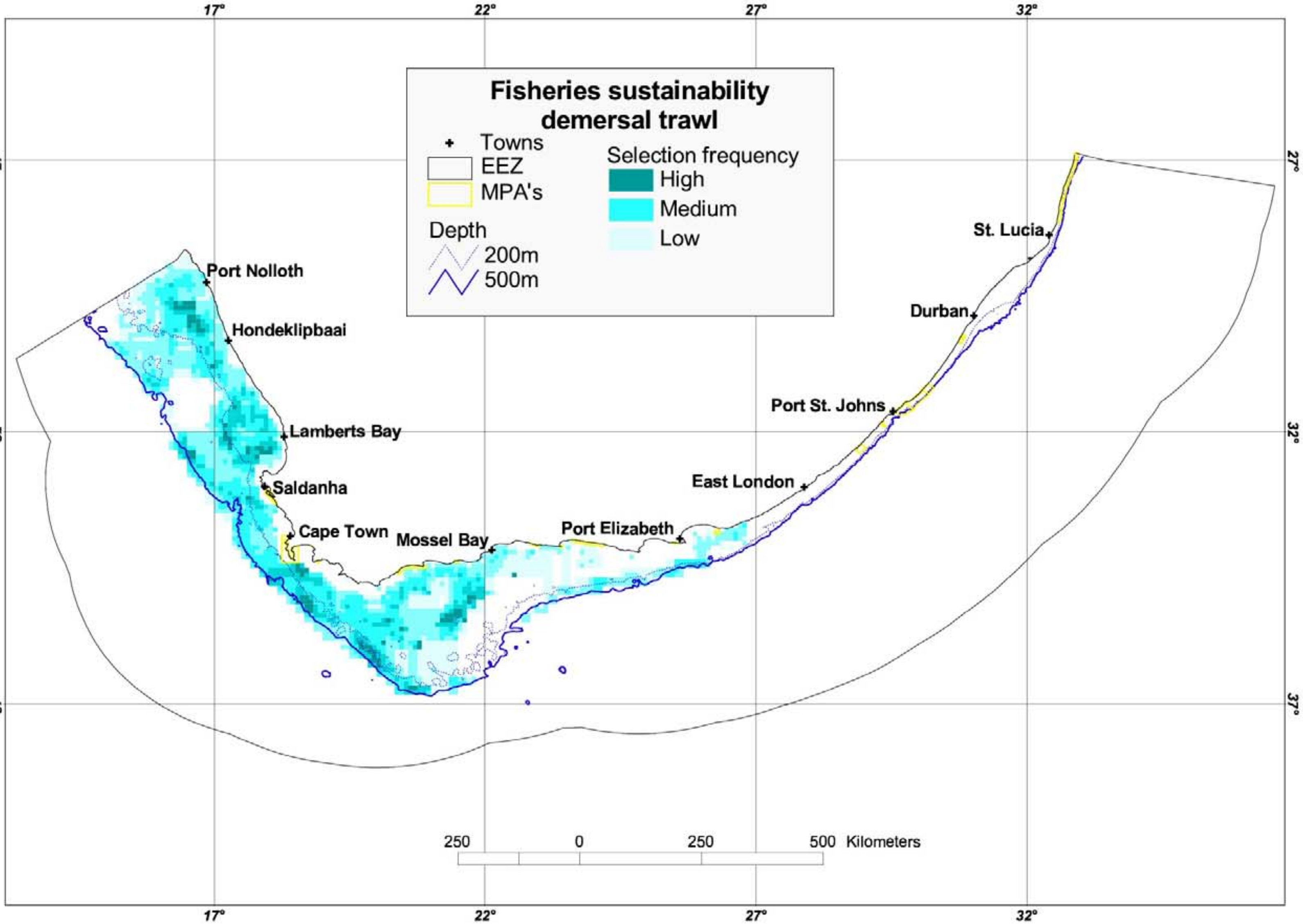


Figure 16: Potential priority areas to implement management to contribute to the sustainability of the demersal hake trawl fishery in South Africa. Targets included protection of spawning area, nursery areas and areas with higher abundance of large hake for both species *M. capensis* and *M. paradoxus*.

Bycatch Reduction

Scenarios to explore potential priority areas for reducing bycatch were explored for four fishery sectors; the inshore and offshore demersal trawl sectors, the crustacean trawl sector in KwaZulu-Natal and the large pelagic sector (not shown in this report). The latter analysis was excluded because of data quality concerns and data constraints with results unable to avoid areas of highest fishing effort. As the large seabirds tend to follow fishing vessels, there is considerable debate as to the potential application of closed areas in mitigating bird bycatch

Inshore trawl bycatch management

The first analysis undertaken to explore potential spatial priorities to reduce bycatch in the inshore demersal trawl sector (Figure 17) indicated some flexibility in achieving targets for 27 species. The highest selection frequency was 59% and no planning units had 100% selection frequency. Highest selection frequencies were found in two planning units just east of Algoa Bay (Port Elizabeth) in commercial trawl grids 640 and 636. Other areas with high (>40%) selection frequency included additional planning units in these grids, several planning units in grid 513 (off Wilderness) planning units in the Blues (grid 568 and 553) and planning units in grid 525 offshore of Vlees Baai (just west of Mossel Bay) (Figure 17).

The high selection frequencies in grid 640 are driven by the very limited distribution of CPUE data for fingerfins and sandsoldier (see Lombard *et al.* 2010 and Attwood and Petersen 2010) and the much higher CPUE values for the more widely distributed sciaenid *Umbrina canariensis* in this grid. The relatively high CPUE of lesser guitarfish *Rhinobatos annulatus,* bull ray *Myliobatis aquila*, silver kob *Argyrosomus inodorus*, Geelbek *Atractoscion aequidens*, panga *Pterogynus laniarius,* white stumpnose *Rhabdosargus globiceps,* soupfin shark *Galeorhinus galeus,* skates *Raja* spp., and dogsharks (*Squalus* spp.) contribute to the high selection frequency off Algoa Bay (grids 640, 636, 633 and 629). A relatively higher CPUE of shysharks (Order Scyliorhinidae), electric rays (Order Torpediniformes) and houndsharks (*Mustelus* spp.) drives the selection of the area off Vlees Bay (grid 513). The area on the central Agulhas Bank or Blues (grid 568 and 553 offshore from Struisbaai) is selected due to higher CPUE values for carpenter *Argyrozona argyrozona*, This area would also contribute to bycatch reduction for panga, roughnose skate *Cruriraja parcomaculata* (especially grid 553), catsharks *Halaelurus* spp. (especially grid 568) and dogsharks *Squalus* spp. (553). The medium-high selection frequency off Tsitsikamma (grid 531 and 530) is related to contributions made by several targeted species including panga, striped catshark *Poroderma africanum, gurnard Chelidonichthys* spp. and St Joseph shark *Callorhinus capensis*. There are no clear drivers for the higher selection frequency in grid 525 although this grid helps meet targets for many nominal taxa (including skates, white stumpnose, lesser guitarshark, catsharks, St Josheph sharks, white seacatfish and redfish.). Grids 595 and 604 contribute more to bycatch reduction of more offshore species including the Cape dory *Zeus capensis*, jacopever and *Helicolenus dactyylopterus.*

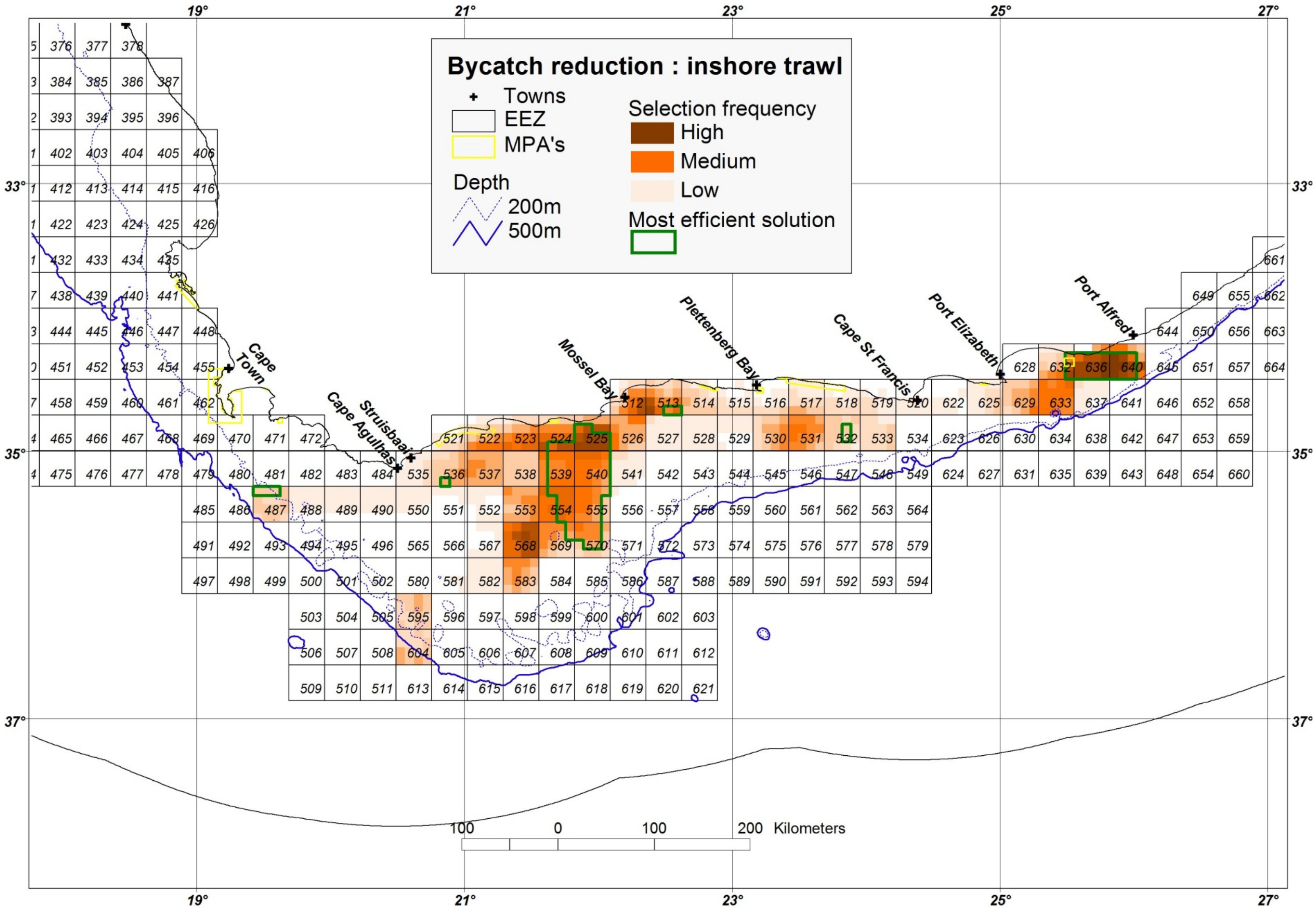


Figure 17: Potential priority areas to implement management to reduce bycatch in the inshore trawl sector as determined from the OMPA data set using a five minute planning grid.

In a more recent analysis (Figure 18) using the 20 minute grid (as opposed to the finer 5 minute grid used in the previous and all other Offshore MPA project analyses), Lombard *et al.* (2010) set targets for reducing inshore trawl bycatch using the same CPUE data but also included size frequency data to preferentially select areas with more smaller fish. This analysis also used a 20% target for 27 species, preferentially selecting gridcells with more smaller fish for 4 bycatch species (Carpenter, Geelbek, Panga and Silver kob) and one target species, shallow-water hake. Only 29 commercial trawl grids had sufficient data for inclusion in this analysis and targets could be met (and exceeded for several species) in seven commercial grids with 4 grids having 100% selection frequency (Grids 640 and 629 in Algoa Bay; Grid 513 off Wilderness and Grid 553 in the Blues) *(*Figure 17 and Lombard *et al.* 2010). The high selection frequency of grid 640, 513 and 553 is driven by the same patterns interpreted in the previous analysis (Figure 17) described above. In grid 629 high CPUE of gurnard *Cheilodonichthys* spp., panga, squid *Loligo vulgaris* and white seacatfish *Galeichthys felieps* lead to high selection frequency in this grid. The most efficient solution also included grid 517 off Tsitsikamma (97% selection frequency), grid 632 in Algoa Bay (92%), and grid 515 off Knysna (55%). The area off Tsitsikamma (Grid 517) could help reduce bycatch of geelbek and redfish (sparids such as red steenbras and roman). Grid 632 has a relatively high CPUE of silver kob, white stumpnose, white seacatfish, geelbek, lesser guitarfish, panga and carpenter. See Lombard *et al.* (2010) and the detailed background document (Attwood and Petersen 2010) for further detail about this analysis.

The differences between these two analyses result from the inclusion of additional catch and effort data (i.e. more commercial grids) in the first analysis (Figure 17), the inclusion of size frequency data and targets in the second analysis and the difference in planning unit size. Grids such as 487, 595, 604, 583, 569 and 570 were excluded from the second analysis as effort data was unavailable for these grids (Lombard *et al.* 2010). The larger planning unit is more appropriate as the observer data is collected at this scale and in the first analysis, the same CPUE values were assigned to all planning units within a grid cell when in reality, CPUE values may vary across a grid. The division of each commercial grid into 16 planning units provides more flexibility in the analysis as reflected in the lower maximum selection frequencies. The effect of the size structure data is not clear from the results of the second analysis (Figure 18) although this may explain the higher selection frequencies in grids that did not have high or as high selection frequency in the first analysis (e.g. grids 517, 515 and 629) and other variation between these two analyses. Grid 568 had higher selection frequency in the first analysis but in the second, the adjacent grid 553 was selected more frequently. Size structure data for panga and carpenter is likely to drive this pattern. The greater importance of grid 513 in the second analysis may be related to greater abundance of small hake in this grid.

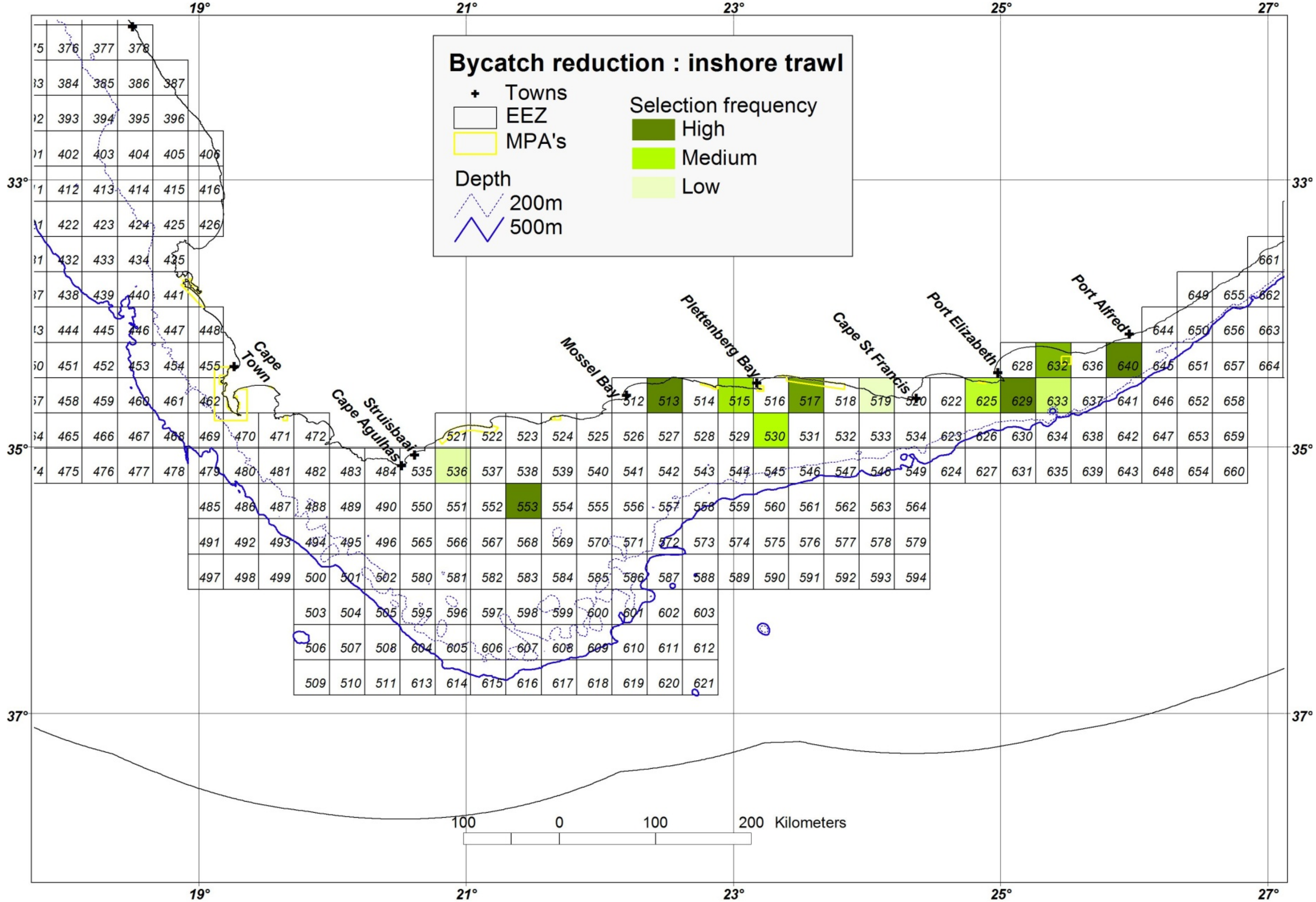


Figure 18: Potential priority areas to implement management to reduce bycatch in the inshore trawl sector as determined using the twenty minute commercial trawl grid as planning units and preferentially selecting areas with higher numbers of small hake (M. capensis), silver kob, geelbek, carpenter and panga (Lombard *et al.* 2010).

Offshore trawl bycatch management priorities

The scenario aimed principally at supporting the management of key offshore demersal trawl bycatch species (kingklip, monk and skate) showed important areas along the west coast and the shelf break area between Cape St Francis and Port Elizabeth (Figure 19). The highest selection frequency in this analysis was 76% with all planning units with a selection frequency above 60% offshore of Port Elizabeth in commercial grids 626 and 630. Selection frequencies on the west coast did not exceed 60% but important areas (50-60%) included commercial grids 362 and 372 along the shelf edge off Hondeklipbaai (near Childs Bank), grids 441 and 421 along the shelf edge off Lamberts Bay and an area along the shelf edge between Cape Town and Cape Agulhas (grids 501, 502 and 604). This western edge of the Agulhas Bank is known as Browns Bank. Planning units near Child's Bank were selected because of lower effort, relatively higher monk abundance and catch, high bycatch of skate and high kingklip catch in the commercial data. High commercial catch rates of kingklip, monk and skate drive selection frequencies in the Browns Bank area. The planning units off Port Elizabeth have very high selection frequency due to high kingklip catch or catch rates in all three data sets (demersal research, commercial and observer data).

Crustacean trawl bycatch management priorities

Targets were set at 20% for all kob and grunter species with the resulting areas of highest selection frequencies being inshore and offshore of the Tugela mouth (Figure 20). The maximum selection frequency was 69% with only 4 planning units having a selection frequency above 40%. Full targets could be met in three planning units and the areas of highest fishing effort were avoided in the selection of priority areas. Inshore, the highest selection frequency area off Tugela mouth (just north of Stanger) is driven by snapper kob *Otolithes ruber*, square tail kob *Argyrosomus thorpei* and grunters *Pomadasys kakaan* and *P. Commersonnii*. Catches of longfin kob *Atrobucca nibe* and the much lower effort values drive the offshore priority area along the shelf break. An area directly off St Lucia had medium selection frequency, driven mostly by the high bycatch of grunters. These species are associated with estuaries (particularly as juveniles) and with sandy or muddy offshore banks with turbid water conditions.

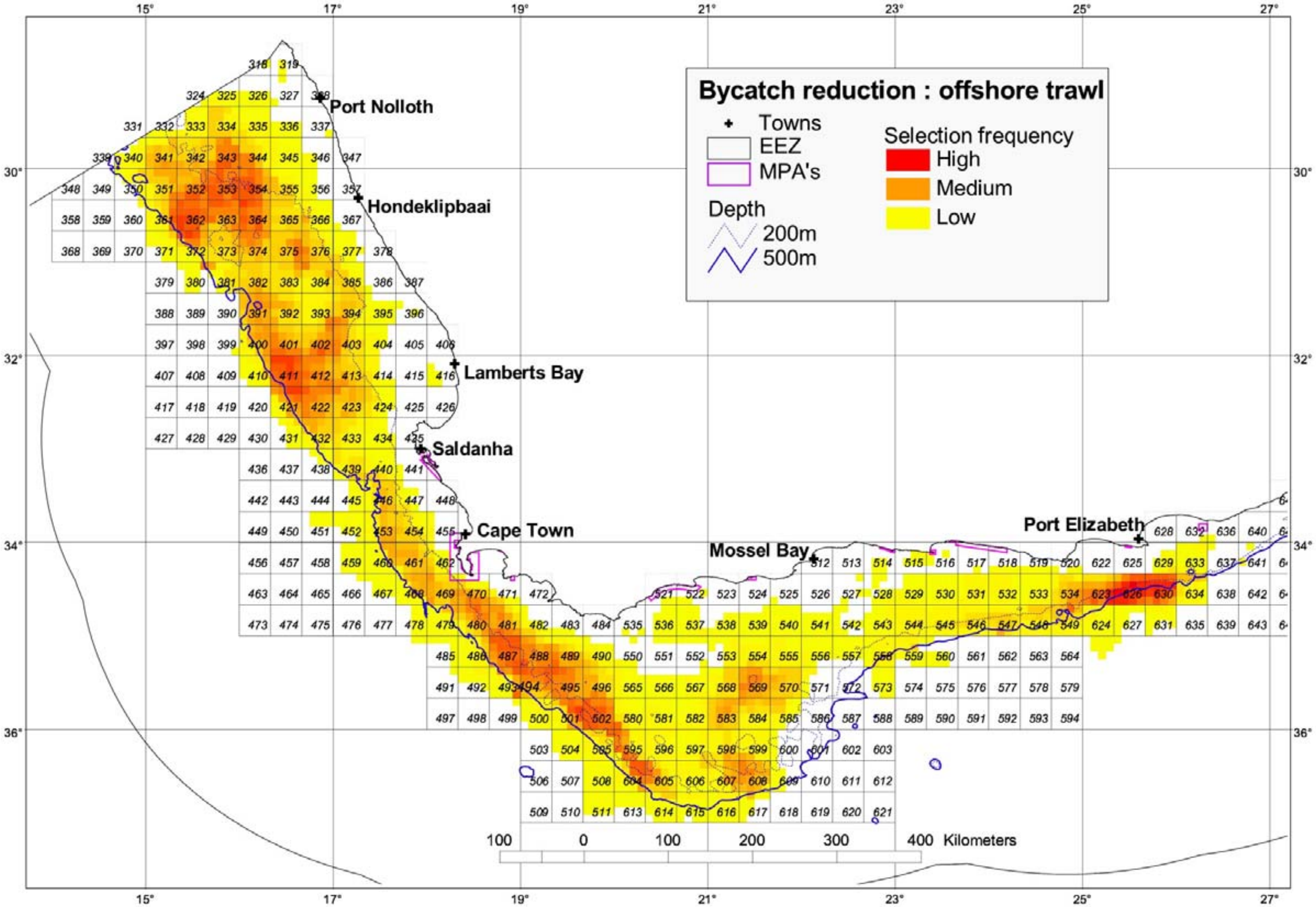


Figure 19: Potential priority areas to implement management to reduce bycatch in the offshore trawl sector.

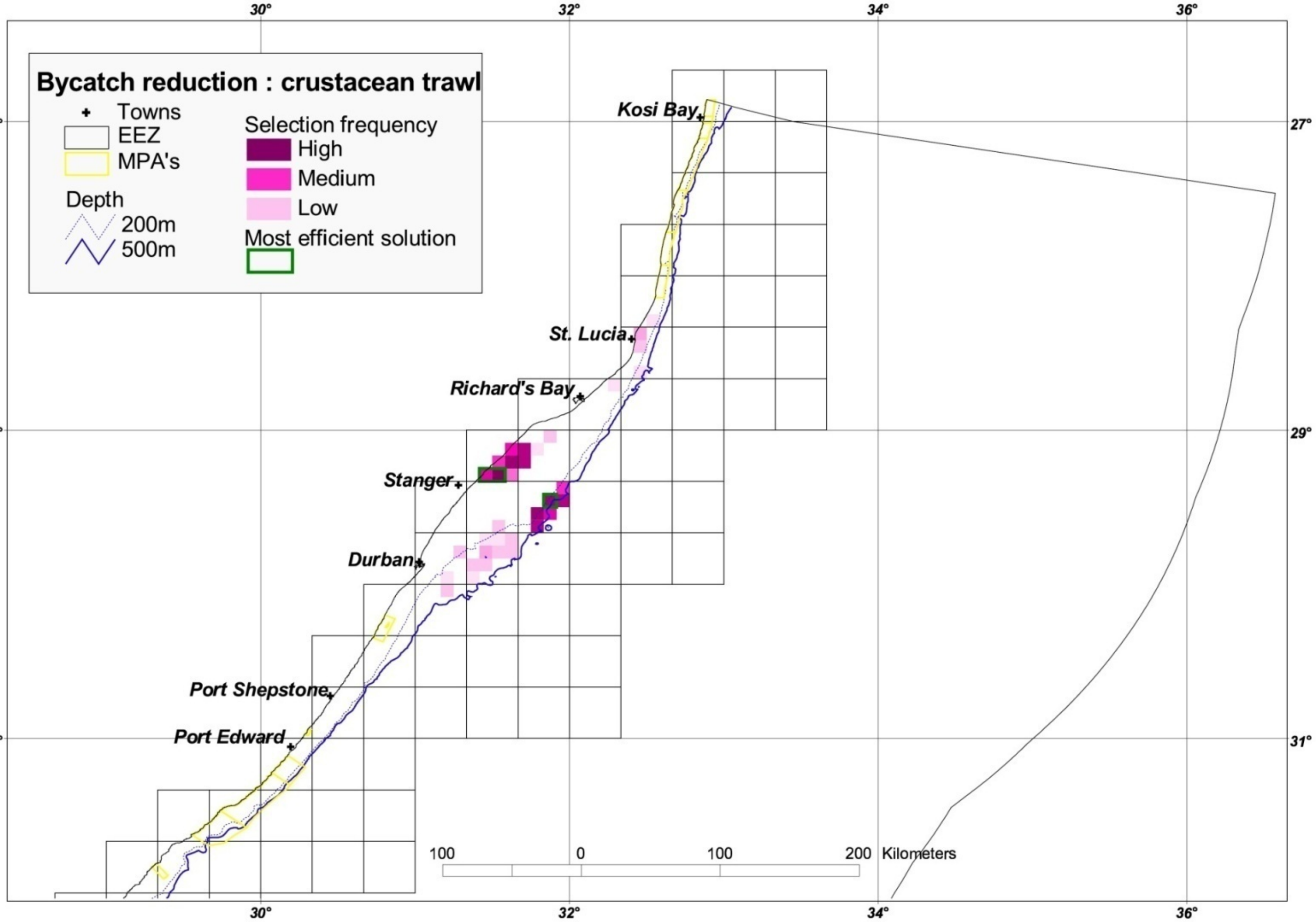


Figure 20: Potential priority areas to implement management to reduce bycatch of kobs and grunter in the crustacean trawl fishery in KwaZulu-Natal on the east coast of South Africa

Integrated analysis

The scenario that included all biodiversity targets used in all other scenarios simultaneously was termed the integrated analysis (Figure 21). The integrated scenario was interpreted using the results from the simpler scenarios that helped to identify the underlying drivers of selection. Of the total 15 534 planning units, only 5 had 100% selection frequency, including 2 planning units covering a section of Child's Bank, one that included Ibhubesi reef (off Hondeklipbaai), a planning unit offshore of Mbotyi in the controlled use zone of the existing Pondoland MPA and a planning unit off Port Alfred which includes a deep reef and cold water coral records. Many of the other planning units in the vicinity of the submarine feature known as Childs Bank had high selection frequency (70-99%) indicating that this feature strongly drives selection in the integrated analysis. Other features that drove selection included those benthic features of limited extent (particularly the potential vulnerable marine ecosystems which had higher targets than other seabed habitat types) and the important areas for threatened species (seabirds and leatherback turtles). Few planning units had selection frequencies in the 70-80% range but these included areas near Dassen Island off Saldahna on the west coast and additional planning units offshore of Mbotyi. Planning units in the 60-70% selection frequency range included additional planning units off Saldahna, off the uThukela River, offshore of St Lucia in northern KwaZulu-Natal and off Shelley Beach in southern KwaZulu-Natal. Groups of planning units in the 50-60% selection frequency range emerged offshore of Port Elizabeth.

Several broad areas that included high selection frequency (>60%) emerged from this analysis. These areas, from west to east, include:

- An area off Hondeklipbaai that includes Childs Bank, the adjacent shelf edge and the Ibhubesi cold water coral reef inshore of the bank
- Cape canyon, the shelf edge, outer and inner shelf areas in the area offshore of Saldana Bay on the west coast
- The southern tip of the African continental shelf (the shelf edge offshore of the area between Cape Agulhas and Mossel Bay)
- The inner shelf of the Agulhas Bank between the eastern boundary of De Hoop MPA and Gouritzmond (offshore of the Still Bay MPA)
- The shelf and shelf edge between Cape St Francis and Port Alfred, including the area offshore of Port Elizabeth
- An area offshore of the KwaZulu-Natal south coast
- An area of shelf and shelf edge between Tinley Manor and Mtunzini (south of Richards Bay) including a portion of the Tugela Banks
- An area offshore of the existing St Lucia MPA, from the Red sands sanctuary boundary to offshore of the town of St Lucia

(Figures 21 and 22)

The area near Child's Bank and Ibhubesi reef (off Hondeklipbaai) is an important area with no other options for meeting targets for the benthic protection of submarine banks and cold water coral reefs (Figure 10). Offshore trawl bycatch targets (kingklip, monk and skate) also play a role in driving selection in this area (see Figure 19).

The offshore area around Saldanha Bay has high selection frequency due to threatened seabirds (Figure 13), the presence of low oxygen habitat, deep reefs and hard grounds as well as the Cape canyon (Figure 10). The head of Cape Canyon has a slightly higher overall selection frequency compared to the Cape Valley (the other Southern Benguela submarine canyon) off Cape Point. This is driven by lower general and benthic cost values and the convergence of more features in the vicinity of Cape Canyon. This area also contributes to fisheries sustainability in the demersal trawl and small pelagic sector (Figures 14 and 15).

There are several areas on the Agulhas Bank that have high frequencies in planning units where deep reef, sediment types of limited spatial extent and targets to reduce bycatch in the inshore trawl sector drive selection (see Figures 10, 17 and 18). Important habitats that contribute to high selection frequency in this area include the Agulhas sandy gravel, terrigenous muds, muddy sands, relict shelly sands and hard grounds in the inner shelf (also reflected in Figure 10). The area offshore of Still Bay, emerges as a priority area for offshore protection because of targets to support bycatch management for 27 species in the inshore trawl sector (Figures 17 and 18).

Further offshore, at the southern tip of the African continental shelf, the presence of multiple biozones and pelagic “habitats”, multiple sediment and geological types, hard grounds and features relating to the sustainability of demersal trawl fisheries drive selection of this area (Figures 10, 11, 15 and 16). Key geological features include gravels, relict shelly sands, muddy sands and authigenic sediments of different types as classified by the 7 benthic biozones that are represented within this area. The western edge of this area extends into the very south of the offshore trawl ground along the west coast, known as Browns Bank and is an area that can help meet targets for large hake and spawning hake and contributes to bycatch management for the offshore trawl sector (Figures 16 and 19). The eastern edge of the area could contribute to the sustainability of the small pelagic fishery as this area is the most efficient area to meet targets for protecting large and spawning small pelagic fish (Figure 14). The presence of Southwest Indian seamounts offshore of the eastern edge of the Agulhas Bank drives high selection frequency in this area.

The shelf and shelf edge area off Port Elizabeth has high selection frequency in many scenarios (Figures 10-16 and 19). Threatened seabirds and inshore trawl bycatch play an important role in driving selection in the inner shelf. The shelf edge area is important for meeting many targets for habitat representation and protection and bycatch mitigation for linefish. This area also has relatively high bycatch of turtles, seabirds and sharks by the large pelagic sector. There are four submarine canyons off Port Elizabeth, three types of untrawlable grounds and records of reef-building cold water corals. There is a proposed MPA (Addo) in this area and these offshore priorities should also be considered in planning and zoning for this area. It is recognised that this is an important area for fisheries and further fine-scale work is required to guide MPA planning and establishment in this area.

The area offshore of the KwaZulu-Natal south coast (including Protea Banks) has high selection frequency in the integrated analysis (up to 69%) and in the benthic protection and pelagic biodiversity scenarios. This is driven by submarine canyons, deep reef and the presence of several records of two species of reef-building cold water corals. This area also contributes to meeting targets for protecting priority linefish.

The area north of Durban on the Tugela Bank emerges as a priority area because of its potential role in meeting many biodiversity targets. This area emerged clearly as a priority area in the analysis to determine priority areas for seabed protection (Figure 10). Key benthic habitats that drive selection in this area include Natal and South-west Indian terrigenous muds, Natal sandy mud, Natal authigenic sediments and Natal east coast dunes. Individual cells with high selection frequencies are driven by the presence of submarine canyons as well as their ability to meet targets aimed at reducing kob and grunter bycatch in the crustacean trawl fishery (Figure 20).

The broad area with high selection frequency in the vicinity of St Lucia (and northwards towards Sodwana Bay) is driven by spatial patterns of use by leatherback turtles, the presence of offshore components of submarine canyons and cold water coral records that are currently beyond the 3 nautical mile boundary of the St Lucia Marine Reserve within the iSimangaliso World Heritage Site. Two benthic bioregions intersect at Cape Vidal and protection of this area could facilitate the meeting of multiple benthic and pelagic habitat type targets in a spatially efficient manner.

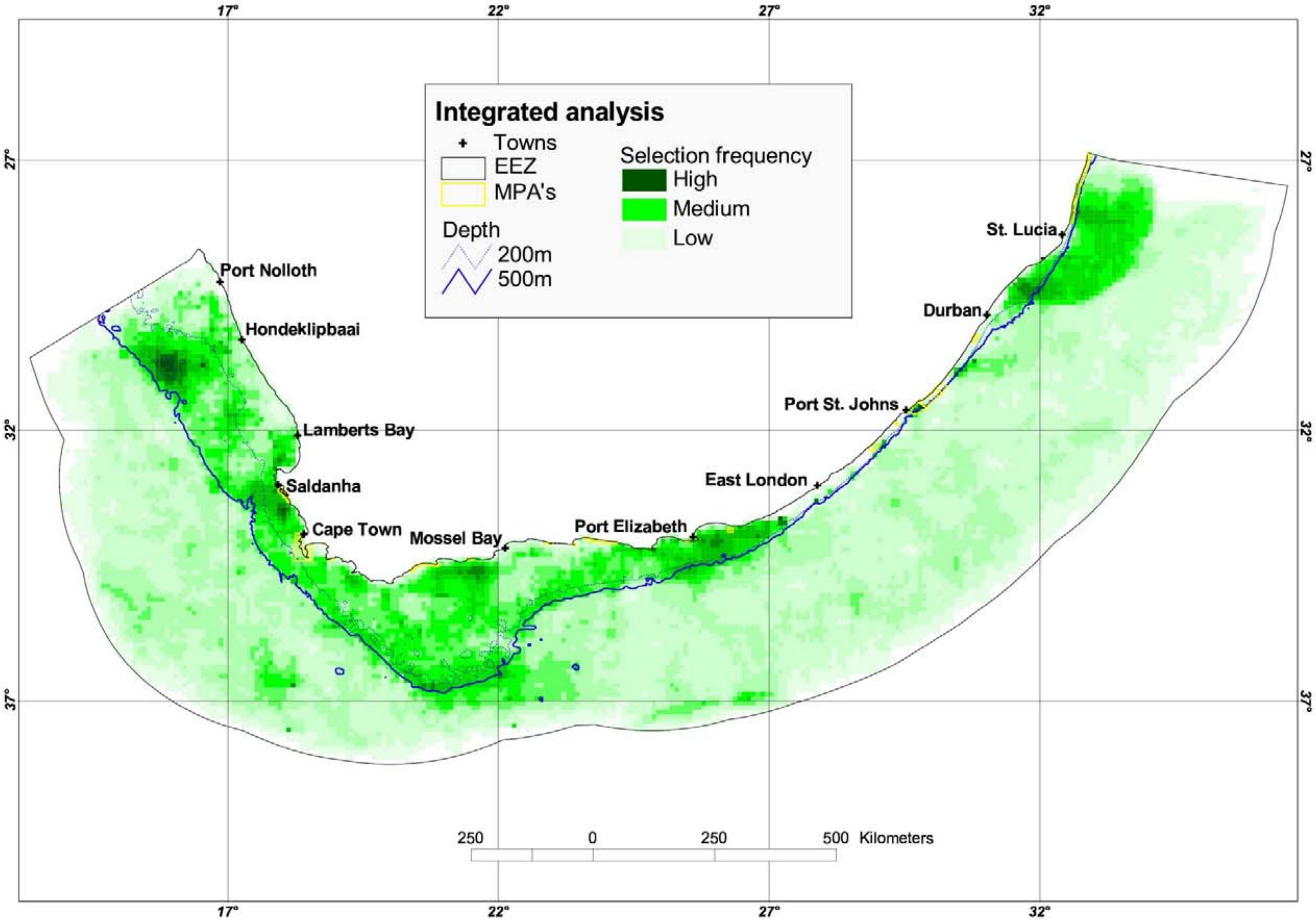


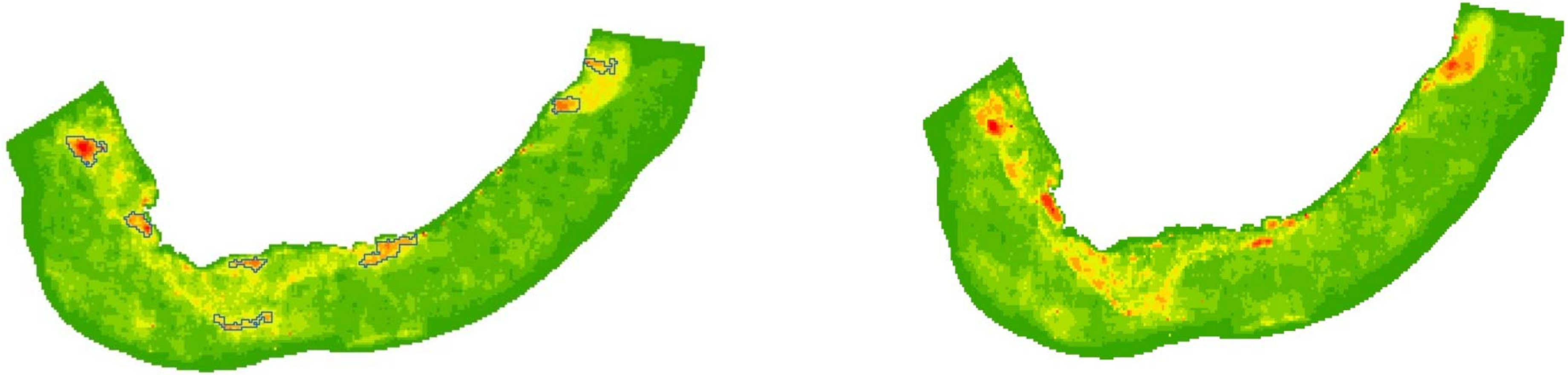
Figure 21: Results from the integrated analysis showing potential priority areas to implement spatial biodiversity management in South Africa. All biodiversity targets including habitat representation, seabed protection, contribution to fisheries sustainability and bycatch reduction were included in this scenario.

Small areas (less than 1000 km^2) that also had relatively high selection frequency (50-60%) in the integrated analysis included;

- An area north of Saldanha Bay (driven by low oxygen water and hard grounds)
- Three planning units along the western edge of the Agulhas Bank in the vicinity of Browns Bank (driven mainly by hard grounds, areas with hake spawning and large hake)
- Planning units at the head of the Cape Valley submarine canyon off Cape Point
- Southwest Indian seamounts offshore of the eastern edge of the Agulhas Bank (Shackleton seamount had highest selection frequency)
- Seamounts in the South Atlantic (Protea seamount had the highest selection frequency)
- Planning units with cold water coral records and or canyon heads between Port Alfred and East London
- An area offshore of Gansbaai (driven by threatened seabirds)
- Deep reefs on the Agulhas Bank (including Alphard, 45 Mile and 72 Mile Bank)
- Areas offshore of the former Transkei (driven by relatively lower cost as well as the presence of vulnerable marine ecosystems and rare benthic habitat types (especially Natal and Southwest Indian muddy sand gravels).

Identification of focus areas for offshore protection

The results from all the scenarios reflected in this report were used to identify a set of focus areas for the development of a network of offshore spatial management measures including MPAs over the next five years. Focus areas are geographic areas with the highest priority for the implementation of offshore spatial management and are similar to the 42 focus areas for land-based protected area expansion as identified by the National Protected Area Expansion Strategy (Government of South Africa 2010). The results from all offshore planning scenarios (Figures 10-21) were carefully examined and processed to demarcate a set of focus areas that reflect the results from the set of systematic planning analyses conducted through this project. These focus areas represent those areas where the most offshore biodiversity targets can be met with the least impact on offshore industries. These focus areas do not represent the boundaries for any spatial management measures which would differ from the focus areas as they will need to be constrained into a practical implementation framework. The proposed boundaries of spatial management measures could be smaller or larger than those reflected by the focus areas.



(a) **(b)**

Figure 22: Important areas for offshore protection as determined by (a) the integrated analysis and (b) the maximum score per planning unit across all scenarios. Red areas have the highest selection frequency and green areas have the lowest selection frequency. Large areas (more than 1000 km^2) with the highest selection frequency (>40% on the selection frequency histogram) are outlined in blue on map (a). Map (b) illustrates the maximum score for each planning unit but review of the selection frequency scores for each analysis was more useful for identifying any smaller areas with high selection frequencies from individual scenarios that were not included in the seven larger areas outlined in map (a).

The results of the integrated analysis were considered the most appropriate set of results to support the development of a first set of priority areas that comprised large, unfragmented areas of high importance suitable for spatial management. These priority areas were identified by applying a size and selection frequency threshold of 1000 km^2 and 40% respectively. This resulted in the identification of seven priority areas (Figure 22a), all of which were discussed above in the interpretation of the map reflecting selection frequencies from the integrated analysis (Figure 21). These priority areas include the areas around Childs Bank off Hondeklipbaai, off Saldanha Bay in the vicinity of the Cape Canyon, an area along the shelf edge at the southern tip of the African continental shelf, an area on the Agulhas Bank, offshore of Port Elizabeth and two areas in northern KwaZulu-Natal. These seven large priority areas each constitute the core of a focus area for offshore protection but smaller areas of very high importance were also considered. Smaller areas of high importance were examined first in the integrated analysis but then also in all individual scenarios (Figures 10-20 and summarised in Figure 22b). Larger areas of high importance in the individual scenarios were also considered.

In the integrated analysis, the application of a size threshold excluded isolated areas of very high selection frequency. This includes two planning units with 100% selection frequency, one within the existing Pondoland MPA and one off Port Alfred which includes a deep reef and cold water coral records. The former is within an existing MPA but the latter is without any protection. The only other planning units with selection frequency above 60% in the integrated analysis that were not included in the seven large priority areas were (1) those that included Shackleton seamount, (2) two other planning units off Port Alfred, (3) one planning unit in the Gxulu area of the Amathole MPA, (4) one planning unit offshore of the existing Dwesa MPA and (5) three planning units on the KwaZulu-Natal south coast in the vicinity of Protea Banks.

Although the integrated analysis represents the most spatially efficient design to achieve all objectives, it also excluded some areas that were identified as important in some individual scenarios. To address this, the maximum scores for each planning unit (considering all scenarios listed in Table 3) were examined to explore the relative importance of all planning units across all planning scenarios (Figure 22b). Two large potentially important areas were reflected in Figure 22b that were not included in the outlines of the priority areas shown in Figure 22a. These include a shelf edge area offshore of Lamberts Bay and an area along the western edge of the Agulhas Bank (Browns Bank). Both these areas are driven by the high scores in the scenarios aimed at reducing bycatch and supporting sustainability (by protecting spawning areas, large fish and nursery areas) in the offshore trawl fishery (Figures 15,16 and 19), although hard grounds in the Browns Bank area also increased selection frequency in this area. Smaller areas that had high selection frequencies in the map summarising maximum scores included those planning units that included benthic biodiversity features of limited extent such as seamounts, submarine canyons, cold water coral records and rare sediment types. East of Port Elizabeth, along the narrow shelf and shelf edge, five very small areas (3-5 planning units) had high selection frequencies apparent in both the integrated analysis (Figure 22a) and the summarised version of maximum selection frequency scores across all analyses (Figure 22b). The largest of these areas is located in the area between Trafalgar and Umzumbe (including Protea Banks) along the KwaZulu-Natal south coast. The second largest is already protected in South Africa's only MPA that makes a substantial contribution to the protection of offshore habitats, the Pondoland MPA. However, within this area the highest selection frequency is within a zone currently open to offshore fishing. The remaining three small areas are offshore of Port Alfred, the Gxulu area of the Amathole MPA and the Dwesa MPA.

The approach of using a single selection frequency threshold to identify additional areas with high frequency was not considered appropriate for use in the map reflecting maximum scores (Figure 22b) as different planning scenarios resulted in a wide range of selection frequencies (maximum values ranging between 30 and 100%) and the application of a single threshold would bias selection of areas in favour of certain planning scenarios with the least flexibility. Such an approach would continue to miss important areas identified in scenarios that had greater flexibility. Rather, the most frequently selected planning units in each main analysis were reviewed to determine which may not have been included in the priority areas reflected in Figure 22a. Both the 20 most frequently selected planning units and all planning units with a selection frequency above 60% were considered as important areas in the individual scenarios. These frequently selected planning units were within the seven large priority areas determined from the integrated analysis in most cases with a few exceptions;

- Benthic protection - Planning units at Protea and Mallory Seamount, 2 planning units that include deep reefs on the Agulhas Bank, three adjacent planning units off Port Alfred, one off Dwesa MPA and five adjacent planning units near Protea Bank in southern KwaZulu-Natal.
- Pelagic biodiversity - Three adjacent planning units off Port Alfred, four adjacent planning units near Protea Bank and one planning unit offshore of the existing iSimangaliso MPA (inshore of the priority area outlined in Figure 22b).
- Threatened species - No additional important planning units identified.
- Small pelagic fisheries sustainability - Two additional disparate important planning units identified on the central Agulhas Bank.
- Demersal trawl fishery sustainability - Three disparate planning units off Lamberts Bay, two planning units in the Browns Bank area (north west of the priority area reflected in Figure 22a) and 7 planning units offshore of Port Nolloth (within the De Beers ML3 Mining license area).
- Inshore trawl bycatch reduction – Several planning units in commercial grid 568, one in commercial grid 513 off Herolds Bay (Figure 17) and commercial grid 517 off Tsitsikamma (Figure 18).
- Offshore trawl – one planning unit in commercial grid 411 off Lamberts Bay and two adjacent planning units in the vicinity of Browns Bank.

- Crustacean trawl – one planning unit off Durban.

It was not deemed practical to add many small areas to the seven large priority areas identified in Figure 22b and many options were explored to prioritise protection using different selection frequency and size thresholds for the individual analyses. Ultimately, the addition of two further priority areas and minor modification of those identified in Figure 22a was able to capture the majority of the additional important planning units (as reflected by small areas of high importance in the integrated scenario and the most important areas identified for each individual scenario) with few exceptions. Two new focus areas that included Protea seamount and Protea Bank were needed to achieve this. Then, modification of the priority area around the southern tip of the African continental shelf was required to capture Mallory and Shackleton seamounts and to capture important planning units in the vicinity of Browns Bank. Other planning units on the Agulhas Bank were highlighted for inclusion in the existing priority area and a slight westward extension of the priority area off Port Elizabeth could accommodate important planning units off Port Alfred. Where important planning units lay close to (within 3 planning units) of the larger priority areas identified from the integrated analysis, they were targeted for inclusion in the nearest focus area. The priority area near Cape Canyon was extended slightly north to include important planning units off Saldanha Bay within the focus area. The Agulhas Bank priority area was adjusted to included important deep reef habitats and the priority area offshore of iSimangaliso was extended slightly south to include an important planning unit into the focus area.

This approach ensured that all multiple adjacent important planning units were captured and that all planning units that were identified as important in more than one analysis were included in a priority area. Exceptions that were not covered using this approach mostly include single isolated planning units (such as those off Lamberts Bay, off Gxulu and Dwesa MPA, one planning unit off Durban and the seven planning units offshore of Port Nolloth which lie within the only offshore diamond mining lease area).

The focus areas were demarcated as polygons using GIS software (ArcMap). The results from the analyses (integrated and other) were used as a baseline for demarcating the focus areas along with other fine-scale GIS layers (reflecting biodiversity features, cost data, industry activity and other spatial management measures). These focus area polygons were constructed around the planning units that have high selection frequency with minor adjustments as described above. Other minor adjustments to support practical implementation were also undertaken using fine-scale industry data (e.g. trawl footprint and trawl track data) to minimise impacts on industry and maximise conservation opportunities (e.g. preferentially selecting untrawled habitat) and ensure that entire features that drove selection (such as entire seamounts) were included in the focus areas. Finer-scale cost layers were checked to ensure that any minor adjustments avoided planning units of very high cost, in all cases.

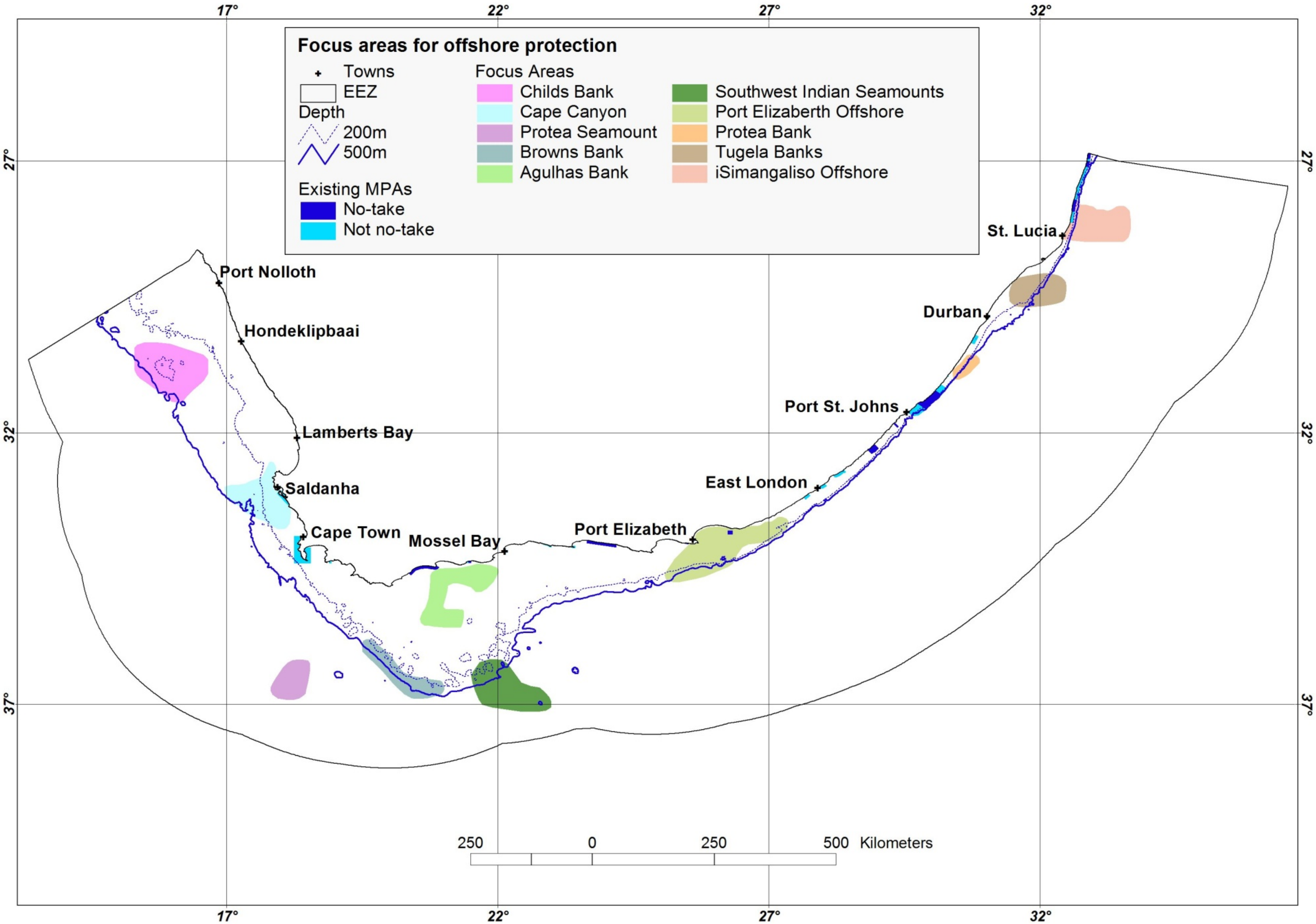


Figure 23: The ten focus areas for offshore biodiversity protection through MPAs or other types of spatial management.

Table 4: Focus areas for offshore biodiversity protection including key objectives, key stakeholders and management considerations.

Focal Area Name	Objectives	Key stakeholders	Potential spatial management measures & other considerations
Childs Bank	• Offshore habitat representation • Benthic protection (submarine bank, shelf, shelf edge and cold water corals) • Bycatch management (offshore trawl) • Fisheries management (demersal trawl)	Offshore trawl fishery Demersal longline fishery Petroleum Mining	Experimental closure for benthic fisheries along the shelf (linked to the SADSTIA proposed trawl closure committed as part of eco-certification conditions) is recommended. Full seabed protection is advised for the Child's Bank submarine feature and it is suggested that this is effected prior to implementation of the closure so as not to shift effort onto this potential vulnerable marine ecosystem. iBhubesi reef is also recommended as a seabed protection zone and further engagement with the petroleum sector is needed in this regard. The broader focus area is important for large pelagic fishing, seabed protection and support for the management of demersal resources. It may not be necessary to exclude pelagic fisheries from this area.
Cape Canyon	• Offshore habitat representation • Pelagic habitats and processes • Benthic protection (canyon) • Threatened species • Fisheries sustainability	Offshore trawl fishery Demersal longline fishery Small pelagic Petroleum Mining	A zoned MPA including no-take areas, seabed protection zones and zones to minimise user conflict could help achieve multiple objectives in this area. The existing MPAs (Langebaan, Sixteen Mile Beach, Marcus Island, Malgas Island and, Jutten Island) in the area should be considered for consolidation, extension or re-zoning to resolve existing resource conflicts, protect threatened species in core areas and minimise stakeholder impacts. This area is important for small pelagic fisheries who are interested in negotiation to achieve increased protection of core seabird habitat in return for access to part of the Sixteen mile beach MPA.
Protea Seamount	• Offshore habitat representation • Benthic protection (seamount)	Large pelagic Mining	Two seamounts in this area should be included within a zoned MPA that includes a no-take area and a benthic protection zone. Fishing could be excluded from the seamount where lowest effort has been exerted. A portion of the Ferro-manganese nodule habitat must be included in the MPA.
Browns Bank	• Offshore habitat representation • Benthic protection • Fisheries sustainability (demersal trawl & longlining) • Bycatch management (offshore trawl)	Offshore trawl fishery Demersal longline fishery Demersal shark South coast rock lobster	Sector specific Fishery management Areas, seabed protection zones or MPAs can be considered in this area. The Browns Bank area is an important spawning area for hake and data suggests that large hake frequent this area. As such a small closed area, including the more vulnerable hard ground habitat, could support the sustainability of the hake fisheries. There are hard grounds in this focus area which should receive formal protection (effected in legislation) from fishing and mining. Activities that affect the seabed should be prevented from extending into deeper water along this shelf edge area.
Agulhas Bank	• Offshore habitat representation • Benthic protection (deep reefs) • Bycatch management (inshore trawl) • Fisheries sustainability (linefish, hake) • Threatened species	Inshore trawl Linefish Demersal shark South coast rock lobster Petroleum	A zoned MPA is recommended in this area to represent poorly protected habitats (especially mud and gravel habitats), protect vulnerable marine ecosystems (deep reefs, hard grounds) and support fisheries sustainability. This could include or supplement independent spatial management aimed at supporting bycatch management for the inshore trawl sector. A network of linked (but not necessarily contiguous) spatial management measures across the bank may be most appropriate in this focus area. Key features for inclusion include the Alphard Bank, the 45 Mile Bank, unrepresented gravel and mud habitats and different fish communities that are caught by the inshore trawl sector.

Focal Area Name	Objectives	Key stakeholders	Potential spatial management measures & other considerations
	(linefish)		
Southwest Indian Seamounts	• Offshore habitat representation • Benthic protection (seamount, shelf edge) • Fisheries sustainability (small pelagic species) • Bycatch reduction (large pelagic)	Offshore trawl Large pelagic	A fully protected or zoned MPA is suggested to achieve the multiple objectives for this area. Very rough ground and strong currents already offer some protection to this area which has lower cost than many other shelf edge areas. Unprotected habitats of very limited spatial extent should be considered for inclusion (e.g. shelf edge gravels). Two separate management areas or a large single zoned area could be considered.
Offshore Port Elizabeth	• Offshore benthic habitat representation • Benthic protection (cold water corals, canyon, shelf edge, deep reefs) • Fisheries sustainability (kingklip, hake, linefish, squid) • Bycatch management (inshore and offshore trawl) • Threatened species (seabirds)	Inshore trawl fishery Offshore trawl fishery Midwater trawl fishery Linefishery Demersal longline fishery Demersal shark fishery Large pelagic fishery South coast rock lobster fishery Petroleum	Seabed Protection zones, Fishery Management Areas and expansion of existing or proposed Marine Protected Areas should all be considered in this complex area. There are offshore features in this area that have few alternative options for conservation which is why this area is still selected despite relatively high cost values in this area. Existing planning for the proposed Addo MPA and the existing seasonal kingklip closure should also be considered in the development of offshore spatial management measures in this area and a suite of smaller appropriately zoned areas across this focus area could be appropriate.
Protea Bank	• Offshore benthic habitat representation • Pelagic habitats and processes representation • Benthic protection (cold water corals, canyon, shelf edge, deep reefs) • Fisheries sustainability (linefish) • Threatened species (linefish)	Linefishery Recreational fishers Scuba divers Large pelagic fishery (if offshore of 20 nm)	A zoned Marine Protected Area should be considered in this area which also has potential to provide for non-consumptive resource use. This focus area was also identified by fine-scale planning conducted in KwaZulu-Natal through the SeaPlan project. The presence of 4 submarine canyons, deep reefs and 7cold water coral records highlight the need for effective seabed protection in this area although there is evidence that this area is important for pelagic processes (high frequency of fronts) and sharks. This area could contribute to reef types that are currently underprotected in the bioregion and could help recovery of overexploited linefish. Conflict between divers and fishers needs to be addressed but there is currently some voluntary effort to stop fishing in some areas.
Tugela Banks	• Offshore habitat representation • Benthic protection (cold water corals, canyon, shelf edge,	Crustacean trawl fishery Linefishery Large pelagic Petroleum (new	A zoned Marine Protected Area and industry –specific fisheries or bycatch management areas should be considered for implementation in this area. Unprotected pelagic and seabed habitats (such as Natal shelf muds and gravels and submarine canyons) warrant protection in this area which has complex sedimentary patterns and complex oceanography. This area is highly productive and serves a nursery area for many species. This focus area was also identified by fine-scale planning conducted in KwaZulu-Natal through the

Focal Area Name	Objectives	Key stakeholders	Potential spatial management measures & other considerations
	deep reefs) • Bycatch management (crustacean trawl) • Threatened species (turtles, linefish)	leases) Mining	SeaPlan project led by Ezemvelo KZN Wildlife.
iSimangaliso Offshore	• Offshore benthic habitat representation • Pelagic habitats and processes representation • Benthic protection (canyons, corals) • Bycatch management (crustacean trawl) • Fisheries sustainability (linefish) • Threatened species (turtles, linefish)	Crustacean trawl fishery Linefishery Large pelagic fishery (if extends beyond 20 nm) Recreational fishers	Southern and offshore expansion of the existing Marine Protected Area and World Heritage Site with appropriate zonation is recommended in this area. Large pelagic fishing is not permitted within 20 nm of the coastline and costs are low within this zone of the focus area. This focus area was also identified by fine-scale planning conducted in KwaZulu-Natal (SeaPlan project). This area is important for threatened species, particularly turtles and linefish. Entire canyons and cold water coral records offshore of the current MPA must be included.

Limitations and research priorities

The inclusion of available scientific knowledge to guide the design of an MPA network is a critical component of our methodology. We recognise that knowledge of offshore biodiversity in South Africa is limited (Gibbons *et al.* 1999, Attwood *et al*. 2000, Leslie *et al*. 2000, Sink *et al.* 2006, Griffiths *et al.* 2010) but a flexible approach to planning, which can adapt with increasing knowledge, has been implemented. The project draws from previous and current research focused on offshore biodiversity patterns, processes (such as research on spawning or nursery areas) and impacts of commercial activities within the EEZ. The database and planning framework developed for this project can be updated as new information becomes available. Such updates and new analyses are not, however, without cost.

Key limitations of this project include those related to data quality and knowledge gaps. Key data gaps include data to reflect transport pathways and connectivity in the ocean. Offshore habitat data needs to be improved with better information at a finer resolution for the distribution of offshore reefs, banks and hard grounds. The distribution of cold water corals needs to be further investigated and muds, gravels and other rare unconsolidated habitat types should be more accurately mapped. Pelagic biodiversity pattern and process data needs verification and better data is needed to reflect key patterns of use of important pelagic species.

Several fisheries data sets need to be improved including spatial data for the squid, tuna pole and linefish sectors. The only sector not considered in this study was the recreational fishing sector. Key areas for improvement include the development of data layers for additional key ecological support areas for fisheries including important areas for spawning of linefish, improved spawning data for demersal species of fish and size structure data for fisheries, target and bycatch species. Better data to reflect pathways of successful transport and support an effectively linked network of spatial management (Hutchings *et al.* 1988, 2002) are needed. Conservation assessments to identify threatened marine species and new or improved spatial data for these species will also help identify other important areas for threatened species. Threatened seabirds could benefit from further dedicated analyses that incorporate the number of breeding birds in colonies and that take cognisance of global change.

Inadequate data was available to reflect important areas for offshore seabirds such as albatrosses and petrels, although we did collate spatial data reflecting incidental mortality for some of these species in the large pelagic fishery (data not shown in this report). Identification of important bird areas for threatened offshore seabirds is a priority and the results of this work must feed into future assessments and spatial planning work.

A further limitation is the dynamic nature of offshore industry sectors that will result in changing patterns of use and changing cost layer data for the offshore environment. This highlights the need for current implementation as substantial implementation delays will alter spatial patterns of use and could lead to the need for new analyses and a repeat of the stakeholder engagement process.

Next steps

These analyses were used to identify focus areas for offshore MPAs and other types of spatial management in the next five years. The focus areas include the best options to meet multiple objectives for protection and sustainable use of South Africa's offshore environment. The last phase of this project is the implementation phase. Practical proposed boundaries for each focus area must now be determined through finer-scale interrogation of spatial data and further stakeholder consultation. The focus areas include those planning units where targets are most likely to be met, although the final proposed boundaries for offshore spatial management will differ from the boundaries reflected on the map of focus areas in this report. The final proposed boundaries could be smaller or larger than those reflected by the focus areas. Individual data layers and maps should guide the development of boundaries and individual cost layer maps and maps of industry activity should guide the type of management and zonation as appropriate. Practical compliance considerations must also be taken into account in determining proposed boundaries (Kroese 2009).

Types of spatial management could include zoned Marine Protected Areas or Fisheries Management Areas promulgated through South Africa's Marine Living Resources Act. Other types of management could include seabed protection zones, experimental closures or listing of threatened or protected ecosystems through South Africa's Biodiversity Act. Initially, an experimental approach is advocated (Sink and Attwood 2010). This will facilitate learning about the potential benefits and effects of spatial management and is likely to provide other lessons pertinent to the implementation of offshore closures and spatial management. Such lessons can guide the implementation of a network of spatial management measures into the future. Over the next few years, the co-ordinated implementation of a network of spatial management measures is proposed. This will advance the expansion of South Africa's MPA network, minimise cumulative impacts on industry through ad-hoc implementation of individual spatial management measures and will ensure that offshore habitats are represented in a spatially efficient network of spatial management measures that meet multiple objectives.

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Appendix 1:

Data layers, source of data and data application (biodiversity targets, design considerations) used in the spatial planning analyses for the identification of a potential offshore Marine Protected Area network for South Africa. VME refers to vulnerable marine ecosystems. MCM refers to the former Branch of Marine and Coastal Management in the Department of Environment.

Data layer or feature	Data source	Target % (or no.)	Target and /or design consideration rationale (Notes)
Biodiversity pattern			
Benthic biozones – 22 biozones that capture biogeographic pattern and depth zones	Amended from Lombard *et al.* (2004) on the basis of expert knowledge (Sink 2010) & current research results	10%	Representation of biodiversity pattern Provision of reference areas
Pelagic habitats – 16 types (Outputs from pelagic habitat classification, includes data for mean, maximum and variation in sea surface temperature (SST) chlorophyll, nutrients, frequency of SST and chlorophyll fronts and cyclonic and anti-cyclonic eddies)	Lagabrielle *et al.* 2009	5%	Representation of biodiversity pattern and process. Retention targets were excluded from final analyses.
Pelagic processes - (fronts, eddies, chlorophyll and retention per pelagic biozone)			
Selected geological features – 22 geological types (authigenic sediments, pre-Mezozoic basement, ferro-manganese deposits, terrigenous muds, west coast shelly sands and east coast dunes, classified by bioregion)	Lombard *et al.* (2004), Dingle *et al.* 1987	10%	Representation of biodiversity pattern Provision of reference areas
Sediment types classified by bioregion – 30 types (texture map)	Lombard *et al.* (2004) with editing	10%	
Canyons classified by bioregion – 4 types	Lombard *et al.* (2004) with editing	20%	
Reef building cold water corals records – 3 species with 2 sub classified by bioregion (5 types in total)	Iziko (South African Museum)	50%	
Cold water coral reefs (Ibhubesi reef)	Forest Oil	(1) 30%	
Hard grounds classified by biozone (12 types)	MCM demersal section	30%	
Shelf break classified by bioregion – 4 types	NSBA 2004	10 %	
Offshore reefs classified by biozone – 8 types	Reef Atlas Project	10%	Representation of biodiversity pattern Protection of potential VME Provision of reference areas Contribution to linefishery sustainability
Linefish species richness (no. unique species / 5‘ grid (corrected for effort and transformed) – surrogate for reef habitat (filtered out lowest 20%))	MCM	10%	
Sumarine bank	Expert knowledge based on geological maps & GEBCO 2009	30%	Representation of biodiversity pattern Protection of potential VME
Seamounts classified by bioregion – 2 types	NSBA 2004	30%	Representation of biodiversity pattern Protection of potential VMEs Note: Entire seamounts (this can only be achieved post analyses)

Data layer or feature	Data source	Target % (or no.)	Target and /or design consideration rationale (Notes)
Suberites sp. sponge beds (Filtered out all cells with less than 100 kg of catch)	MCM	(30%)*	Representation of biodiversity pattern Protection of potential VMEs Provision of reference areas
Low oxygen areas classified by biozone (3 types)	MCM data (Hutchings)	10%	Representation of biodiversity pattern Provision of reference areas
Threatened species			
Core foraging areas for African penguins (Vu) (20 km radius, tracking data)	Lorien Pichegru	30%	Protection of threatened species Representation
Core foraging areas for Cape gannets (Vu) (100km radius but we have tracking data)	Lorien Pichegru	30%	
Coastal bird foraging areas for Bank cormorants (En), (10 km foraging range)	Crawford *et al.* 1999	30%	
Foraging areas for Cape Cormorants	Kemper *et al.* 2007	30%	
Leatherback turtle tracks and 50% utilisation density polygons	Ronel Nel (MCM data)	30%	Protection of threatened species Reduction of incidental mortality
Distribution of priority linefish for conservation (per bioregion)	MCM	30%	
Fisheries sustainability			
Hake spawning layer (*note –data inadequate)	SADSTIA	(*10%)	Contribute to fisheries sustainability by protecting spawning fish
Big hake layers (*M. capensis* and *M. paradoxus)*	SADSTIA	5%	Contribute to fisheries sustainability by protecting larger, more fecund fish
Average catch of *M. capensis* and *M. paradoxus* <21 cm / grid block (research database) and relative proportion of small fish to total hake catch	MCM	NA	Contribute to fisheries sustainability by protecting nursery areas, Prevent waste by protecting hotspots of small fish
Large sardines and anchovy (anchovy >14 cm and sardines >22 cm)	MCM	NA	Contribute to fisheries sustainability by protecting larger, more fecund fish
Small pelagic species – annual egg density data for sardines and anchovy	MCM	10%	Contribute to fisheries sustainability by protecting areas of high egg density (i.e. spawning areas)
Squid nests	Warrick Sauer	10%	Benthic protection
Squid egg catches in research trawls	MCM demersal	10%	Contribute to fisheries sustainability by protecting nursery areas
Catches of overexploited linefish (priorty fisheries and conservation species)	MCM linefish	10%	Contribute to fisheries sustainability
Bycatch			
Average and maximum and variability in kingklip and monk catch (kg) / grid block	MPA	20%	Bias MPA and BMA selection towards areas of high bycatch to reduce bycatch
Offshore demersal trawl kingklip bycatch (observer)	Capfish	20%	Identify areas of high kinglip bycatch for consideration of further spatial management
Inshore demersal trawl bycatch (observer data processed by Attwood)	MCM	20%	Bias towards areas of high bycatch (i.e. reduce bycatch)
Large Pelagic Longline bycatch (observer data): sharks, turtles, seabirds	MCM (Capfish)	30%	Bias towards areas of high bycatch (i.e. reduce bycatch)

Data layer or feature	Data source	Target % (or no.)	Target and /or design consideration rationale (Notes)
Industry activities:			
Offshore Trawl footprint	SADSTIA	80%	Avoid footprint to minimize impact on industry
Inshore Trawl footprint	SADSTIA	80%	
Offshore Demersal Trawl 2000-2008 - Average hours, catch for 11 species	MCM	80%	Avoid footprint to minimize impact on industry , Bias MPA selection towards areas of lower effort to minimise impact on industry and favour less trawled ground.
Inshore trawl 2000-8 Average hours, average annual catch 10 species	MCM	80%	
Crustacean trawl (KZN) – 2001-2005 - Average effort and catch	MCM	80%	
South coast rock lobster – 2001-2007/8, no. of traps and catch	MCM	80%	Avoid footprint to minimize impact on industry , Bias MPA selection towards areas of lower effort to minimise impact on industry.
Hake longline 2002-2008 Total and av No. of hooks, start and end positions (No catch data)	MCM	80%	
West coast rock lobster 2000-2007 Inshore and offshore. By zone, area and subarea, no. of traps and catch, also fishing positions	MCM	80%	
Midwater trawl – 2000-2008 cumulative hours Tracks 2003-2008.	MCM	80%	
Large pelagic species - 1997-2008 no. of hooks	MCM	80%	
Small pelagic species commercial data – sardine, anchovy and redeye. Total and average catch per 10' grid block for period 1987-2008	MCM	80%	Bias MPA selection towards areas of lowest catches to minimise impact on industry (Note: effort data is not collected for this purse seine fishery that targets shoals of small pelagic fish)
Linefish – 2001- 2007 Effort data	MCM	80%	Bias towards areas of lower effort to minimize impact on industry
Squid – number of fishing records per pelagic fishing grid block 1985-2007	MCM	80%	
Diamond mining and prospecting leases	Department of Mineral Resources	80%	Bias towards areas outside of mining areas first, then outside of prospecting areas to minimize impact on industry. Select for areas where prospecting has been undertaken but licences have not been renewed. Spread any impact between rightsholders
Petroleum mining and prospecting leases and wellheads	Petroleum Agency South Africa SANHO 2009 (wellheads)	80%	Bias towards areas outside of production areas first, then outside of exploration areas, then outside of technical co-operation areas to minimize impact on industry. Spread any impact between rightsholders
Shipping routes	Halpern *et al.* 2008	80%	Avoid heavy ship traffic to reduce risks and pressure (such as oil spills, ship strikes and pollution) in MPAs
Existing spatial management			
MPAs	Lombard *et al.* (2004) updated using government gazette		Assess for contribution to offshore protection and consider selecting adjacent to existing MPAs
Industry proposed Namaqua MPA	SADSTIA		
SANParks proposed Namaqua MPA	SAN Parks		
Trawl exclusion zones	MCM Permit conditions		
Kingklip closed area (seasonal)	MCM Permit conditions		
Small pelagic feasibility areas and exclusion zones	MCM Permit conditions		