CONCEPT FOR A PROPOSED SEA-BASED AQUACULTURE DEVELOPMENT ZONE IN SALDANHA BAY, SOUTH AFRICA

MARINE ECOLOGY SPECIALIST STUDY

DRAFT 8

06 February 2017

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In collaboration with Capricorn Marine Environmental (Pty) Ltd based on the Project Definition:

Concept for a Proposed Sea-Based Aquaculture Development Zone in Saldanha Bay, South Africa

For the Environmental Assessment Practitioner:

SRK Consulting

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CONTENTS	Page N°

TABLES	Page N°

FIGURES	Page N°

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7 August 2016

EXPERTISE AND DECLARATION OF INDEPENDENCE

This report was prepared by Dr Andrea Pulfrich of Pisces Environmental Services (Pty) Ltd and David Japp and Sarah Wilkinson of Capricorn Marine Environmental (Pty) Ltd (previously CapFish SA (Pty) Ltd). Dr Pulfrich has a doctorate in Marine Science (University of Cape Town) and David Japp has a BSC in Zoology, University of Cape Town (UCT) and a MSc degree in Fisheries Science from Rhodes University. Sarah Wilkinson has a BSc (Hons) degree in Botany from UCT.

Dr Pulfrich has extensive experience in undertaking specialist environmental impact assessments relating to the marine environment and marine ecology. Dave Japp has worked in the field of Fisheries Science and resource assessment since 1987. His work has included environmental economic assessments and the evaluation of the environmental impacts on fishing. Sarah Wilkinson has worked on marine resource assessments, specialising in spatial and temporal analysis (GIS), as well as the economic impacts of fisheries exploitation.

This specialist report was compiled for SRK Consulting on behalf of the Department of Agriculture, Forestry and Fisheries for their use in the Environmental Impact Assessment (EIA) process and compiling the EIA Report for the proposed Aquaculture Development Zone in Saldanha Bay, South Africa. We do hereby declare that Capricorn Marine Environmental (Pty) Ltd is financially and otherwise independent of the Applicant and SRK Consulting.

Dr A. Pulfrich (Chief Executive Officer)	David Japp (Project Excecutant)

ABBREVIATIONS, UNITS AND GLOSSARY

ADZ	Aquaculture Development Zone
AOC	Assimilable Organic Carbon
ASC	Aquaculture Stewardship Council
BB	Big Bay
BCLME	Benguela Current Large Marine Ecosystem
BRBA	Biodiversity Risk and Benefit Assessment
Chl a	Chlorophyl a
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DEAT	Department of Environmental Affairs and Tourism
DO	Dissolved Oxygen
DSP	Diarrehetic shellfish poising
DWAF	Department of Water Affairs and Forestry
E	East
ECC	Ecological Carrying Capacity
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
GCQ	General Cargo Quay
HAB	Harmful algal blooms
IUCN	International Union for the Conservation of Nature
IMTA	Integrated multi-trophic Aquaculture
LNG	Liquid Natural Gas
LPG	Liquified Petroleum Gas
MFFASA	Marine Fin Fish Association of South Africa
MPA	Marine Protected Area
NE	North East
NW	North West
NEMA	National Environmental Management Act
NEMBA	National Environmental Management: Biodiversity Act (No. 10 of 2004)
NTU	nephelometric turbidity units
NW	Northwest
PAH	Poly aromatic hydrocarbon
PCC	Production Carrying Capacity
PIM	Particulate Inorganic Matter
POM	Particulate Organic Matter
PSP	Paralytic shellfish poisoning
RSA	Republic of South Africa
SB	Small Bay
SCC	Social Carrying Capacity
SRK	SRK Consulting (South Africa) Pty Ltd
TNPA	Transnet National Ports Authority
TOC	Total Organic Carbon
TON	Total Organic Nitrogen
TPH	Total petroleum hydrocarbon
UCT	University of Cape Town

Units used in the report

cm	centimetres
g C/m^2/day	grams Carbon per square metre per day
h	hours
ha	hectares
kg	kilogram
km	kilometres
km^2	square kilometres
m	metres
M	Million
mm	millimetres
m^2	square metres
m/s	current velocity measured in meters per sec
psu	practical salinity units which in normal oceanic salinity ranges are the same as $^0/_{00}$
s	seconds
%	percentage
~	approximately
<	less than
>	greater than
˚C	degrees centigrade

Glossary

Anti-cyclonic :	An extensive system of winds spiralling outward anti-clockwise (in Southern Hemisphere) the from a high-pressure centre.
Barotropic reversals :	Reversal of constant weather conditions
Bedload :	The sediment transported by a current in the form of particles too heavy to be in suspension.
Benthic :	Referring to organisms living in or on the sediments of aquatic habitats (lakes, rivers, ponds, etc.).
Benthos :	The sum total of organisms living in, or on, the sediments of aquatic habitats.
Benthic organisms :	Organisms living in or on sediments of aquatic habitats.
Biodiversity :	The variety of life forms, including the plants, animals and micro-organisms, the genes they contain and the ecosystems and ecological processes of which they are a part.
Biogenic :	produced or brought about by living organisms
Biomass:	The living weight of a plant or animal population, usually expressed on a unit area basis.
Biota :	The sum total of the living organisms of any designated area.
Bivalve :	A mollusk with a hinged double shell.
Community structure :	All the types of taxa present in a community and their relative abundance.
Community :	An assemblage of organisms characterized by a distinctive combination of species occupying a common environment and interacting with one another.
Cyclonic :	An atmospheric system characterized by the rapid inward circulation of air masses about a low-pressure centre; circulating clockwise in the Southern Hemisphere
Dilution :	The reduction in concentration of a substance due to mixing with water.
Dissolved oxygen (DO) :	Oxygen dissolved in a liquid, the solubility depending upon temperature, partial pressure and salinity, expressed in milligrams/litre or millilitres/litre.
Diurnal :	daily, or during the day
Effluent :	A complex waste material (e.g. liquid industrial discharge or sewage) that may be discharged into the environment.
Epifauna :	Organisms, which live at or on the sediment surface being either attached (sessile) or capable of movement.
Ecosystem :	A community of plants, animals and organisms interacting with each other and with the non-living (physical and chemical) components of their environment.
Environmental impact :	A positive or negative environmental change (biophysical, social and/or economic) caused by human action.
Environmental quality objective :	A statement of the quality requirement for a body of water to be suitable for a particular use (also referred to as Resource Quality Objective).
Euphotic/photic zone :	The zone in the ocean that extends from the surface down to a depth where light intensity falls to one percent of that at the surface; i.e. there is to sufficient sunlight for photosynthesis to occur.
Fouling/biofouling :	The accumulation of microorganisms, algae and marine invertebrate fauna on wetted and submerged surfaces.
Habitat :	The place where a population (e.g. animal, plant, micro-organism) lives and its surroundings, both living and non-living.
Hypoxic :	Deficiency in oxygen.

Infauna :	Animals of any size living within the sediment. They move freely through interstitial spaces between sedimentary particles or they build burrows or tubes.
Intertidal :	The area of a seashore which is covered at high tide and uncovered at low tide.
Macrofauna :	Animals >1 mm.
Macrophyte :	A member of the macroscopic plant life of an area, especially of a body of water; large aquatic plant.
Meiofauna :	Animals <1 mm.
Mariculture :	Cultivation of marine plants and animals in natural and artificial environments.
Marine discharge :	Discharging wastewater to the marine environment either to an estuary or the surf-zone or through a marine outfall (*i.e.* to the offshore marine environment).
Marine environment :	Marine environment includes estuaries, coastal marine and near-shore zones, and open-ocean-deep-sea regions.
Pelagic :	Of or pertaining to the open seas or oceans; living at or near the surface of ocean.
Pollution :	The introduction of unwanted components into waters, air or soil, usually as result of human activity; e.g. hot water in rivers, sewage in the sea, oil on land.
Population :	Population is defined as the total number of individuals of the species or taxon.
Recruitment :	The replenishment or addition of individuals of an animal or plant population through reproduction, dispersion and migration.
Sediment :	Unconsolidated mineral and organic particulate material that settles to the bottom of aquatic environment.
Species :	A group of organisms that resemble each other to a greater degree than members of other groups and that form a reproductively isolated group that will not produce viable offspring if bred with members of another group.
Seston :	The organisms (bioseston) and non-living matter (abioseston) swimming or floating in a water body. Plankton can be regarded as bioseston.
Subtidal :	The zone below the low-tide level, *i.e.* it is never exposed at low tide.
Supratidal :	The zone above the high-tide level.
Surf-zone :	Also referred to as the 'breaker zone' where water depths are less than half the wavelength of the incoming waves with the result that the orbital pattern of the waves collapses and breakers are formed.
Suspended material :	Total mass of material suspended in a given volume of water, measured in mg/ℓ.
Suspended matter :	Suspended material.
Suspended sediment :	Unconsolidated mineral and organic particulate material that is suspended in a given volume of water, measured in mg/ℓ.
Synoptic:	summary of the distribution, movement and patterns of air pressure, rainfall, wind and temperature
Tainting :	This refers to the tainting of seafood products as a result of the presence of objectionable chemical constituents which may greatly influence the quality and market price of cultured products.

Taxon (Taxa) :	Any group of organisms considered to be sufficiently distinct from other such groups to be treated as a separate unit (e.g. species, genera, families).
Toxicity :	The inherent potential or capacity of a material to cause adverse effects in a living organism.
Turbidity :	Measure of the light-scattering properties of a volume of water, usually measured in nephelometric turbidity units.
Turgor :	The normal rigid state of fullness of a cell or blood vessel or capillary resulting from pressure of the contents against the wall or membrane.
Vulnerable :	A taxon is vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future.

EXECUTIVE SUMMARY

The Department of Agriculture, Forestry and Fisheries (DAFF) aims to develop and facilitate aquaculture in South Africa to supply food, create jobs in marginalised coastal communities and contribute to national income. As Saldanha Bay is a highly productive marine environment with an established aquaculture industry, with potential for growth, DAFF proposes to establish a sea-based Aquaculture Development Zone (ADZ) in Saldanha Bay to encourage investor and consumer confidence, create incentives for industry development, provide marine aquaculture services, manage the risks associated with aquaculture and provide skills development and employment for coastal communities.

This marine ecology specialist assessment adopted a desktop approach and was restricted to only those species and farming methods identified for the proposed Saldanha Bay ADZ during the Project Definition phase (Heinecken *et al*. 2016). Precincts within the ADZ were proposed for Big Bay North, Big Bay South, Outer Bay North and Outer Bay South, with no further expansion above existing allocated areas being recommended for Small Bay.

The description of the baseline environment provides information on the geographical setting of the project and the physical and biological marine environment. Beneficial uses of the area and existing environmental impacts were identified to provide a context for the marine ecology impact assessment.

As details for individual farm infrastructure, location and culture species were not yet available, the assessment was by default generic in nature. The impacts assessed related to the full extent of the proposed ADZ (1 871 ha) relative to the total extent of Saldanha Bay, and assumed a total potential annual (ungraded) shellfish production of ~27 600 tpa, with an additional 40 tons per ha for finfish in those areas identified as suitable for cage culture. The upper limits applied to the assessment can be considered the worst-case scenario. Consequently the significance ratings for the identified impacts can be considered conservative.

Potential impacts to the marine ecology as a result of the proposed development of the ADZ include:

Construction impacts

- Crushing of biota in sediments during placement of anchor blocks

Effects on the seabed (operations)

- Biodeposition of faeces, pseudofaeces and detritus
- Changes to physico-chemical properties of the sediments
- Changes to biological properties of the sediments
- Modification of benthic habitat through accumulation of live and dead shells on the seabed
- Shading from farm structures and crop

Effects on the water column (operations)

- Effects of farm structures on currents and waves
- Effects on seawater nutrient chemistry and clarity
- Depletion of food sources, especially phytoplankton, for other organisms
- Alteration of plankton community structure
- Harmful algal blooms

Wider ecological effects (operations)

- Habitat creation by farm structures
- Effects on fish (and ichthyoplankton)
- Effects on seabirds
- Effects on marine mammals: seals, dolphins and whales
- Biosecurity risks relating to the spread of diseases, parasites and biofouling pests

- Genetic interactions with wild populations, and effects of escapees (fish culture)
- Effects of therapeutants and trace contaminants (fish culture)

Effects on other users (operations)

- Pulse disturbances during harvest practices
- Conflict with other users

The impacts before and after mitigation on marine habitats and communities associated with the proposed project are summarised below:

Impact	Significance (before mitigation)	Significance (after mitigation)
Construction Phase		
Benthic impacts from placement and mooring of longlines, rafts, oyster stacks and cages	Low	Low
Operational Phase: Shellfish Farming		
Effects on the seabed		
Effects of suspended shellfish culture on biodeposition and associated physico-chemical changes to sediment properties	Medium	Low
Changes in biological communities in response to changes in sediment properties	Medium	Low
Modification of seabed habitat at suspended shellfish cultivation sites	Medium	Medium
Shading of the seabed under suspended shellfish cultivation facilities	Low	Low
Effects on the water column		
Effects of farm structures on currents and waves	High	Medium
Effects of farm structures on seawater nutrient chemistry	Medium	Very Low
Removal of seston from the water column by suspended shellfish cultivation	High	Low
Preferential feeding by shellfish may alter plankton community structure	Low	Very Low
Increased incidence of HABs as a result of suspended shellfish cultivation	Insignificant	Insignificant
Wider ecological impacts		
Creation of habitat by farm structures	Medium	Medium
Effects of suspended shellfish cultivation on fish	Medium	Medium
Effects of suspended shellfish cultivation on seabirds	Medium	Low
Effects of suspended shellfish cultivation on marine mammals	Medium	Very Low
Introduction of alien invasive species or spread of fouling pests	Very High	Medium
Transmission of diseases from cultured stock to wild populations	High	Very Low
Risks of Genetic interactions with wild mussel populations - mussels	Low	Low
Risks of Genetic interactions with wild oyster, scallop or abalone	Medium	Low

Impact	Significance (before mitigation)	Significance (after mitigation)
populations		
Contamination of sediments or the water body from suspended shellfish cultivation	Very Low	Very Low
Operational Phase: Finfish Farming		
Effects of finfish culture on nutrient enrichment, sediment physico-chemical properties and alteration of benthic communities	High	Medium
Effects of finfish culture on water column chemistry	Medium	Low
Effects of finfish culture on habitat creation	Medium	Medium
Introduction of alien invasive species or spread of fouling pests	Very High	Medium
Effects of finfish cage culture on seabirds, marine mammals and piscivorous predators	High	Low
Risks of genetic interactions of endemic culture species with wild populations	High	Low
Transmission of diseases from cultured stock to wild populations	High	Very Low
Impacts of therapeutants and trace contaminants	Medium	Low
Operational Phase: Seaweed Farming		
Effects of seaweed culture	Low	Very Low

Essential Mitigation Measures

Environmental best practices to be considered during the siting of individual aquaculture farms and expansion of the ADZ include:

- Precincts should be carefully selected to favour well-flushed, deep and productive areas (Big Bay North, Outer Bay North, Outer Bay South) and avoid overlap with potentially sensitive and valuable habitats such as conservation areas (Malgas Island, Jutten Island, Langebaan Lagoon MPAs), biogenic habitats (e.g. kelp beds) and reefs (e.g. Lynch Blinder, North Bay blinder). To this end a 500 m buffer zone in which no shellfish mariculture development is permitted and a 1 000 m buffer in which no finfish culture is permitted is recommended around all MPAs, it being understood that the existing boundaries of the island MPAs have been set so as to protect the island as well as its surrounding kelpbed/reef habitats. This is particularly important around Malgas Island, where the proximity to the island of finfish culture is expected to attract seals, which prey on the gannets that breed on the island. A 1 000 m buffer would in effect reduce the size of the precincts in Big Bay South, Outher Bay North and Outer Bay South. Furthermore, a minimum of a 100 m-wide buffer is recommended around reefs and blinders. The extent of the proposed buffers is based on model results from New Zealand, which indicated that depositional footprints of >250 m were possible for shellfish farm sites in more energetic environments or greater water depth (Hartstein & Stevens 2005; Stenton-Dozey *et al.* 2008). The results of Mead *et al.* (2009) indicated that nutrient effects in the water column could extend several kilometres from commercial-scale finfish farms. In the siting of finfish farms, sites must be suitably deep, allowing cages to be held at least 5 m off the seabed.

- Assuming the full extent of the proposed ADZ (i.e. no buffer zones) and maximum total ungraded annual shellfish production of 27 600 tpa within the precincts (Heinecken *et al*. 2016), it is deemed essential that predictive analytical and numerical modelling be undertaken before authorisation for the ADZ is granted. This is particularly important where proposed shellfish precincts are located adjacent to MPAs. This would include for example, predicting the effects of shellfish farming on local currents, stratification and wave climates and using the results to develop alternative farm designs to minimise possible localised hydrodynamic changes. Such models could also provide an indication of the extent of depositional footprints of biological and feed wastes generated by farms, effects on water column nutrient parameters (dissolved carbon, nitrogen and phosphorous) and seston depletion shadows (chl a, phytoplankton abundance and species composition) in response to the farm structures and stock, to ensure that these do not impact on sensitive habitats such as the Saldanha Bay shoreline, important reefs and MPAs. This is particularly important in sheltered bays, where hydrodynamics have been compromised by other developments and where proposed precincts are in the immediate vicinity of potentially sensitive and valuable habitats. This is the approach recommended by the MOM management system, and was also recommended for the Algoa ADZ (Hutchings *et al*. 2013) and for Saldanha Bay by Probyn *et al*. (2015). However, if a phased approach is taken to the development of the ADZ and ungraded shellfish production is limited to around 10 000 tpa for the first two years, increasing annually thereafter by 5 000 tpa as monitoring data becomes available, hydrodynamic modelling is not deemed necessary.
- Prior to the development of **finfish culture** in Saldanha Bay, undertake analytical and numerical modelling exercises using detailed, site-specific current modelling data to predict the magnitude and extent of waste plumes generated, and to ensure that these do not impact on sensitive habitats such as the Saldanha Bay Bay shoreline, important reefs and MPAs.

  However, if recommended mitigation measures for siting, buffer zones and managing stocking densities are implemented, a phased approach is taken for the development of finfish cage culture within the ADZ and annual finfish production does not exceed 1 000 tpa, reaching a maximum production of 5 000 tpa after five years, increasing thereafter only if monitoring results indicate environment health is maintained and impacts remain managable, analytical and numerical modelling around the precincts or individual farms is not deemed necessary.

  Furthermore, should production be expanded above 5 000 tpa, a precautionary approach must be applied, involving strict and intensified monitoring programmes and adherence to environmental quality standards. Should standards or precautionary limits be approached or exceeded, the monitoring plans should have a response procedure that leads to appropriate downward adjustments of fish production.
- Regardless of final proposed future production figures, a phased approach to expansion of shellfish and finfish farms within the Saldanha Bay ADZ is considered prudent. Should proposed production levels exceed the recommended initial annual ungraded shellfish production of 10 000 tpa, and annual finfish production of 1 000 tpa, or the ADZ be further expanded, a modelling approach to predict the effects of the farms on the marine environment should be applied.
- Ensure mooring systems are well designed to prevent/limit movement of anchors and chains over the sea floor.
- Leave mooring anchors or blocks in place when undertaking cage net maintenance or fallowing sites to avoid repetitive impacts of the same activity at each site

Essential mitigation measures for farm operation include:

- Avoid high density culture and overcrowding of mussel droppers, oyster stacks and other structures in shellfish farms. The recommended density is one raft of 800 droppers per ha; 11 longlines of 832 droppers per ha; 11 longlines of 176 oyster stacks/abalone barrels per ha (Heinecken *et al.* 2016).
- Fish cages should be located at suitably deep sites that allow cages to be held at least 5 m off the seabed. The configuration of finfish cages should not exceed a total coverage of 30% of the total area allocated for finfish farming, both within individual licence areas and overall within the portions of the ADZ identified for finfish culture.
- Implement recommended monitoring of biodeposition and physico-chemical changes in seabed properties, infaunal and epifaunal macrobenthic communities, at shellfish and finfish farming sites relative to undisturbed control sites (Recommended marine monitoring components of an EMPr for the Saldanha Bay ADZ are given in Appendix II). For finfish farms, adopt the (relevant aspects of) MOM management system (or similar) in monitor infaunal and epifaunal macrobenthic communities at farming sites.
- Manage fish stocking densities to ensure the environmental and stock health is maintained. Optimum stocking densities and feeding rates, during each season and for different species of fish of different size classes, can only be determined after several seasons of rearing have taken place at each site (Schoonbee & Bok 2006).
- Monitor and manage feeding regimes in finfish farms to minimise feed wastage and chemical usage.
- Use species and system-specific highly digestible, high energy and low phosphorus fish feeds to maximize food conversion ratios and minimize waste.
- Rotate cages within production areas to allow recovery of benthos.
- Install visual deterents for birds (e.g. tori line type deterents).
- Ensure debris and waste material does not enter the water to minimise the risk of attraction and entanglement by seabirds, marine mammals and large predators.
- Keep a log of all cetaceans, seabirds and predators recorded in the vicinity of fish farms, including behavioural observations.
- Monitoring by farm personnel of presence (and absence) of marine mammal species in the vicinity or general region of the farm sites, as well as observations of any time spent under or around the farm structures. These data should be periodically compiled and analysed by experts.
- Use predator exclusion nets as necessary; enclose nets at the bottom to minimise entanglement, keep nets taut, use mesh sizes of < 6 cm (Kemper *et al.* 2003), and keep nets well maintained (e.g. repairing holes).
- Remove any injured or dead fish from finfish cages promptly and do not release any blood and/or offal (organic waste) from finfish into the bay.
- Develop disentanglement protocols in collaboration with DAFF, DEA and the SA Whale Disentanglement Network and establish a rapid response unit to deal with entanglements.
- Minimise the potential for litter entering the marine environment (particularly plastic wastes).
- Do not apply antifoulants on site and use environmentally friendly alternatives where effective.

Essential mitigation measures regarding biosecurity, genetics and disease include:

- Ensure a high level of biosecurity management and planning is in place within hatcheries, holding tanks and sea cages to limit the introduction of pests and diseases and to be able to respond quickly and effectively should biosecurity risks be identified.
- Have good house-keeping practices in place at all times i.e. keep nets clean and allow sufficient fallowing time on sites to ensure low environmental levels of intermediates hosts and or pathogens.
- Farm operators should undertake routine surveillance on and around marine farm structures and associated vessels and infrastructure for indications of non-native fouling species.
- Maintain effective antifouling coatings and regularly inspect farm structures and vessels for pests; clean structures and hulls regularly to ensure eradication of pests before they become established.
- Fouling organisms removed from oyster stacks, abalone barrels and finfish cages (taken onshore for maintenance) should not be discharged back into the marine environment thereby ensuring that any introduced non-native fouling species not detected previously are not released into the wild.
- Develop South African bivalve hatcheries to reduce the reliance on spat import, and hence the risk of non-intentional introduction of associated alien species and diseases.
- If spat import cannot be avoided, culture facilities should only be permitted to use spat sourced from biosecure certified hatcheries and/or quarantine facilities.
- Ensure that veterinarian protocols to eliminate any pests, parasites and diseases are strictly adhered to.
- Ensure suitable management and planning measures are in place to limit the possibility of genetic interactions.
- Ensure good physical and biological containment to limit the effects of escaped stocks.
- Implement the "Genetic Best Practice Management Guidelines for Marine Finfish Hatcheries" developed by DAFF and ensure adequate genetic monitoring of brood stock rotation.
- Develop the technology to create sterile fry for stocking of cages.
- Use robust, well-maintained containment systems to reduce the likelihood of escapes.
- Develop and implement recovery procedures should escapes from finfish farms occur.
- Ensure all spat and fry undergo a health examination prior to stocking in sea cages.
- Take necessary action to eliminate pathogens through the use of therapeutic chemicals or improved farm management.
- Regularly inspect stock for disease and/parasites as part of a formalised stock health monitoring programme.
- Maintain comprehensive records of all pathogens and parasites detected as well as logs detailing the efficacy of treatments applied.
- Locate cages stocked with different cohorts of the same species as far apart as possible; if possible stock different species in cages successively.

- Have good house-keeping practices in place at all times i.e. keep nets clean and allow sufficient fallowing time on sites to ensure low environmental levels of intermediates hosts and or pathogens.
- Treat adjacent cages simultaneously even if infections have not yet been detected.
- Use only approved veterinary chemicals and antifoulants.
- Reduce levels of nutritional therapeutants and trace contaminants in fish feed using only the lowest effective doses.
- Use the most efficient drug delivery mechanisms that minimise the concentrations of biologically active ingredients entering the environment.
- When farming seaweeds, use only locally sourced Gracilaria for stocking the ropes.
- Use seaweeds as a co-culture species for use in Integrated Multi-Trophic Aquaculture (IMTA) rather than as monoculture.

Best Management Practices include:

- Implement monitoring of the immediate water column around the precincts or specific farms for nutrient parameters (dissolved carbon, nitrogen and phosphorous).
- Implement monitoring of the immediate water column around the precincts or specific farms for key plankton (chl a, phytoplankton abundance and species composition) parameters.
- Ensuring that minimal non-navigational lighting occurs at night and using downward-pointing and shaded lights.
- Develop and enforce strict maintenance and operational guidelines and standards in relation to potential entanglement risks on the farm including loose ropes, lines, buoys or floats.
- Ensure all mooring lines and rafts are highly visible (use thick lines and bright antifouling coatings).
- Keep all lines taught through regular inspections and maintenance.
- Develop disentanglement protocols in collaboration with DAFF, DEA and the SA Whale Disentanglement Network and establish a rapid response unit to deal with entanglements.
- Adopt appropriate maintenance and operational guidelines and standards for minimising noise in noise-generating equipment.
- Establish and adhere to guidelines around the use of anti-fouling products in the mariculture industry.
- Restrict stocking densities to below 15-20 fish per m3 to limit the spread of diseases and parasitic infections.
- Avoid the use of fertizers or chemicals in the culture of seaweeds.

Monitoring requirements include:

- Routine monitoring at specific intervals should be undertaken once a site is operational.
- For finfish farms, adopt the (relevant aspects of) MOM management system (or similar) in monitor infaunal and epifaunal macrobenthic communities at farming sites. The basic

concept behind this approach is recognising that certain aspects of the receiving environment are more or less sensitive to the impacts of fish farming, and therefore have different capacities for production. By integrating the EIA, impact monitoring and environmental quality standards, the requirments for analytical and numerical models, and amount of environmental monitoring considered necessary is determined by the degree of the environmental impact. However, as the feasibility and environmental impacts of fish farming in South Africa are as yet unclear, a conservative approach must be adopted during the establishment of commercial scale production as part of the proposed Saldanha Bay ADZ.

- Submission of annual monitoring reports to the authorities should form part of the permit conditions for individual farms. Reporting requirements are detailed in the recommended EMP in Appendix II.

Monitoring requirements for any future sites or production volumes, in addition of those applied for in this process, should include:

- Baseline studies should establish the physical, chemical and biological conditions of the sediments and the water column in the licence area prior to construction, in order to quantitatively assess the degree of disturbance in subsequent years. Protocols for sample collection, analysis and reporting for these parameters should be developed as part of the Environmental Management Plan for the farm operation.
- A bathymetric map should be submitted along with a sketch of the important habitats in the lease area as well as adjacent potentially sensitive and valuable habitats (conservation areas, biogenic habitats and reefs).
- Incorporate any additional information inclusive of all available information from analytical and hydrodynamic studies undertaken for Saldanha Bay or for ecologically comparable locations in other parts of the world. If this available information is not considered scientifically appropriate to the specific site or for the scale of the proposed operations (for example predicting changes in current patterns, the extent of depositional footprints and phytoplankton depletion shadows in response to the farm structures and stock), then site-specific modelling studies should be undertaken to better determine the ecological impacts before permitting any expansion of activities beyond the levels specified.

Based on the results of this assessment, and provided all the appropriate management actions and mitigation measures are in place, there is no reason to suggest that the proposed development of the ADZ not go ahead.

1. INTRODUCTION

1.1 Background

The Department of Agriculture, Forestry and Fisheries (DAFF) aims to develop and facilitate aquaculture (the sea-based or land-based rearing of aquatic animals or the cultivation of aquatic plants for food) in South Africa to supply food, create jobs in marginalised coastal communities and contribute to national income. Saldanha Bay is a highly productive marine environment and has an established aquaculture industry, with potential for growth.

DAFF proposes to establish a sea-based Aquaculture Development Zone (ADZ) in Saldanha Bay, Western Cape to encourage investor and consumer confidence, create incentives for industry development, provide marine aquaculture services, manage the risks associated with aquaculture and provide skills development and employment for coastal communities.

SRK Consulting (Pty) Ltd (SRK) has been appointed as the independent consultant to develop a framework for the Saldanha Bay ADZ and undertake the Environmental Impact Assessment (EIA) process required in terms of the National Environmental Management Act 107 of 1998, as amended (NEMA) and the EIA Regulations, 2014. SRK in turn approached Capricorn Marine Environmental (Pty) Ltd, in association with Pisces Environmental Services (Pty) Ltd, to provide the required Marine Ecological Specialist Study as part of the EIA.

1.2 Scope of Work

The Generic Terms of Reference and principal objectives for the Marine Ecology Specialist Study, as provided by SRK, are to:

- Describe the existing baseline characteristics of the study area and place this in a regional context;
- Identify and assess potential impacts of the project and the alternatives (if any are presented to the specialist), including impacts associated with the construction and operation phases, using SRK's prescribed impact rating methodology;
- Indicate the acceptability of alternatives and recommend a preferred alternative;
- Identify and describe potential cumulative impacts of the proposed development in relation to proposed and existing developments in the surrounding area;
- Recommend mitigation measures to avoid and/or minimise impacts and/or optimise benefits associated with the proposed Project; and
- Recommend and draft a monitoring campaign, if applicable.

The more specific Terms of Reference for the marine ecology specialist study for the BA Initiation Phase were to:

- Describe the ecological baseline of Saldanha Bay, including different habitat types, associated fauna and flora and sensitivity and the current impact of aquaculture on Saldanha Bay;
- Identify and assess impacts on marine and coastal environments from expanded marine aquaculture production, based on the project description derived in the Project Definition Phase;
- Recommend mitigation measures to address impacts.

1.3 Approach to the Study

1.3.1 Marine Environmental Baseline

The ecological assessment is limited to a “desktop” approach and thus relies on existing information only, as well as the information provided by the Project Definition phase (Heinecken *et al.* 2016). The description of the baseline marine environment was compiled following a literature search and review of all relevant, available local and international publications and information sources on southern African West Coast communities, with specific reference to Saldanha Bay.

1.3.2 Environmental Impact Assessment

The identification and description of all factors resulting from the construction and operation of the proposed aquaculture[1] facilities that may influence the marine and coastal environments in the region was based on a review and expert interpretation of all relevant, available local and international publications and information sources on the disturbances and risks associated with aquaculture operations.

1.3.3 Limitations and Assumptions

The following are the assumptions and limitations of the study:

- The study is based on the project description made available to the specialist at the time of the commencement of the study.
- The assessment is restricted to only those species and farming methods identified during the Project Definition phase. For most of these species biological risk assessments already exist. However, for some of the recommended culture species considered unlikely or poor candidates for culture in Saldanha Bay, further ecological risk/impact assessments may be necessary in the future as these have not been incorporated into this EIA.
- A historical ecological baseline has been established, which is associated with the already operational aquaculture operations within Saldanha Bay.
- The baseline description and ecological assessment are limited to a “desktop” approach and thus rely on existing information from peer-reviewed publications only and material available on the internet. No new data were collected as part of this study, although industry representatives were consulted in compiling the Project Definition (Heinecken *et al.* 2016).Potential changes in the marine environment such as sea level rise and/or increases in the severity and frequency of storms related to climate change are not explicitly considered here. Such scenarios are difficult to assess due to the uncertainties surrounding climate change. However, it is not expected that these climate changes will affect the proposed operations to the extent that the conclusions of this study will be altered.

1.4 Structure of the Report

This Marine Ecology Specialist Report describes the effects of the establishment of the proposed sea-based aquaculture facilities on the marine environment, and significance within the context of the receiving environment in Saldanha Bay. The report outlines the approach to the study, assesses impacts identified by marine specialist consultants, and makes recommendations for mitigation, monitoring and management of these impacts. The report is structured as follows:

[1] We use the term “aquaculture” throughout which refers broadly to culture in aquatic systems in general. The term “mariculture” can also be used as it is specific to the culture of marine organisms in the marine environment.

Section 1: General Introduction - provides a general overview to the proposed project, and outlines the Scope of Work and objectives of the study and the report structure. The assessment methodology is outlined and the assumptions and limitations to the study are given.

Section 2: Project Definition - gives a brief overview of the proposed aquaculture species and farming methods.

Section 3: Description of the Marine Environment - describes the receiving biophysical environment that could be impacted by the aquaculture ventures. Existing impacts on the environment are discussed and sensitive and/or potentially threatened habitats or species are identified.

Section 4: Impact Identification and Assessment - identifies key issues and sources of potential impact in terms of the operational phase of the proposed ADZ. Impacts are discussed in more detail and those relative to the expanded Saldanha Bay operations are assessed. The environmental acceptability of the proposed development is discussed, and mitigation measures and monitoring recommendations are presented.

Section 5: Conclusion and Recommendations – summarises the findings of the assessment and presents recommendations should the development proceed.

Section 7: References - provides a full listing of all information sources and literature cited in this report.

1.5 Methodology

SRK's prescribed impact assessment methodology was used to assess the significance of potential impacts. Using this methodology, the **significance** of an impact is defined as a combination of the **consequence** of the impact occurring and the **probability** that the impact will occur. The significance of each identified impact was rated as set out in Appendix 1.

2. PROJECT DEFINITION

The Project Definition (Heinecken *et al*. 2016) provides the foundation on which this marine specialist assessment for the proposed Saldanha Bay ADZ is based. The essential aspects considered in the Marine Ecology Assessment include the following:

a. Species proposed for culture including current and new species
b. Culture method inclusive of gear type proposed
c. Spatial extent inclusive of currently exploited areas and proposed expansion into new areas

2.1 Species Proposed for the ADZ

At present three species of bivalves are commercially cultivated in Saldanha Bay. These are Pacific oysters (*Crassostrea gigas*), Mediterranean mussel (*Mytilus galloprovincialis)* and Black mussel (*Choromytilus meridionalis*). The following species are considered to hold the most potential for farming in the ADZ:

- Currently cultivated bivalve species in Saldanha Bay:
  - ✓ Pacific oysters (*Crassostrea gigas*)
  - ✓ Mediterranean mussel (*Mytilus galloprovincialis)*
  - ✓ Black mussel (*Choromytilus meridionalis*)

- Indigenous shellfish species not currently cultivated:
  - ✓ Abalone (*Haliotis midae*)
  - ✓ South African scallop (*Pecten sulcicostatus*)

- New indigenous finfish species:
  - ✓ White Stumpnose (*Rhabdosargus globiceps*)
  - ✓ Silver kob (*Argyrosomus inodorus*)
  - ✓ Yellowtail (*Seriola lalandi*)

- Alien finfish species:
  - ✓ Atlantic salmon *(Salmo salar)*
  - ✓ Coho salmon *(Oncorhynchus kisutch)*[2]
  - ✓ King/Chinook salmon *(Oncorhynchus tshawytscha)*
  - ✓ Rainbow trout *(Oncorhynchus mykiss)*

- *Seaweed :*
  - ✓ *Gracilaria* *(Gracilaria gracilis)*

The following additional species have been proposed by Interested and Affected parties. While they cannot be entirely excluded, their future culture is not considered pertinent to the establishment of an ADZ in Saldanha Bay at this point in time:

- European oyster (*Ostrea edulis)*
- Chilean scallop (*Argopecten purpurata*)
- Indigenous rock oyster (*Striostrea margaritacea)*
- Indigenous white mussel (*Donax serra)*
- Indigenous trough clam (*Mactra glabrata)*

[2] Although not included in the Project Description for the ADZ (Heinecken *et al.* 2016), these species have received authorisation for culture in Saldanha Bay through a risk assessment process.

2.2 Aquaculture Methods

The following production methods, summarised from Heinecken *et al.* (2016), are considered most viable for farming in the ADZ:

- **Longlines** for bivalve and seaweed culture, comprising surface ropes with floats and moored at each end to fix the lines in position. The production ropes for mussels, *Gracilaria* or oyster [scallop] racks are then suspended from the surface rope. Longlines are robust and can be used in depths up to 100 m and are suitable throughout the ADZ. The lower density of bivalves attached to longlines promotes better current flow and limits the localised impact of sedimentation from mussel faecal deposition. The recommended spacing is ~10 m between longlines and ~40 m between lease areas to allow for vessel movements;

- **Rafts** for bivalve culture, comprising a floating top structure from which mussel ropes are suspended. A raft provides a stable surface structure for initial processing of mussels and reduces dependence on larger support vessels for harvesting and processing. However, sediments from faecal deposition and processing waste accumulate below the raft. The recommended density is approximately one raft per hectare, which would equate to a theoretical production of approximately 20 to 30 tonnes of marketable mussels per ha;

- **Cages** for finfish production, constructed of circular flexible high density polyethylene with multi-mooring systems, deployed at depths of more than ~25 m (larger cages) or ~13 m (smaller cages). Cages in Saldanha Bay have a high fouling rate, requiring regular replacement of cages; and

- **Barrel culture** for abalone, which can be deployed from rafts and longlines. Barrel culture requires regular servicing to feed the abalone.

2.3 Proposed Areas

The proposed ADZ comprises five main precincts in Big Bay and Outer Bay, providing an additional 1 404 ha of aquaculture areas in Saldanha Bay (see **Figure 1** and **Table 1**):

- Small Bay (incorporation of the established aquaculture area into the ADZ – no expansion is recommended);

- Big Bay - North: north of Mykonos entrance channel;

- Big Bay - South: south of Mykonos entrance channel – two alternative layouts are proposed for this area;

- Outer Bay - North: north of Port entrance channel, near Malgas Island;

- Outer Bay - South: south of Port entrance channel, near Jutten Island.

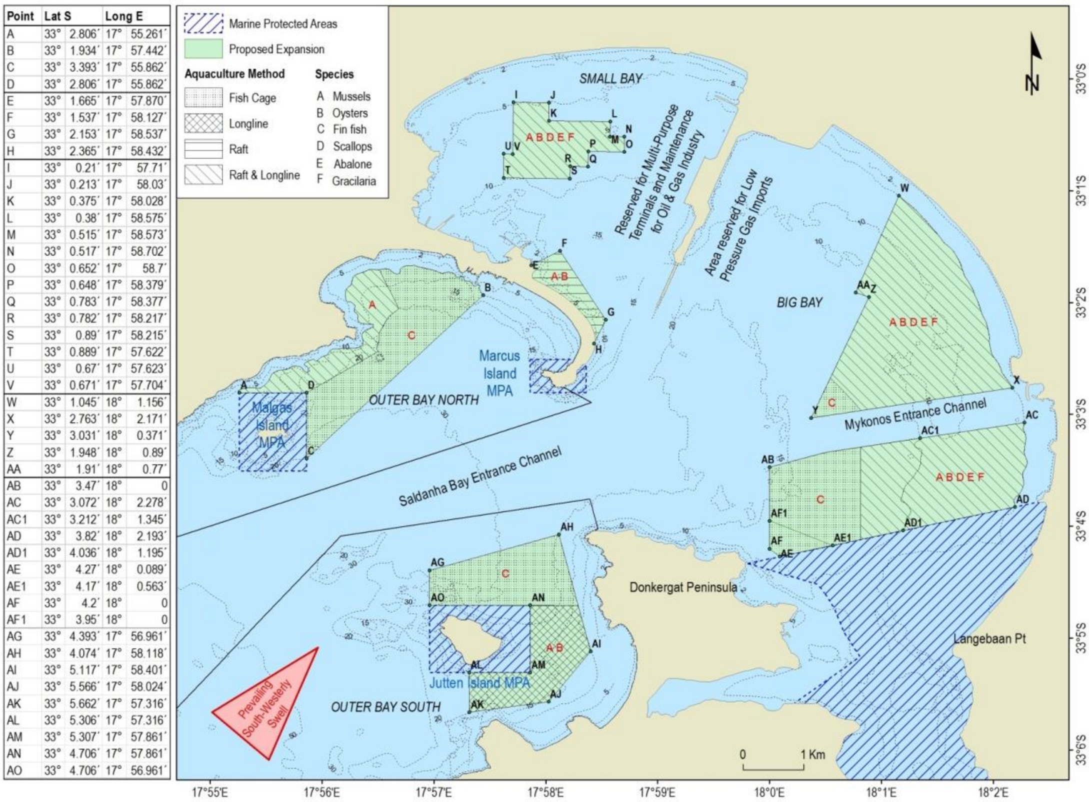


Figure 1 : Schematic representation of the precincts within the proposed Saldanha Bay ADZ and recommended culture methods and species (Heinecken *et al*. 2016).

Table 1 : Areas (ha) of proposed ADZ precincts in Saldanha Bay (Heinecken *et al*. 2016).

Area	Currently allocated	Currently farmed	New area proposed	Potential ADZ Area
Small Bay	163	125	-	163
Big Bay - (North)	254	25	271	525
Big Bay – (South)	4	1	517	521
Outer Bay - North	37	1	299	336
Outer Bay - South	10	-	317	327
Total	**468**	**152**	**1 404**	**1 872**

2.3.4 Small Bay

Small Bay is almost completely protected from oceanic swell by the causeway that extends from the mainland to Marcus Island (Figure1). The iron ore jetty also provides protection from the sea disturbance in prevailing summer south-easterly to southerly winds. This offers protection from the general sea conditions (sea and swell) that in turn results in slight currents and limited exchange of water relative to both Big Bay and the Outer Bay. Boyd & Heasman (1998) state that current flow through a mussel farm can be reduced by up to 30% depending on the stocking density of mussel rafts and longlines. Based on this likelihood the relatively slower currents and low plankton biomass (typical of Small Bay), the food requirements for mussel farming in Small Bay may barely be met (Boyd & Heasman (1998).

In addition, the water in Small Bay experiences regular oxygen deficiency, attributed primarily to reduced flushing rates (due to the causeway and ore jetty construction) and discharges of organic rich effluents from fish processing factories (Monteiro *et al.* 1990; Clark *et al.* 2015). Further, weak current flows as experience in Small Bay, result in poor "flushing" thereby reducing the mitigation effect on the sedimentation below rafts and longlines. Consequently, high deposition of pseudo-faeces will occur as well as the cumulative settling of fouling organisms and unused and broken mussels below rafts and longlines. Studies have already indicated that there is localised anoxia in Small Bay (e.g. under the mussel rafts and within the yacht basin) caused by excessive organic inputs (Stenton-Dozey *et al.* 2001).

Currently 163 ha have been allocated to farmers in this area, of which 125 ha are currently farmed (Table 1). Taking into account the factors described above as well as planned future harbour development in the area, the expansion of the available area for aquaculture for mussels and oyster cultivation beyond the currently leased area is not recommended. However, as some projects are restricted to limit production to below 50 tons per annum, not all the allocated areas are presently being used to their full extent. Consequently, an increase in production within the currently allocated areas can be expected in future. It would probably remain necessary to retain some restrictions on annual production from the combined areas in Small Bay. Under the scenario of expanded shellfish production in Small Bay, it is unlikely that the cultivation of macrophytes, such as *Gracilaria* (*G. gracilis*) or *Ulva* spp. would be viable.

Gracilaria cultivation was attempted in both Small Bay and St Helena Bay in the mid-1980s. These commercial ventures failed, however, primarily due to unfavourable growth conditions (Saldanha Bay) and black tide events[3] (St Helena Bay) (Anderson *et al.* 1989). In Saldanha Bay, one of the main problems experienced in suspended rope trials to *Gracilaria* was fouling from mussel settlement on the ropes. However, the demand for algae both as an abalone feed and for fertilizer may incentivise further research and new ventures in the cultivation of seaweeds in the future. The enhanced nutrient levels in the bay (from fish factories, sewage treatment works and stormwater runoff) could also have a positive effect on the growth of *Gracilaria* or other potential macrophyte species, and may locally enhance phytoplankton production.

2.3.3 Big Bay - North

This precinct extends from the 5 m contour towards the Port jetty up to the proposed Port of Saldanha liquid natural gas (LNG) and liquified petroleum gas (LPG) developments, and south to the Mykonos harbour entrance channel. This area was already demarcated for aquaculture in the 1980s. The area is reasonably sheltered from south-westerly swells and northerly winds (June to August), and wave heights are limited. Tidal currents may mitigate low DO conditions. Areas deeper than 15 m in the south-western portion of the precinct may be suitable for finfish cage culture. Surface longlines and rafts for bivalve production may be viable in the precinct due to the protection from extreme oceanographic conditions.

2.3.4 Big Bay – South

This precinct extends from the Mykonos harbour entrance channel towards the Langebaan Lagoon MPA, and from the 5 m depth contour towards the Donkergat Peninsula. An *alternative layout* for this precinct extends from the 10 m depth contour towards the Donkergat Peninsula to accommodate recreational users in shallow waters south of Mykonos and vessel traffic into and out of the Langebaan Lagoon near Donkergat. This area was already demarcated for aquaculture in the 1980s. The Bay provides optimal shelter from south-westerly swells and wind. Tidal currents may mitigate low DO conditions. Areas deeper than 15 m in the western portion of the precinct may be suitable for finfish cage culture. Surface longlines and rafts for bivalve production may be viable in the precinct due to

[3] Natural low-oxygen events severe enough to lead to the production of toxic levels of H_2S

the protection from extreme oceanographic conditions.

2.3.1 Outer Bay - North

This precinct extends from the Marcus Island causeway to the Malgas Island Marine Protected Area (MPA) and from the 10 m depth contour to the 30 m depth contour north of the Port entrance channel. The area is sheltered from northerly winds (June to August) but exposed to southerly winds (September to May). Waves reach up to 7.5 m. Water temperature and exposure make this area suitable for mussel culture and possibly other bivalve species with cold water tolerance. Previous finfish cage culture suffered from periodic events of low Dissolved Oxygen (DO) in this area. Indigenous finfish species may be more resistant to these natural conditions and present a viable option in the future. Areas deeper than 15 m may be suitable for finfish cage culture or submerged longlines. Shallower areas may be suitable for surface longlines. Rafts are likely not viable due to oceanographic conditions.

2.3.2 Outer Bay - South

This precinct extends from the Donkergat Peninsula to the Jutten Island MPA and from the 10 m depth contour towards the Port entrance channel. Jutten Island and the mainland provide limited protection from south-westerly swells, and the areas has some shelter from southerly winds (September to May). Waves remain well below 7.5 m. Areas deeper than 15 m may be suitable for finfish cage culture or submerged longlines (but strong currents between Jutten Island and the mainland could present challenges). Areas deeper than 10 m in the more protected sections between the mainland and Jutten Island may be suitable for bivalve surface longlines, which benefit from the currents. Rafts are likely not viable due to oceanographic conditions.

2.4 Proposed Areas and Annual Production Assessed in Marine Ecology Study

The full extent of the proposed areas presented in Figure 1 and Table 1 were assessed in this marine ecology specialist study. The assessment is based on the assumption that the maximum annual ungraded[4] production limits for mussels and oysters (Heinecken *et al.* 2016) are achieved in the ADZ. Using the production carrying capacity for the Bay based on estimated provided by Probyn *et al.* (2015), Heinecken *et al.* (2016) calculated the upper and lower ecological carrying capacity (ECC) per hectare for the potential ADZ areas and scaled these figures up to obtain upper and lower production limits for mussels and oysters for all proposed ADZ precincts (**Table 2**). The assumptions made in obtaining these estimates are detailed in the PD report (Heinecken *et al.* 2016). Based on the total future area of the ADZ of 1 871 ha, the lower and upper limits of the ECC for ungraded bivalve aquaculture production would be 8 345 tpa (low) and 27 597 tpa (high). Achieving the lower or upper ECC would represent a production increase of 231% and 1 280%, respectively, of the current graded production of approximately 2 000 tpa.

[4] Ungraded production refers to the total production volume (marketed, re-seeded and discarded) of mussels. Oysters are generally all removed from the baskets/stacks without any discard back into the water, so that ungraded equals graded volumes for oysters.

Table 2: Total ungraded production limits for mussels and oysters for all proposed ADZ precincts (estimates for graded volumes are given in parentheses)

Location	Area (hectares)	10% ECC Low production Scenario tons/annum		25% ECC High production scenario tons/annum	
		Mussels	Oysters	Mussels	Oysters
Small Bay	163	652 (326)	75	2 160 (1 080)	245
Big Bay North	525	2 100 (1 050)	242	6 956 (3 478)	788
Big Bay South	521	2 080 (1 040)	239	6 890 (3 445)	780
Outer Bay North	336	1 344 (672)	155	4 452 (2 226)	504
Outer Bay South	327	1 308 (336)	150	4 333 (2 167)	491
Total Area	**1872**	**7484 (3 742)**	**861**	**24 791 (12 396)**	**2 807**
Combined Mussels & Oysters		**8 345t (4 603 t)**		**27 597t (15 203 t)**	

In the case of finfish farming, the assessment of potential impacts is based on the assumption that the theoretical maximum production levels for finfish within the ADZ areas allocated for cage culture will be 10 320 tpa as per **Table 3** (Heinecken *et al*. 2016, and summarised in the BAR). The assumptions made in obtaining these estimates are detailed in Appendix 3 of this report (compiled by Heinecken *et al*. 2016). Analysis of possible nutrient input, however, indicated that a more realistic maximum fish production volume would be in the order of 5 000 tpa, and this adjusted production level was ultimately assumed for the purposes of the assessment.

Table 3: Extent of identified post-mitigation ADZ areas for fish (ha)

Location	Total ADZ area	Fish area (ha)	Max. fish production (tpa)
Small Bay	163	-	-
Big Bay North	409	22	880
Outer Bay North	216	140	5 600
Outer Bay South	96	96	3 840
Total	**884**	**258**	**10 320**

Based on the outcome of the assessment and recommended international best practice for the development of aquaculture farms, recommendations are provided to further refine the selection and extent of the proposed ADZ precincts. It is also recommended that a phased approach is taken to the development of the ADZ and that for the first two years total annual (ungraded) shellfish production is limited to around 10 000 tpa, increasing annually thereafter by 5 000 tpa to a maximum of 27 600 tpa as monitoring data becomes available. This is presented in Chapter 5. For finfish production, the recommended ramp-up rate is 1 000 tpa reaching a maximum production of 5 000 tpa after 5 years. This production equates to an estimated 15% of the total waste nutrient load (Heinecken *et al*. 2016, and summarised in the BAR).

3. DESCRIPTION OF THE AFFECTED ENVIRONMENT

The description of the biophysical environment in Saldanha Bay presented below is drawn largely from Atkinson *et al.*2006; van Ballegooyen *et al*. 2007; and Clark *et al*. 2009, 2010, 2011, 2012, 2014, 2015.

3.1 Geographical Setting

Saldanha Bay is the only natural harbour of significant size on the west coast of South Africa, and offers relative protection from the high energy coastline (Shannon & Stander 1977; Weeks *et al*. 1991a). It is directly linked to the shallow, tidal Langebaan Lagoon (see Figure 4). The Saldanha Bay-Langebaan system can be divided into Outer Bay, Saldanha Bay (comprising Big Bay and Small Bay) and Langebaan Lagoon. The system contains five offshore islands, namely Malgas, Jutten, Marcus, Meeuw and Schaapen Islands. The Saldanha Bay-Langebaan Lagoon system is marine, with its waters originating in the continental shelf waters of the adjacent Benguela upwelling system (Shannon & Stander 1977). In winter, however, there is a small seepage of fresh water into the system due to rain (Day 1981). Most of the commercial activities in Saldanha Bay are concentrated in or just outside of Small Bay, while Langebaan Lagoon remains largely pristine in terms of existing development and forms part of the West Coast National Park. Langebaan Lagoon is internationally recognised as a Ramsar site in terms of the Convention on Wetlands of International Importance, especially as waterfowl habitat.

Saldanha Bay is a deep water bay with no significant river inflows, which might lead to siltation. Being in proximity to the productive West Coast fishing grounds, it hosts a substantial fishing industry and fish processing factories. The overall surface area of the Saldanha Bay-Langebaan system is estimated to be 9 610 ha. Of this surface area, Small Bay comprises 1 410 ha, Big Bay 4 310 ha and Langebaan Lagoon 3 890 ha. The mid-tide volume of the whole system is 734 million m^3. Of this total volume, Small Bay contributes 128 million m^3, Big Bay 517 million m^3 and Langebaan Lagoon 89 million m^3 (Weeks *et al*. 1990).

Although the construction of the iron ore jetty in 1974/75 impacted significantly on the water circulation in the Bay, Small Bay, Big Bay and Langebaan Lagoon can be considered to comprise one large ecosystem with strong interdependencies between the various regions. Despite being considered a semi-enclosed coastal embayment, significant exchanges and flushing of the various sub-components by water from the adjacent continental shelf do occur. Estimated exchanges between the various regions of the bay are provided in Table 3.

Table 4 : Estimated water fluxes between the various regions of Saldanha Bay and Langebaan Lagoon (Source: van Ballegooyen *et al*. 2007).

Location of cross-section	Exchange fluxes*	
	Neap tides (m^3/s)	Spring tides (m^3/s)
Flux across the mouth of Small Bay	210	1 680
Flux across the mouth of Big Bay (*i.e.* between Saldanha Bay and the adjacent continental shelf)	1 100	7 950
Flux across the mouth of Langebaan Lagoon (both channels)	500	3 260

3.2 Physical Environment

3.2.1 Winds and Waves

There is a strong seasonality in the winds over Saldanha Bay, reflecting the changes in the synoptic weather patterns prevailing at different times during the year. During summer the winds are predominantly southerly with significant south-westerly and, to a lesser extent, south-easterly wind components. In autumn the winds are predominantly southerly with the development of a north-westerly wind component as the season progresses. The regular passage of cold fronts in winter results in predominantly north-westerly winds with the occurrence of significant south-westerly and south-easterly wind components. The spring wind regime is similar to the summer wind regime but with increased south-easterly wind components.

The winds along the West Coast have a significant diurnal component (Jury & Guastella 1987), with the wind speed typically reaching a maximum in the late afternoon. These diurnal changes in the winds impact significantly on the heat fluxes at the sea surface over a 24 hour period.

The wave conditions inside the bay are sheltered compared to those outside, since all energy reaching the bay has to pass through the relatively narrow channel between Marcus Island and Elandspunt. The median significant wave height measured in the entrance to the bay is 1.1 m, while the greatest occurrence of peak periods lies in the 10 to 12 second (s) range. The most frequent direction of wave approach outside the bay is from the southwest.

In addition to waves originating from offshore, small wind-waves (up to 1 m in height) can be generated by strong winds within Saldanha Bay. Measurements of long wave energy in Saldanha Bay indicate significant energy in the period range of 30 s to 200 s.

3.2.2 Tides and Currents

The tides along the West Coast, including Saldanha Bay, are semi-diurnal with an approximate 2 m tidal range during spring tides. The currents in the bay are predominantly wind- and tide-forced, the relative importance of the two processes changing with depth and location in the bay. In general, wind is the dominant physical forcing mechanism determining the surface layer current speed and direction in both Small and Big Bay (van Ballegooyen *et al*. 2007). Tidal forcing is stronger at depth, in the vicinity of the mouth of Saldanha Bay (Shannon & Stander 1977) and with increasing proximity to Langebaan Lagoon (Weeks *et al*. 1991a, 1991b) (Figures 2 and 3). Wave-driven currents are expected to dominate in the surf-zone.

Although residual tidal flows occur in the bay, the greatest water exchange between Saldanha Bay and the shelf is due to synoptic weather events, which occur on time scales of 3 to 10 days. South-south-easterly wind events result in a general surface outflow and a subsurface inflow of cold bottom water (Spolander 1996; Monteiro & Largier 1999), while north-westerly wind events typically lead to the inflow of surface waters in the northern region of the mouth of Saldanha Bay (Figures 4 and 5). Thus the surface, mid-water and bottom currents often are observed to be flowing in different, and at times, opposite directions. Such three-dimensional flow structure need, however, not be restricted to strongly stratified conditions (see for example Weeks *et al*. 1991b).

During periods of slack winds, generally weak tidal currents dominate and are the sole mechanism for flushing the bay. The tidal currents are generally weak, however strong tidal flows are observed at the entrance to the lagoon, particularly during spring tides. During tidal exchange, it is estimated that approximately half of the lagoon water passes through the Lagoon entrance channels into Saldanha Bay (Shannon & Stander 1977) and velocities of up to 1.0 m/s are observed in the two channels connecting Big Bay and Langebaan Lagoon (Krug 1999).

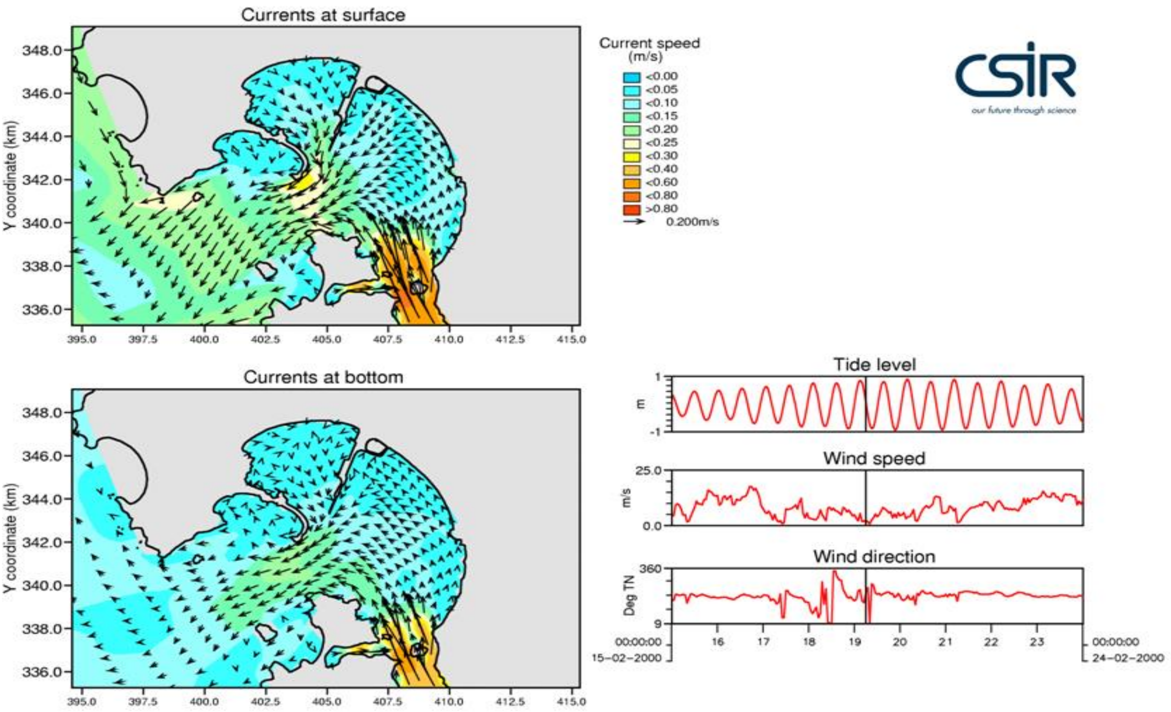


Figure 2 : Flood tide surface and bottom currents in Saldanha Bay during spring tide and under relatively calm conditions.

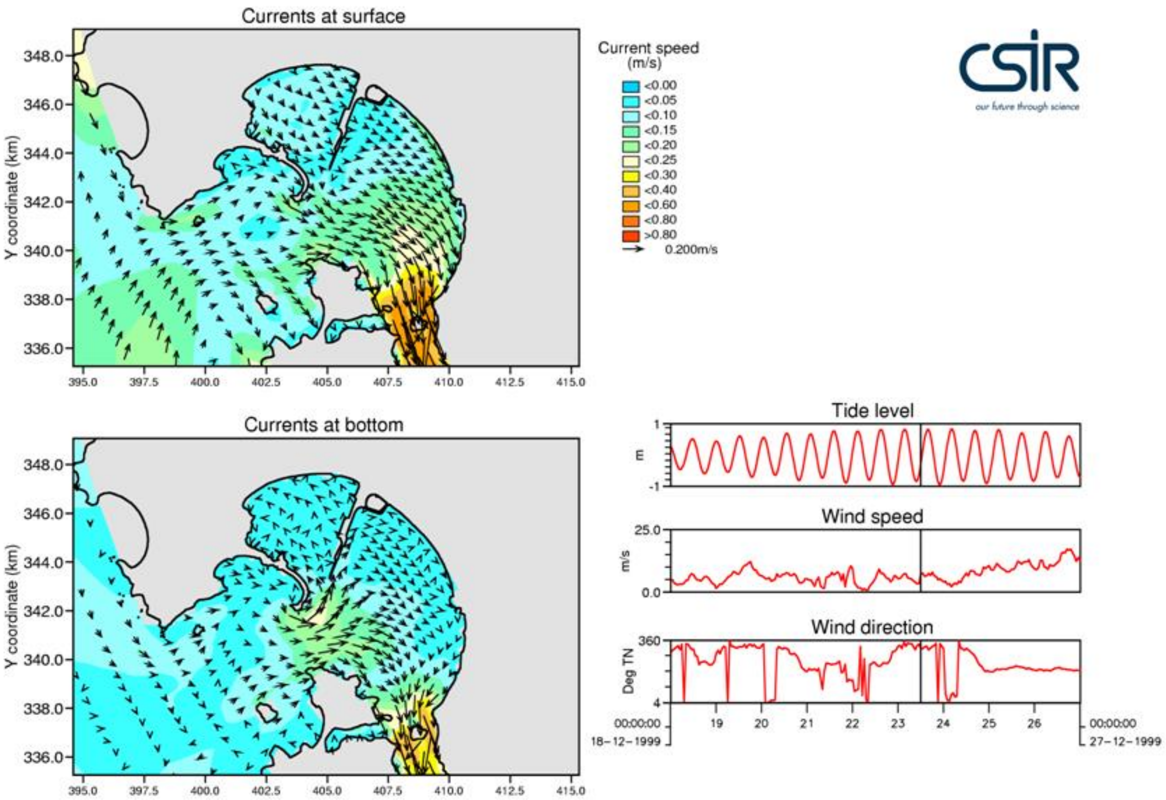


Figure 3 : Ebb tide surface and bottom currents in Saldanha Bay during spring tide and under relatively calm conditions

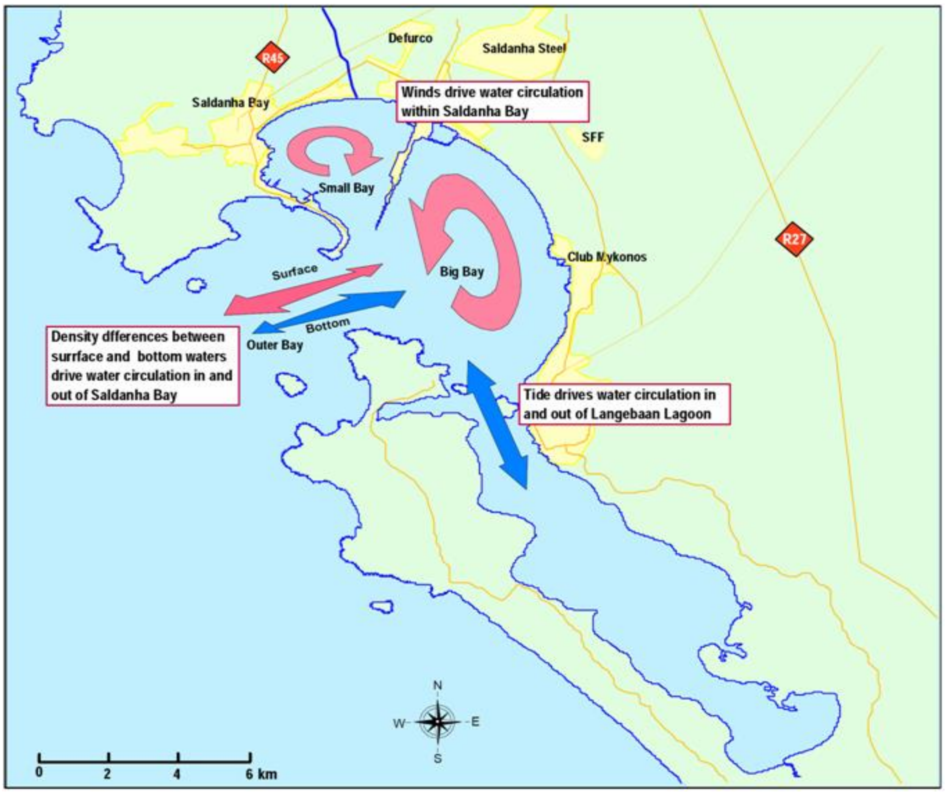


Figure 4 : Schematic of the wind driven and tidal currents in Saldanha Bay under Southerly wind conditions.

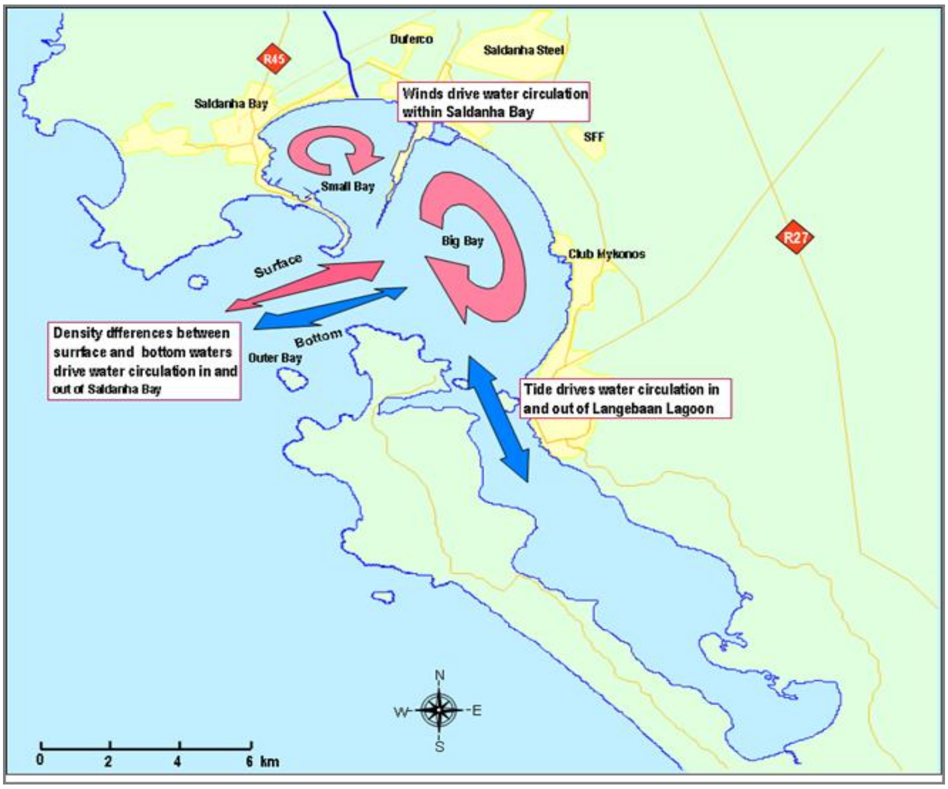


Figure 5 : Schematic of the wind driven and tidal currents in Saldanha Bay under North Westerly wind conditions.

3.2.3 Water Column Stratification

The water column structure in Saldanha Bay is seasonal, varying from a strongly thermally stratified water column for most of the year (August to May) to well-mixed conditions during the mid-winter months (June to July). Strong stratification is maintained by atmospheric heat fluxes into the surface waters and the inflow of cold bottom waters from upwelling on the adjacent continental shelf. The local winds periodically mix the water column and break down the thermocline, thus interrupting the stratification until it builds up again (Monteiro & Largier 1999). These processes control the thermocline dynamics and vertical mixing of the water column, which together with wind- and tidally-driven currents, ultimately determine the behaviour of biogeochemical parameters and pollutants within the bay.

The variability in the water column stratification is predominantly synoptic and responds strongly to wind-forcing, which has a periodicity of 6 to 10 days in this region (Nelson & Hutchings 1983). During the mid-winter months the water column within the bay is largely well-mixed, due to reduced heat fluxes into surface waters and the reduced upwelling over the adjacent continental shelf.

3.2.4 Seawater Temperature and Salinity

The natural seawater temperature fluctuations in Saldanha Bay are substantial and typically occur on four time scales, namely diurnal, synoptic, seasonal and interannual.

Diurnal temperature changes are greatest in summer when the surface waters experience diurnal temperature changes of typically 0,5°C to 1°C, but up to 2°C on occasion (Monteiro & Largier 1999; CSIR 1995). In winter the water column is largely unstratified, and the diurnal temperature fluctuations are substantially reduced at all depths.

Changes in the **synoptic weather events** lead to substantial variability in water column temperature within the bay and over the adjacent shelf region (CSIR 1976; CSIR 1995; Monteiro & Largier 1999; Shannon 1985). In Small Bay, temperature throughout the water column may change during a synoptic cycle by as much as 6°C to 8°C in summer and 1°C to 2°C in winter (CSIR 1995; Monteiro & Largier 1999). This is mostly due to changes in the vertical mixing of the water column due to local winds, although during the upwelling season advection of cold bottom waters into Small Bay also play a significant role (Monteiro & Largier 1999). Under north-westerly wind conditions warmer surface waters flow into Saldanha Bay (CSIR 1976).

The **mean seasonal change** in sea surface temperature is about 6°C (Greenwood & Taunton-Clark 1992), the magnitude of which is highest in Langebaan Lagoon and much smaller near the more exposed mouth of Saldanha Bay. The seasonal changes in water temperature of the deeper waters in the bay (approximately 2.5 °C) are substantially less than those observed in the surface waters.

The **interannual sea surface temperature variability** typically has a magnitude of between 1°C and 2°C (Greenwood & Taunton-Clark 1994). These longer period changes in temperature are most likely due to persistent changes in the local synoptic weather conditions. The temperature signals associated with such episodic events are, however, largely masked in the surface waters by seasonal temperature variations due to changes in atmospheric heat input and vertical mixing of the water column (Monteiro & Brundrit 1990).

Salinities of the inshore waters along the west coast typically vary between 34.6 - 34.9 psu and the salinity values recorded for Saldanha Bay fall within this range (Atkinson *et al.* 2006). During summer months wind-driven coastal upwelling bring cooler less saline water into Saldanha Bay. Consequently the salinity within the bay usually is slightly lower in summer than in winter, when the upwelling front breaks down and warmer, more saline surface waters enter the bay.

3.2.5 Water Quality

Dissolved Oxygen

The fate and behaviour of dissolved oxygen (DO) and the factors affecting fluctuations in DO levels are of critical importance to marine organisms. The principal anthropogenic activity resulting in changes in DO concentrations in the marine environment is the addition of organic matter.

In the Saldanha Bay system, the water in Small Bay experiences regular oxygen deficits during the late summer and winter months, whilst Big Bay experiences less frequent and lower magnitude oxygen deficits (Atkinson *et al.* 2006). The oxygen deficit in Small Bay is largely attributed to reduced flushing rates (due to the causeway and ore jetty construction) and discharges of organic rich effluents from fish processing factories (Monteiro *et al.* 1990; Clark *et al.* 2015). Localised anoxia in Small Bay (*e.g.* under the mussel rafts and within the yacht basin) is caused by excessive organic inputs (Stenton-Dozey *et al.* 2001).

Turbidity

The water of Saldanha Bay is fairly turbid (Carter 1996), the turbidity comprising both organic and inorganic particulates. During active upwelling the turbidity of bottom waters decreases, but under strong wind conditions both wind and wave action result in significant water column turbidity. Particularly in Big Bay, the light coloured sediments result in significant discolouration of the waters. The waters of Langebaan Lagoon, in contrast, are typically very clear and of low turbidity.

Dissolved trace metals

The Mussel Watch Programme regularly records concentrations of Cadmium, Copper, Lead, Zinc, Iron and Manganese present in the flesh of mussels at several sites along the shoreline of the Bay and from the aquaculture farms in the Bay (Atkinson *et al.* 2006). For the monitored sites *along the shore* in Small Bay, the results show that for the 10 years prior to 2011, concentrations of Lead in mussels have consistently been above guideline limits for foodstuff, while Cadmium concentrations frequently, and Zinc concentrations occasionally, exceed these limits. Concentrations of Copper are, however, well below specified levels (Clark *et al.* 2015). No clear trends over time are evident for any of the trace metals.

In contrast to the nearshore mussels, trace metal concentrations in *farmed mussels away from the shore* are much lower and mostly meet guideline values for foodstuff for human consumption. This may be linked to higher growth rates of farmed mussels, and the fact that the cultured mussels are feeding on phytoplankton blooms in freshly upwelled water that has only recently been advected into the Bay from outside (Clark *et al.* 2011).

Microbial Contamination

Pathogenic microorganisms, which are primarily introduced into coastal waters by faecal pollution, pose a risk to both water users and aquaculture ventures. According to Clark *et al.* (2011), in 2010 coastal waters in Small Bay had faecal coliform counts in excess of safety guidelines for both aquaculture and recreational use the majority of the time, despite noticeable improvements in water quality since 2004. Faecal coliform and *E. coli* counts are lower in Big Bay and Langebaan Lagoon when compared to Small Bay, but several sites (Paradise Beach, Seafarm at Transnet National Ports Authority and Mykonos Harbour) still suffer from bacterial contamination. Clark (2015), however, reports that regular monitoring of microbiological indicators at 20 stations in the Bay (10 in Small Bay, 5 in Big Bay and 5 in Langebaan Lagoon) indicate that the historical chronic problems with faecal coliform pollution have improved considerably in recent years.

3.2.6 Sediments

Sediment Composition

Under natural circumstances, the nature of the sediments in Saldanha Bay are governed by the wave energy and current circulation patterns prevalent in the system. High wave energy and strong currents keep fine sediment in suspension, and these are then flushed out of the Bay, with the coarser (heavier) sand or gravel particles remaining. Thus, prior to the various industrial developments in Saldanha Bay, the seabed sediments comprised mainly sands (size range from 60 - 1,000 µm), with negligible contributions by the finer mud fractions (Flemming 1977). However, construction of the Marcus Island causeway and iron ore jetty in the 1970s resulted in some level of obstruction to the natural patterns of wave action and current circulation in the Bay, with concomitant shifts in sediment composition. In addition, large-scale disturbances such as dredging of sediments, can lead to re-suspension of fine particles that were buried beneath the sand and gravel. As the quantity and distribution of the different sediment fractions (gravel, sand and mud) prescribes the status of biological communities and the extent of possible organic and trace-metal loading, the sediments in Saldanha Bay have been regularly monitored over the past few decades.

After the development of the causeway and ore jetty, there occurred a slow increase in the percentage of mud particles, which was greatly aggravated by extensive dredging adjacent to the ore jetty in 1997/98 (Jackson & McGibbon 1991). The areas most affected were the General Cargo Quay (GCQ), Channel end of the ore jetty, the Yacht Club basin and the Mussel Farm area (Monteiro *et al*. 1999).

Subsequent studies have indicated that the mud content has shown a progressive decline at most sites monitored, although several deeper and more sheltered sites within Small Bay and Big Bay still have elevated mud fractions (Clark *et al*. 2015), with the most significantly affected sites being adjacent to the Ore Terminal, in the Yacht Club basin and below the mussel rafts. Trends in the mud component of Saldanha Bay sediments are of particular interest as contaminants (trace metals and toxic pollutants) are predominantly associated with the fine sediment fractions due to their higher adsorption potential. Accumulation of organic matter in the sediments can also lead to reduced environmental health through depletion of oxygen both in the sediments and surrounding water column. Higher proportions of mud, relative to sand or gravel, can thus lead to high organic loading and trace metal contamination

Organic Content

Clark *et al*. (2015) reported an overall decline in Total Organic Carbon (TOC) and Total Organic Nitrogen (TON) levels at most sites despite the slight increases during 2015, except near the Yacht Club basin and the Ore Terminal where elevated levels have persisted in the sediments since 2008. The most likely origin of the TOC and TON is associated with waste discharge from the fish factories and faecal waste from the mussel rafts, sewage effluent and waste water runoff. Accumulation of organic waste, especially in sheltered areas with limited water flushing, can lead to anoxic conditions and can negatively impact the marine environment, as evident from the species composition and abundance of the benthic communities inhabiting the sediments in the affected areas (see **Section 4.1).**

Trace Metals

In areas of the Bay where fine sediments tend to accumulate, trace metals and toxic pollutants sometimes exceed acceptable threshold levels. This is due either to naturally occurring high levels of the contaminants in the environment (e.g. in the case of cadmium) or due to impacts of human activities (e.g. lead, copper and nickel associated with ore exports). Such trace metals are generally biologically inactive when buried in the sediment, but can become toxic to the environment when mechanical disturbance of the sediments (e.g. dredging) results in re-suspension of sediments. On average, the concentrations of all metals were highest in Small Bay, lower in Big Bay and below detection limits in Langebaan lagoon (Clark *et al*. 2015). Following the major dredging event in 1999, cadmium concentrations in certain areas in Small Bay exceeded internationally accepted safety levels, while concentrations of other trace metals (e.g. lead, copper and nickel) approached threshold levels. Data collected in 2015 indicated that contaminants have returned to levels well within safety thresholds, as fine sediments along with the associated contaminants released during various dredging events have either been flushed out of the bay or have been reburied. Exceptions to this were observed at a few sites in Small Bay where thresholds were exceeded in 2015. Key areas of concern regarding trace metal pollution include the Yacht Club Basin, where cadmium and copper exceeded recommended thresholds, and adjacent to the Multi-purpose terminal, where levels of cadmium and lead were in excess of internationally accepted guidelines. Recent increases in concentrations of manganese around the ore-terminal have also been noted (Clark *et al*. 2014, 2015).

Hydrocarbons

Poly-aromatic hydrocarbons (PAH) contamination has been measured in the Saldanha Bay sediments since 1999, and values have been well below levels considered an environmental risk. No poly-cyclic, poly-nuclear compounds or pesticides were detected in sediments. In recent years, however, Total petroleum hydrocarbon (TPH) levels in the vicinity of the ore terminal have fluctuated considerably, and in 2014 TPH levels were found to be exceptionally high at some sites, indicating heavily polluted conditions, possibly associated either with a pollution incident associated with shipping activities or routine operational activities on the jetty itself (Clark *et al*. 2014, 2015). In 2015, TPH and PAH levels presented no major concern.

3.3 Biological Environment

The Saldanha Bay - Langebaan Lagoon system falls within the Namaqua biogeographic province that extends from Cape Point to Lüderitz within the southern Benguela upwelling region (Emanuel *et al*. 1992). The bay and the lagoon together form one of the few sheltered habitats along the South African West Coast, with graded changes in wave action and substratum. The shallow lagoon is fully marine with a strong tidal exchange (Shannon & Stander 1977), and comprises extensive intertidal sandflats and salt marshes (Day 1959).

The description of the biological environment focusses primarily on the habitats in Saldanha Bay, as this is the marine environment potentially directly affected by the project, with only occasional reference to the lagoon. Marine ecosystems within the Saldanha Bay comprise a range of habitats, each supporting a characteristic biological community, including:

- Sandy intertidal and subtidal substrates,
- Intertidal rocky shores and subtidal reefs,
- Macrophyte beds, and
- The water body.

The biological communities in each of these habitats are described briefly below, with the main focus on potentially sensitive communities that may be affected by the proposed project.

3.3.1 Sandy Substrate Habitats and Biota

The benthic biota of soft bottom substrates constitutes invertebrates that live on (epifauna), or burrow within (infauna), the sediments, and are generally divided into macrofauna (animals >1 mm) and meiofauna (<1 mm).

Intertidal Sandy Beaches

Sandy beaches are one of the most dynamic coastal environments. The composition of their faunal communities is largely dependent on the interaction of wave energy, beach slope and sand particle size.

There is a noticeable scarcity of published information on the intertidal beach biota of Saldanha Bay, as previous research on the West Coast has primarily focussed on 'open coast' beaches (*e.g.* Soares 2003). In an account of four sandy shores from the Saldanha Bay system, Day (1959) described an increase in species richness and a significant change in species composition with increasing shelter. His work, however, precedes the construction of the causeway and ore jetty, and the resulting changes in wave and current patterns in the bay. Unpublished data from Langebaan Lagoon and Lynch Point (unpublished UCT student data: 1995 and 1996; provided by Prof. C. Griffith) confirm the dramatic change in species richness and composition between the exposed Saldanha Bay beach and the sheltered lagoon beaches.

At the *exposed* Lynch Point, the fauna is sparse and includes the semi-terrestrial isopod *Tylos granulatus* and the talitrid amphipod *Talorchestia* spp. in the supralittoral zone above the high water spring mark. Similarly in the midlittoral zone the fauna include the amphipods *Pontogeloides latipes*, *Eurydice longicornis*, and the polychaetes *Glycera convoluta* and *Scololepis squamata*. The mysid *Gastrosaccus psammodytes* occurs at, and below, the low tide level. The macrofaunal species encountered are generally ubiquitous to the West Coast (Day 1959; Soares 2003).

In contrast, the extremely *sheltered* intertidal flats in Langebaan Lagoon harboured >30 species (Day (1959) recorded 55 species), many of which are either South Coast species known to occur on the West Coast only in Langebaan Lagoon, typical estuarine species, or species normally found in pools and crevices on exposed rocky shores (Day 1959). Noteworthy is that many of the typical West Coast beach species (e.g. *Tylos, Talorchestia, Eurydice*) are not found in the lagoon.

Subtidal Sandy Habitats

The structure and composition of benthic soft bottom communities is primarily a function of water depth and sediment grain size, but other factors such as current velocity, organic content, and food abundance also play a role (Snelgrove & Butman 1994; Flach & Thomsen 1998; Ellingsen 2002). Changes in benthic community structure in Saldanha Bay as a result of anthropogenic impacts have been reported by numerous authors (Christie & Moldan 1977; Moldan 1978; Jackson & McGibbon 1991, amongst others). In Small Bay there has been a shift from communities dominated by suspension-feeders to communities characterised by deposit-feeders. More specifically, the sea pen *Virgularia schultzei*, a suspension feeder, was historically widespread in the bay, but has not been recorded since 1989. Although it re-appeared in Big Bay in 2004, it is still absent in Small Bay. In contrast, the deposit-feeding polychaete *Polydora* sp. has undergone a dramatic increase over the last decades, especially in Small Bay (Jackson & McGibbon 1991). This shift in community composition has been attributed to changes in water circulation patterns in the Bay, as well as organic pollution from fish factories and mussel farming in Small Bay.

The mud prawn *Upogebia capensis* is one of the most dominant species in the bay, particularly in Small Bay. Other important species in Small Bay include the polychaete *Polydora* sp., the amphipod *Ampelisca spinimana*, the tongue worm *Ochaetostoma capense* and the crab *Thaumastoplax spiralis*, which lives commensally in the tube of the tongue worm (Day 1974). Aside from the mud prawn and the tongue worm, Big Bay was dominated by two amphipod species (*A. spinimana* and *Urothoe grimaldi*), and the polychaete *Orbinia angrapequensis*. *U. capensis*, *O. capense* and *Callianassa kraussi* contributed the most to the overall biomass in Small Bay and Big Bay. In the turbulent surf-zone, particularly between 2 – 5 m depth, the faunal diversity is usually lower and primarily includes amphipods and polychaetes (Christie 1976).

The most recent study on benthic macrofauna was commissioned by the Saldanha Bay Water Quality Forum Trust in 2015 (Clark *et al.* 2015). It revealed that benthic macrofaunal communities over the period 1999-2015 have been relatively stable in most parts of the Bay and Lagoon. An exception was 2008, when a dramatic shift occurred involving a decrease in the abundance and biomass of filter feeders and an increase in shorter lived opportunistic detritivores. This shift was attributed to the extensive dredging undertaken during 2007-2008. Filter feeding species are typically more sensitive to changes in water quality than detritivores or scavengers and account for much of the variation in overall abundance and biomass in the Bay.

Localised impacts on and subsequent improvements in health have been also detected in the Yacht Club basin and at Salamander Bay following construction of the boat dock. In 2008, benthic fauna in the Yacht Club basin were almost entirely eliminated due to high levels of trace metals and other contaminants at this site (TOC, Cu, Cd and Ni). Benthic macrofauna communities have, however, steadily recovered and are now almost on a par with other areas in Small Bay. In Salamander Bay, impacts of the dredging activities for the expansions of the Naval Boatyard in 2010 were also clearly evident in the benthic communities for several subsequent years, but by 2015 had returned to more natural levels.

Other notable improvements in the health of benthic communities in the system include the return in 2004, after an absence of more than 10 years, of the suspension feeding sea-pen *Virgularia schultzei* to Big Bay and Langebaan Lagoon, as well as an increase in the percentage biomass of large, long lived species such as the tongue worm *Ochaetostoma capense*, and several gastropods. However, certain areas of Small Bay still have impoverished macrofauna communities (e.g. base of the ore jetty, near the Small Craft Harbour and near mussel rafts). This is primarily due to reduced water circulation patterns in those areas, which results in the accumulation of fine sediment, organic material and trace metals (aggravated by anthropogenic inputs).

The epifaunal community composition similarly underwent dramatic changes following the harbour development, with a decline in species number and a shift in species composition being reported (Kruger *et al.* 2005). Polychaetes, in particular, showed a substantial decline in species number, whereas the whelk *Nassarius speciosus* and the crab *Hymenosoma orbiculare* increased significantly in abundance. Altered wave energy, a shift towards finer sediment and increased organic matter within Saldanha Bay as a result of harbour construction, and fish factory and mussel-farm outputs, are thought to be responsible for these changes (Kruger *et al.* 2005).

Macrophyte beds

Subtidal macrophyte beds are dominated by the agarophyte alga species *Gracilaria gracilis*, which occurs in Small Bay and adjacent to Schaapen Island in the southern portion of Big Bay. The alga is also characteristic of the subtidal sandy sediments in the Langebaan Lagoon (Schils *et al.* 2001). It occurs on sandy substrates at 2 - 10 m depths, and may either be anchored or drifting (Anderson *et al.* 1993). *Gracilaria* formed the basis of a small industry that collected cast material from the beaches for export to agar processing plants.

3.3.2 Rocky Habitats and Biota

Intertidal Rocky Shores

Despite the known changes that have taken place within the Saldanha Bay – Langebaan Lagoon system over the last fifty years, almost no historical data exist on the state of rocky shores in the area. Only recently have surveys covering a range of different rocky habitats been undertaken (Atkinson *et al.* 2006; Clark *et al.* 2009, 2010, 2011), and these showed that, similar to other South African rocky shores, wave exposure and the type of rock substratum were important determinants of community structure.

The rocky intertidal can be divided into different zones according to height on the shore. Each zone is distinguishable by its different biological communities, which is largely a result of the different exposure times to air. The level of wave action is particularly important on the low shore. Generally, biomass is greater on exposed shores, which are dominated by filter-feeders. Sheltered shores support lower biomass, and algae form a large portion of this biomass (McQuaid & Branch 1984; McQuaid *et al.* 1985).

Construction of the iron ore causeway and the Marcus Island causeway altered the wave exposure zones in the Bay. The causeway increased the extent of sheltered and semi-sheltered zones in Small Bay, with semi-exposed shores being absent in this area (Luger *et al.* 1999). Although wave exposure in Big Bay was less dramatically altered, the extent of sheltered and semi-sheltered wave exposure areas increased after harbour development (Luger *et al.* 1999). No historical data prior to the construction of the causeway exist, but the sheltering effect of the causeway is thought to have negatively affected the intertidal communities along the Small Bay shoreline and changed their compositions (Atkinson *et al.* 2006; Clark *et al.* 2009, 2010).

The taxa encountered on Saldanha Bay's rocky shores are generally common to the South African West Coast (e.g. Day 1974, Branch *et al.* 2010). In terms of zonation, important species in the:

- High shore are the grazers *Afrolittorina knysnaensis*, *Oxystele variegata* and the alga *Porphyra capensis*;
- Mid-shore levels are dominated by the alien barnacle *B. glandula*, the limpets *Siphonaria capensis* and *Scutellastra granularis*, the carnivorous whelk *Burnupena* sp., the algae *Ulva* spp. and *Caulacanthus ustulatus*, and the alien invasive mussel *M. galloprovincialis*;
- At sheltered sites, the low shore is characterized by algae such as *Ulva* spp., *Gigartina polycarpa*, and crustose algae, and the faunal component includes *Burnupena* sp., and limited cover of *M. galloprovincialis* and the indigenous mussel *C. meridionalis*; and
- At more exposed sites, the low shore is covered primarily by *M. galloprovincialis*. *M. galloprovincialis* is displacing the indigenous species *Choromytilus meridionalis* and *Aulacomya ater* (Robinson *et al.* 2007b). Further, because of greater structural complexity within beds of *M. galloprovincialis* compared to those of indigenous mussels, there have been changes to overall community composition in areas colonised by this species (Robinson *et al.* 2007b).

A study of the intertidal macroalgal assemblages in Saldanha Bay and Langebaan Lagoon identified two distinct floral entities on rocky shores: (i) Saldanha Bay (including Small Bay and Big Bay) and (ii) Langebaan Lagoon (Schils *et al.* 2001). The transition between the floral entities is located at the mouth of the Lagoon. The species richness of the bay area is greater than in the lagoon. The change in algal composition was explained by environmental variables, of which wave exposure is the most significant. In terms of biogeographical affinities of the different algal entities, it was shown that the bay area supports a typical West Coast flora. The algal flora of the lagoon is also dominated by West Coast species, but is typified by species characteristic of sheltered habitats, and with a number of species which otherwise only occur on the geographically distant South Coast (east of Cape Agulhas) (Schils *et al.* 2001).

Rocky Subtidal Habitats

Rocky subtidal reefs are not extensive in Saldanha Bay, but artificial habitats such as harbour structures and their reinforcements serve as additional settlement substrates. The dominant organisms on these structures are mussels (*M. galloprovincialis* and to a lesser extent *C. meridionalis* and *A. ater*), *Pyura stolonifera,* and whelks and barnacles with associated macroalgae. Typical kelp species along the West Coast are *Ecklonia maxima* and *Laminaria pallida* (Stegenga *et al.* 1997). In Saldanha

Bay, however, *E. maxima* appears to be replaced by *L. pallida* due to reduced wave exposure within the bay (Simons 1977). Individuals of *E. maxima* occur as far as the entrance of Langebaan Lagoon but do not penetrate further into the lagoon, whereas isolated specimens of *L. pallida* can be found further into the lagoon (Schils *et al.* 2001).

3.3.3 Invasive Alien Species

Saldanha Bay is thought to be the introduction point for many marine alien species. The main vectors responsible for the introduction of non-native species are fouling of ship hulls (Mead *et al.* 2011; Jurk 2011) or ballast water, and via aquaculture (Robinson *et al.* 2005a; Rius *et al.* 2011; Haupt *et al.* 2012).). At least 30 introduced marine species are known to occur in Saldanha Bay and/or Langebaan Lagoon (Awad *et al.* 2003; Mead *et al.* 2011; Clark *et al.* 2015). Many of these alien species are considered invasive, including the Mediterranean mussel *Mytilus galloprovincialis* (Hockey & van Erkom Schurink 1992), the recently detected acorn barnacle *Balanus glandula* (Simon-Blecher *et al.* 2008; Laird & Griffiths 2008) and the Pacific South American mussel *Semimytilus algosus* (de Greef *et al.* 2013). An additional 20 species in Saldanha Bay are currently regarded as cryptogenic (of unknown origin) but very likely introduced to Saldanha Bay.

Populations of Mediterranean mussels and acorn barnacles are by far the most dominant animal species on rocky shores in the Bay. *Mytilus* populations increased from an average of 5.4% cover in 2005 to 7.8-11.1% in 2012, declining again to around 7% in 2015. After peaking at 7.5% in 2009, populations of *Balanus* also seem to be declining, with abundance (% cover) at around 3.4% in 2015.

Populations of the Western Pea crab *Pinnixa occidentalis* were first detected in the Bay in 2004, with both the abundance and range subsequently expanding fairly rapidly, extending to the mouth of the lagoon in 2009 (Clark *et al.* 2011; Clark & Griffiths 2012), and now also being recorded at Danger Bay (Clark *et al.* 2015).

A detailed account of the non-native species recorded in the Saldanha Bay – Langebaan Lagoon system is provided in Clark *et al.* (2015). Marine aliens are considered to represent one of the greatest threats to rocky shore communities in Saldanha Bay, owing to their potential to become invasive and displacing indigenous species. Changes in the population of these species in Saldanha Bay are being carefully monitored.

3.3.4 Pelagic Communities

The pelagic communities are typically divided into plankton (phytoplankton and zooplankton including ichthyoplankton) and fish, and their main predators, marine mammals (seals, dolphins and whales).

Plankton

Saldanha Bay is protected from the high-energy coastline, but remains a highly productive system owing to its link to the Benguela upwelling system (Pitcher & Calder 1998). Due to the nutrient supply from this upwelling system, phytoplankton concentrations in Saldanha Bay can attain chlorophyll concentrations of 18 mg Chl a /m^3, with a mean value of 8.62 mg Chl a /m^3 (Pitcher & Calder 1998). Highest values typically occur during the upwelling season. Phytoplankton exhibits short term variability in distribution as it responds to variations in light levels, induced by natural turbidity, nutrient supply to the surface layers resulting from wind mixing of the water column, and the presence and location of thermoclines dividing oligotrophic surface layers from cooler, nutrient rich subsurface water. Through the above processes, high phytoplankton biomasses can occur in surface waters, be limited to subsurface maxima associated with thermoclines, or be reduced to low levels as characteristically occurs in winter. Phytoplankton production is estimated at 3.40 g C/m^2/day (Pitcher & Calder 1998). This is comparable to estimates for the adjacent southern Benguela upwelling system

(Shannon & Pillar 1986). The phytoplankton species assemblage within Saldanha Bay appears to be largely similar to that of the adjacent continental shelf.

Harmful algal blooms (HABs) are a regular late summer feature in the southern Benguela region (Pitcher & Calder 2000). The occurrence of harmful algal blooms and their dynamics has been summarised by Carter (2008). Paralytic shellfish poisoning (PSP) due to *Alexandrium catenella*, and diarrehetic shellfish poising (DSP) caused primarily by *Dinophysis acuminate* and *D. fortii* pose a threat to shellfish aquaculture operations, and mussel harvesting in Saldanha Bay was compromised for the first time in 1994 by PSP (Pitcher *et al.* 1994). In subsequent years, both PSP and DSP have become regular problems for the aquaculture operations in the bay (Probyn *et al.* 2001). The geographical scales of Saldanha Bay are considered unsuitable for *in situ* development of HABs (Pitcher *et al.* 1994). Blooms, however, can be advected into Saldanha Bay from the adjacent continental shelf waters, but their development and duration in the bay is restricted by the system of exchange that operates between the bay and the coastal upwelling system, in that there is a net export of surface waters from the bay (Probyn *et al.* 2001).

In contrast, blooms of the brown tide organism, *Aureococcus anophagefferens*, have been recorded in Saldanha Bay but not on the adjacent continental shelf (Pitcher & Calder 2000; Probyn *et al.* 2001). The blooms were mainly limited to the reclamation (oyster) dam in 1997, but spread throughout the entire system, including Langebaan Lagoon, in 1998 (Probyn *et al.* 2001), and led to retarded growth rates in mussels and oysters.

Zooplankton species in Saldanha Bay are composed predominately of species similar to those of the adjacent continental shelf (Grindley 1977). The zooplankton species of Langebaan Lagoon, however, were found to be distinctly different from that of Saldanha Bay, although elements of the Saldanha Bay communities did penetrate the lagoon to various extents.

Fish

Atkinson *et al.* (2006) report on fish distributions in Saldanha Bay and Langebaan Lagoon, which were surveyed using a variety of sampling gear. The waters of the Saldanha Bay system support an abundant and diverse fish fauna with a total of 47 species being recorded. Considering information from all surveys undertaken to date, species diversity was greatest in Big Bay (33), followed by Small Bay (32) and the Lagoon (23). However, species richness is typically highest in Small Bay, having varied little over time. Overall there is no indication of a trend in species richness over time in any of the three parts of the Bay (Clark *et al.* 2015). There was a trend of increasing fish diversity and abundance with decreasing wave exposure as reported previously by Clark (1997). For example, wave exposed beaches yielded <1 fish/m^2, less exposed beaches around 2 fish/m^2, and >4 fish/m^2 at the top of the lagoon where waves are all but absent.

Dominant species in Saldanha Bay are harders (*Liza richardsonii*), silversides (*Antherina breviceps*) and gobies (*Caffrogobius* sp.). Other important fish species in the bay are the white stumpnose *Rhadosargus globiceps*, West Coast steenbras *Lithognathus aureti*, steentjie *Spondyliosoma emarginatum*, gurnard *Cheilidonichtyes capensis*, Cape sole *Heteromyctus capensis*, super klipvis *Clinus superciliosus*, and sand shark *Rhinobatos annulatus* (Atkinson *et al.* 2006; www.environment.gov.za/soer/nsoer/resource/wetland/langebaan_ris).

The Saldanha Bay/Langebaan Lagoon complex is considered to be an important nursery area for a number of ecologically important fish species as its sheltered, nutrient rich and sun-warmed waters provide a refuge from the cold and highly energetic adjacent continental shelf (Atkinson *et al.* 2006). The surf zone and shallow subtidal area in Big Bay extending southwards from the base of the iron ore quay appears to be particularly important in this respect, supporting juvenile white stumpnose (Dr C Attwood, UCT, pers comm.). Since 2007, however, there has been a consistent declining trend in juvenile white stumpnose abundance in the nursery surf-zone habitats, suggesting that the protection afforded by the Langebaan MPA may not be enough to sustain the fishery at the current high effort levels.

Marine Mammals

The Cape fur seal *Arctocephalus pusillus pusillus* no longer breeds on islands in Saldanha Bay, but is a regular visitor in both the inner and outer bays during all months of the year (Cooper 1995). The nearest seal colonies are at Paternoster Rocks and Jacobs Reef at Cape Columbine. Five whale species have been recorded within Saldanha Bay: Killer whale (*Orcinus orca*), Humpback whale (*Megapteran ovaeangliae*) and southern Right whales (*Balaena glacialis*), along with Minke (*Balaenoptera acutorostrata*) and Bryde's (*B. edeni*) whales in the outer bay between Malgas, Jutten and Marcus Islands (Cooper 1995). Dusky dolphins (*Lagenorhynchus obscurus*) and Heaviside's dolphin (*Cephalorhynchus heavisidii*) have been observed along the seaward side of the Marcus Island causeway (Cooper 1995). Of these the Humpback and Southern whales have an IUCN Conservation Status of "least concern", Bryde's and Minke whales are "data deficient", as are the toothed whales (Killer whale, Dusky and Heaviside's dolphins) that have been reported from the bay.

The most abundant migratory baleen whale species around southern Africa are southern right and humpback whales. In the last decade both species have been increasingly observed to remain on the West Coast well after the 'traditional' South African whale season (June – November) to feed in the upwelling zones off Saldanha and St Helena Bays (Barendse *et al.* 2011; Mate *et al.* 2011) during spring and early summer (October – February). Both species can be encountered close inshore as they favour sheltered bays as calving areas, but occurrence within the bay is likely to be infrequent.

3.3.5 Birds

Saldanha Bay and the associated islands provide important shelter, feeding and breeding habitat for at least 53 species of seabirds, 11 of which are known to breed on the islands (Atkinson *et al.* 2006; Clark *et al.* 2015). The islands of Malgas, Marcus, Jutten, Schaapen and Vondeling support breeding populations of African Penguin, Cape Gannet, four species of marine cormorants, Kelp and Hartlaub's Gulls, and Swift Terns. The islands also support important populations of the rare and endemic African Black Oystercatcher.

All four islands in the Bay have experienced an overall decrease in the breeding population of African Penguin. The population in Saldanha Bay grew from 552 breeding pairs in 1987 to a peak of 2 156 breeding pairs in 2001 before undergoing a severe decline to just 314 breeding pairs in 2014. Bank Cormorant numbers in Saldanha Bay have similarly declined by approximately 80% since 1990, dropping to as low as 22 pairs in 2013. Numbers have since increased slightly to 50 breeding pairs in 2014. Numbers of both white-breasted cormorants and crowned cormorants in Saldanha Bay have been relatively constant, with no evidence of a long term decline.

Langebaan Lagoon provides an important habitat for 67 species of waterbirds, of which half are waders. The lagoon has been identified as the most important wetland for waders on the west coast of southern Africa, with 17 of the wader species being regular migrants from the Palearctic region of Eurasia. Waterbird abundance is thus highest in summer, and decreases in winter. Since 1980, there has been a decline in the numbers of waders, which has been attributed to the siltation of the lagoon reducing the amount of suitable feeding grounds, and increasing levels of human disturbance (Atkinson *et al.* 2006).

3.3.6 Beneficial Uses

The identification and mapping of designated uses of the marine environment in Saldanha Bay is drawn from the study by Taljaard & Monteiro (2002), and summarized below.

Conservation Areas

Langebaan Lagoon was designated as a Ramsar site in April 1988 under the Convention on Wetlands of International Importance especially as Waterfowl Habitat. The Ramsar site includes the islands Schaapen (29 ha), Marcus (17 ha), Malgas (18 ha) and Jutten (43 ha), the Langebaan Lagoon, and a section of Atlantic coastline. The Langebaan Lagoon is also included within the boundaries of the West Coast National Park, which was established in 1985.

There are also a number of marine protected areas (MPAs) declared under the Marine Living Resources Act 18 of 1998 (Figure 6):

- Langebaan Lagoon MPA
- Sixteen Mile Beach MPA
- Malgas Island MPA
- Jutten Island MPA
- Marcus Island MPA

Conservation areas of the Cape Nature Conservation Board include an area within the military base, SAS Saldanha and Vondeling Island.

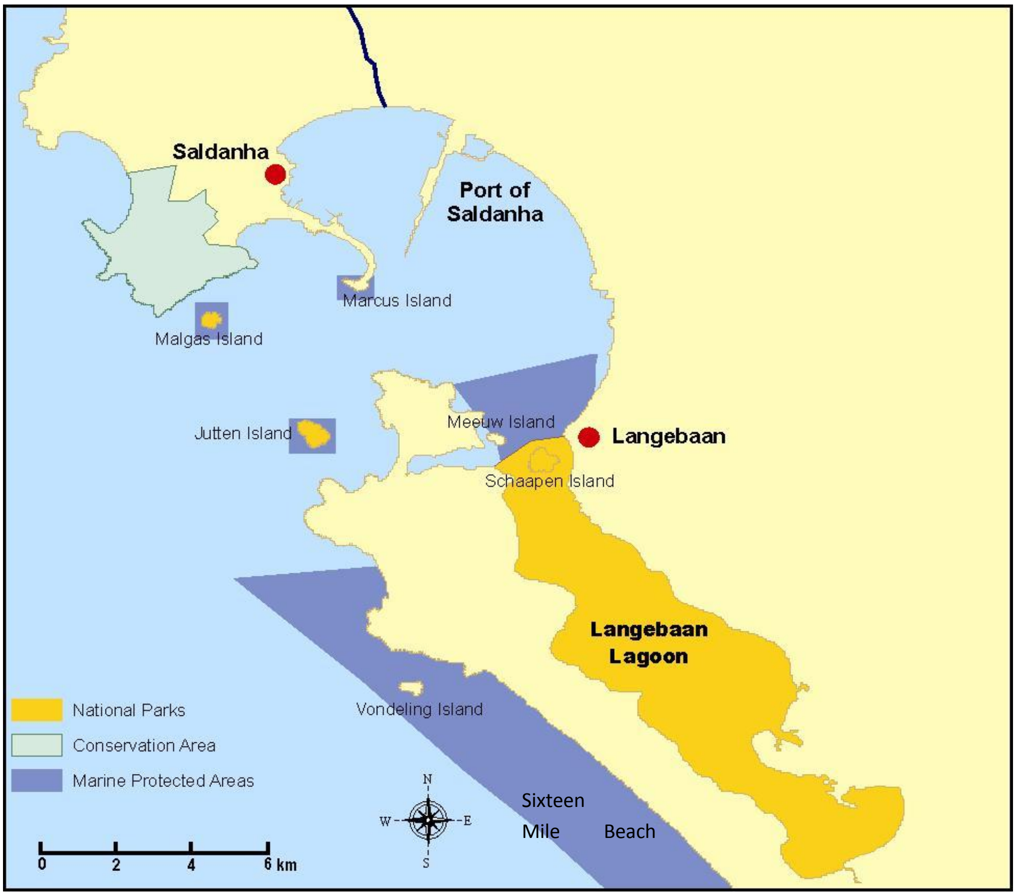


Figure 6: Conservation areas in Saldanha Bay (adapted from Taljaard & Monteiro 2002).

Aquaculture Areas[5]

The Transnet National Ports Authority (TNPA) set aside a total of 395 ha of sea area within Saldanha Bay for aquaculture activities, of which 200 ha are situated in Big Bay, 130 ha are located in Small Bay and a further 65 ha lie adjacent to the breakwater and Small Craft Harbour (Figure 8)[6]. There are currently nine aquaculture operators that farm mussels, oysters, and various other species in the Bay. A total area of approximately 165 ha has been allocated to these operators. Table 4 and Figure 7 provide a summary of the current lease holders and the areas and location of their leases.

i) Mussel Farming

The alien Mediterranean mussel *Mytilus galloprovincialis* and the indigenous black mussel *Choromytilus meridionalis* are cultured on dropper ropes, clustered 60 cm apart and suspended from rafts to a depth of 6 m. Settlement of larvae onto the ropes occurs naturally from the water column. Mussels are harvested, washed and graded on board a boat, and juvenile mussels are hung back onto the ropes and held in place by cotton mesh 'socks' until attachment. Mussel productivity has been increasing steadily, peaking at 1,116 tons in 2013, contributing 37% to total aquaculture production and making the Saldanha mussel sub-sector the second highest contributor to overall aquaculture in the country (DAFF 2015).

Point	Lat S		Long E	
A	33°	2.806′	17°	55.261′
B	33°	1.934′	17°	57.442′
C	33°	3.306′	17°	55.862′
D	33°	2.806′	17°	55.862′
E	33°	1.665′	17°	57.870′
F	33°	1.537′	17°	58.127′
G	33°	2.153′	17°	58.537′
H	33°	2.365′	17°	58.432′
I	33°	0.210′	17°	57.710′
J	33°	0.213′	17°	58.030′
K	33°	0.375′	17°	58.028′
L	33°	0.378′	17°	58.447′
M	33°	0.648′	17°	58.443′
N	33°	0.648′	17°	58.379′
O	33°	0.783′	17°	58.377′
P	33°	0.782′	17°	58.217′
Q	33°	0.890′	17°	58.215′
R	33°	0.885′	17°	57.700′
S	33°	1.045′	18°	1.156′
T	33°	2.763′	18°	2.171′
U	33°	3.031′	18°	0.371′
V	33°	1.948′	18°	0.890′
W	33°	1.910′	18°	0.770′
X	33°	3.470′	18°	0
Y	33°	3.072′	18°	2.278′
Y1	33°	3.212′	18°	1.345′
Z	33°	3.825′	18°	2.193′
Z1	33°	4.037′	18°	1.193′
AA	33°	4.270′	18°	0.090′
AA1	33°	4.170′	18°	0.563′
AB	33°	4.200′	18°	0
AB1	33°	3.950′	18°	0
AC	33°	4.393′	17°	56.961′
AD	33°	4.074′	17°	58.118′
AE	33°	5.117′	17°	58.401′
AF	33°	5.566′	17°	58.024′
AG	33°	5.662′	17°	57.316′
AH	33°	5.306′	17°	57.316′
AI	33°	5.307′	17°	57.861′
AJ	33°	4.706′	17°	57.861′
AK	33°	4.706′	17°	56.961′

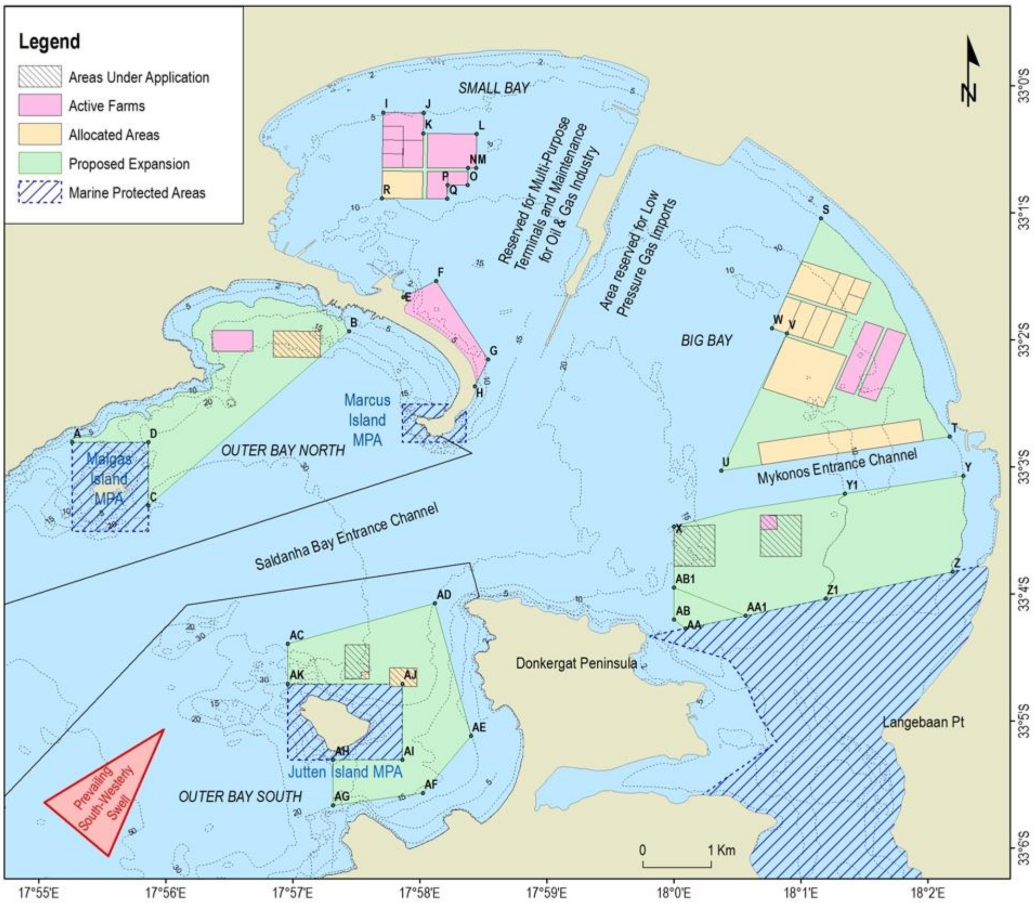


Figure 7 : Mariculture lease holders in Saldanha Bay in 2015 (Source: Heinecken *et al*. 2016).

[5] Refer also to the Project definition which provides more details on aquaculture aspects
[6] Refer also to the Figure 1 in the Project Definition after Heinecken *et al*. 2016

Table 5 : Current Aquaculture lease holders in Saldanha Bay (excluding fish).

Lease Holder	Mussels	Oysters	Abalone	Scallops	Redbait	Seaweed	Lease Area (ha)
Blue Ocean Mussel	X						50.9 (SB)
Blue Sapphire Pearls cc	x	X	x			x	5 (SB) 10 (BB)
Imbaza Mussels (Pty) Ltd	X						30 (SB)
Saldanha Bay Oyster Company	x	X		x			25 (BB)
West Coast Aquaculture (Pty) Ltd	X	X			x		15 (SB)
West Coast Oyster Growers	X	X					15 (SB) 15 (BB)
West Coast Seaweed (Pty) Ltd	x	X					10 (SB)
African Olive Trading232 (Pty) Ltd	X						30 (SB)
Aqua Foods SA (Pty) Ltd	X	X					10 (SB) 20 (BB)
Salamar Trading		X					15
Xisibe	X						15
Oyster Catcher		X					60
Chapmans Mussels	X						15
Requa Mussels	X						15

Note: BB and SB refer to Big Bay and Small Bay, respectively. Large crosses indicate current products of the farms, while small crosses indicate the products for which rights exist but are not currently farmed (Source: Clark *et al*. 2015 and Operation Phakisa info provided).

ii) Oyster Farming

Saldanha Bay Oyster Company farmed the Pacific oyster *Crassostrea gigas* in a completely enclosed tidal dam (reclamation dam) situated in the Port of Saldanha about 20 years ago. This activity has stopped due to partial reclamation of this dam as part of the Phase 1B expansion of the Sishen-Saldanha Iron Ore Export Corridor. Transnet proposes that the remainder of the dam be reclaimed as part of the proposed Phase 2 expansion of the Sishen-Saldanha Iron Ore Export Corridor. There are, however, currently a number of existing and proposed new oyster farming ventures in TNPA lease areas in both Small Bay and Big Bay.

A recent study by Olivier *et al*. (2013) estimated that the oyster and mussel sector in Saldanha Bay has the potential to increase more than 10-fold. Subsequent assessments of the carrying capacity of the Bay in terms of new production advected into the bay from the adjacent shelf area, while factoring in existing oyster and mussel cultivation, confirmed that there was considerable scope for expanding bivalve farming above present levels with minimal threat to the integrity of the ecosystem in the bay (Probyn *et al*. 2015).

iii) Seaweed Harvesting

The agarophyte *Gracilaria gracilis* was previously harvested commercially in Saldanha Bay by Taurus Saldanha Seaweed (Pty) Ltd and trialed for aquaculture by West Coast Seaweeds (Pty) Ltd. No harvesting of gracilarioids in natural beds is permitted, but beach-cast seaweed was collected and dried, before being exported primarily for agar processing. Annual yields, however, varied enormously and the resource has collapsed and recovered twice over the past few decades (Anderson *et al*. 1996a), but has always been vastly reduced at ~300 tons per annum compared to the ~1,000 tons per annum yields prior to the partition of Saldanha Bay into Small and Big Bays by the iron ore quay and the construction of the Marcus Island causeway (Rothman *et al*. 2009).

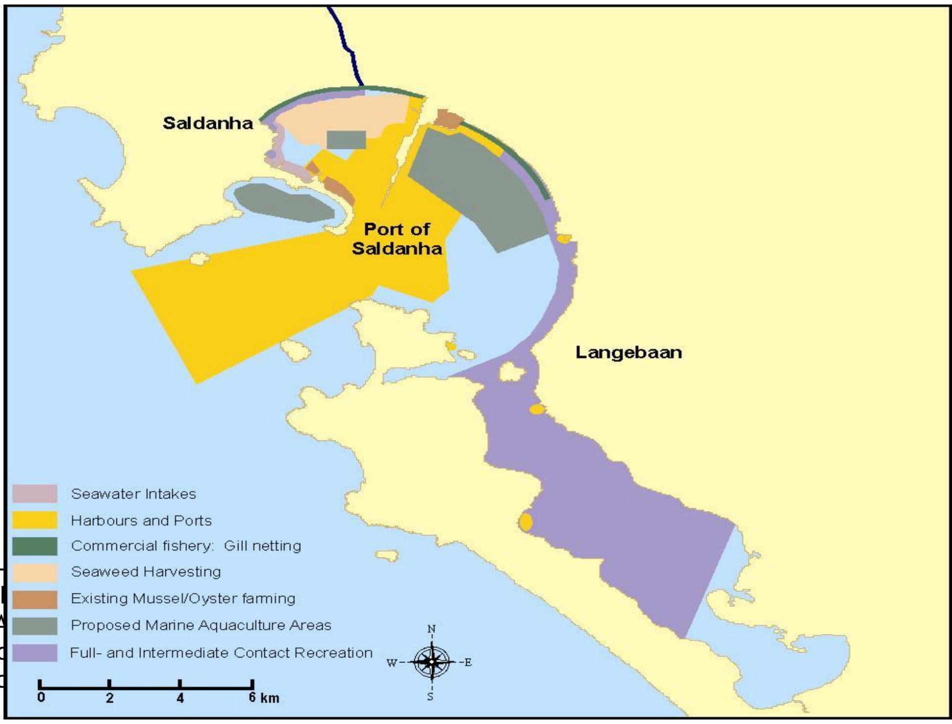
Experimental cultivation of *Gracilaria gracilis* in Small Bay using suspended 'rafts' of rope and netting lines has proven to be technically and economically feasible (Anderson *et al*. 1996b). However, the surface water in the bay often becomes warm and oligotrophic, leading to poor growth or death of *Gracilaria* grown in these experimental suspended systems (Anderson *et al*. 1999), and so far there is no commercial aquaculture of the algae in South Africa (Rothman *et al*. 2009).

iv) Fin Fish

Offshore finfish cage culture, largely focusing on the farming of salmonid species (including Atlantic salmon (*Salmo salar*), Coho salmon (*Oncorhynchus kisutch*), King salmon (*O. tshawytscha*) and rainbow trout (*O. mykiss*), is currently being pioneered in Saldanha Bay. However, it was found that Small Bay was not suitable for Atlantic salmon (although more exposed areas like Outer Bay may be more suitable in the future - see proposed ADZ in the Project Definition - Heinecken *et al*. 2016) due to the susceptibility of this species to amoebic gill disease, which combined with frequent low dissolved oxygen events lead to high mortality rates.

v) Commercial and Recreational Fisheries

The commercial fishery in Saldanha Bay consists mainly of line fishing from small boats and gill netting (Figure 8). Gill-netting is conducted from small ski boats close to or within the surf-zone, primarily at night (S. Lamberth, DAFF, pers. comm.). In 2007, there were 15 gill-net permit holders[7], of which ten operate in Langebaan Lagoon and five in Saldanha Bay (MCM 2007). Those from Saldanha Bay operate both in Small Bay and Big Bay, but the permit conditions allow some of the Langebaan Lagoon permit holders to also operate up to the Iron Ore Jetty in Big Bay (MCM 2006). Gill-net permit holders target harders (Mugilidae) and in 1998 - 1999 landed an estimated 590 tons annually, valued at approximately R 1.8 million (Hutchings & Lamberth 2002). There is one beach-seine netting right available for Saldanha Bay, but at present this right has not been taken up (MCM 2007)[8]. Species such as white stumpnose, white steenbras, kob, elf, steentjie, yellowtail and smoothhound shark support the commercial line fisheries, and also a large shore angling and recreational boat fishery, which contributes to the tourism appeal and regional economy of Saldanha Bay and Langebaan (Atkinson *et al*. 2006).



[7] Subject to c

[8] Currently DA ... f these rights is for nearsho ... acted by the proposed pre

Figure 8 : Designated beneficial use areas in Saldanha Bay (adapted from Taljaard & Monteiro 2002).

3.3.7 Existing Environmental Impacts

Existing activities that potentially have a negative impact on the quality of the marine environment in the Saldanha Bay system have been described in detail by Taljaard & Monteiro (2002). An overview of these activities and sources are provided in Figure 9 and described briefly below.

Discharges from seafood processing industries[9]

There are numerous seafood processing industries situated in Saldanha Bay, primarily in Pepper and Saldanha Bay commercial fishery and processing areas. These include commercial fishing companies (Sea Harvest Corporation Ltd), SA Lobster Exporters (Marine Products) and Live Fish Tanks (West Coast) (Lusitania), as well as more recently sea-based aquaculture support infrastructure adjacent to the commercial fishing harbour (see Clark *et al.* 2015).

Seafood industries discharge land-derived wastewater into Small Bay. The main pollutants in these effluents are:

- Inorganic nitrogen;
- Organic nitrogen and carbon;
- Suspended solids; and
- Microbiological contaminants.

This nitrogen-rich discharge, particularly that from the fish processing factory, has measurable effects on benthic macrofauna (Christie & Moldan 1977), and caused an outbreak of the opportunistic green alga *Ulva lactuca*, which reduced the benthic *Gracilaria* stocks in 1993/94 (Anderson *et al.* 1996; Monteiro *et al.* 1997). The fish waste also provides a significant source of nitrogen for seaweed cultivated throughout the northern area of Small Bay, particularly when the water is highly stratified in summer (Anderson *et al.* 1999). Elevated nutrient levels would also be expected to increase phytoplankton production.

Sewage

In the Saldanha Bay and Langebaan area, sewage can enter the marine environment via the following routes:

a. Sewage effluent from a sewage treatment works (effluent from the Saldanha Bay sewage treatment works is into the Bok River, from where it drains into Saldanha Bay opposite the Blouwaterbaai Resort);
b. Overflow from sewage pump stations (usually the result of pump malfunction or power failures); and
c. Seepage or overflow from septic or conservancy tanks, respectively.

[9] See also Heinecken *et al.* (2016) Project definition report

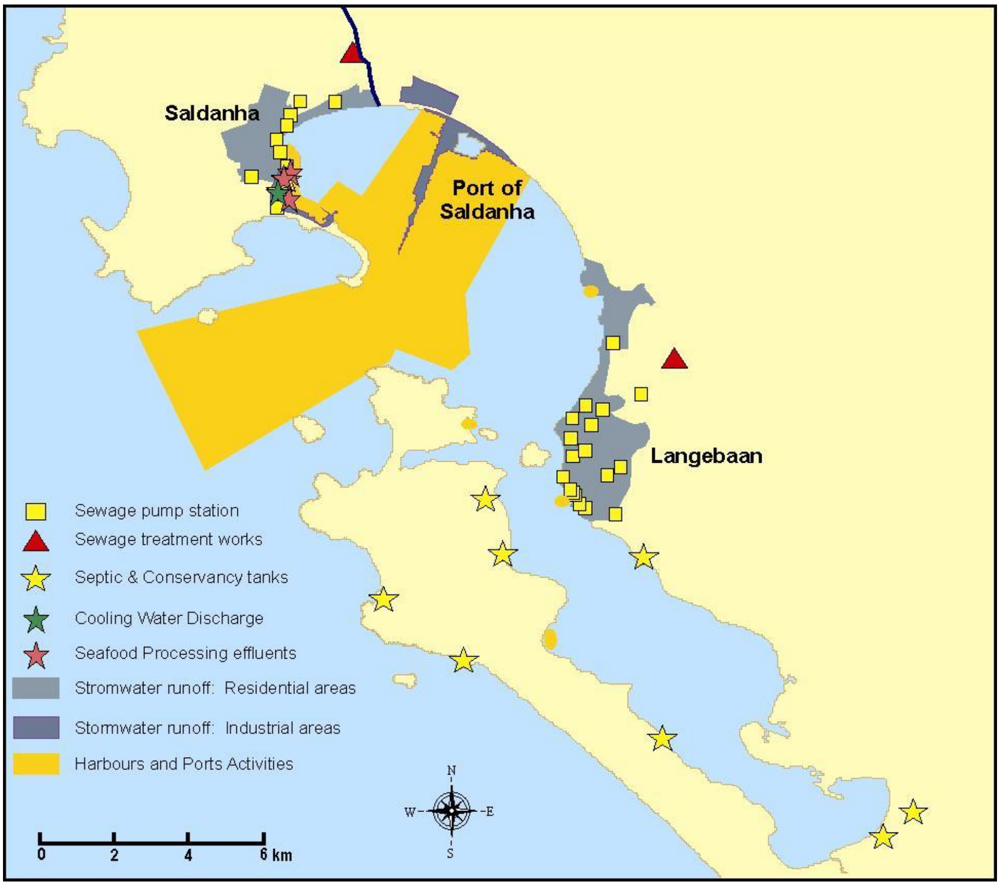


Figure 9 : Existing activities potentially impacting negatively on the marine environment in Saldanha Bay (adapted from Taljaard & Monteiro 2002).

Storm water runoff

Storm water runoff enters the Bay via multiple storm water drains and tarred surfaces. Although difficult to characterise due to the widely varying contaminant concentrations, it is one of the major non-point sources of pollution in the Bay. Typically, storm water contains contaminants such as metals, bacteria, fertilizers (nutrients), hydrocarbons, plastics, pesticides and solvents. As a result of increased industrial and residential developments in the Saldanha – Langebaan area, volumes of storm water runoff have increased and are thought to be directly associated with degradation of aquatic environments. Studies have indicated that the concentrations of several contaminants (nitrate, ammonia, metals and faecal coliforms) in Saldanha Bay storm water runoff are well above accepted guideline limits. More coordinated storm water management is now underway in Langebaan, and a Stormwater Management Master Plan is currently being drafted and may contribute to addressing some of these concerns.

Port activities and associated ship traffic

Activities associated with shipping traffic and the Port of Saldanha that can potentially impact on marine water and sediment quality in the area include:

- Ore dust fallout during ship loading operations;
- Oil spillages;
- Dredging operations and port expansion ; and
- Ballast water discharge.

Activities associated with smaller harbours

There are numerous smaller harbour areas in and around Saldanha Bay and Langebaan Lagoon:

- Small craft harbours (also under the jurisdiction of the TNPA);
- Fishing harbours;
- Military harbour (SAS Saldanha);
- Yacht clubs of Saldanha Bay and Langebaan, and at Club Mykonos.

Activities and operations in harbours that could contribute to the deterioration of marine water quality include:

- Cleaning of vessels in harbour areas, as well as emptying of water closets and toilets into harbour areas;
- Dumping of blood water from fishing vessels into sheltered harbour areas;
- Off-cuts and offal from fish cleaning operations being washed down into storm water drains and eventually ending up in the harbour; and
- Poor waste disposal practices in the scraping and cleaning of vessels (maintenance). Anti-fouling paints are of particular concern, as these often contain significant levels of tributyl-tin, a toxin that can result in the shell deformation in shellfish.

Aquaculture

In this section we refer only broadly to the current aquaculture operations in Saldanha Bay and to their potential impacts. In Section 4, the impacts are dealt with specifically in the context of the ADZ and the potential expansion of aquaculture operations in Saldanha Bay. Note also that the risk assessments and guidelines associated with the culture and introduction of certain alien species has been largely covered in the aquaculture guidelines provided by the Department of Environment Affairs[10] and the biological risks through NEMBA[11] (National Environmental Management: Biodiversity Act 2004 (ACT NO, 10 OF 2004), Alien and Invasive Species Lists, 2014, Government Gazette Vol. 599 Department of Environmental Affairs, 1 August 2014).

Mussel farming in Saldanha Bay currently employs primarily raft production systems comprising dropper ropes suspended in the water column from the rafts. This will in future, however, be eclipsed by longline production systems. Oysters are cultured in baskets or multi-level oyster net-stacks suspended beneath the rafts. Dropper ropes and oyster baskets/net staks are lifted onboard these rafts, where the product is retained, ropes and baskets are cleaned and unwanted material (fouling materials etc.) is discarded to the sea. Raft and longline farming techniques can affect marine sediment and water quality by reducing turbulence in the benthic boundary layer, and through high sedimentation rates of faeces, pseudo-faeces, fallen mussels and foulers onto the seabed under the farm. Mussel debris under rafts can accumulate to a depth of 20 cm, creating organic enrichment and anoxia in sediments. Benthic macrofaunal communities under the rafts were found to be disturbed, displaying a reduction in biomass and an alteration of trophic groups and taxa (Stenton-Dozey *et al*. 1999, 2001).

[10] DEA 2013, Government Gazette No. 36145 11 February 2013 Environmental Impact Assessment Guideline for Aquaculture in South Africa. Compiled by E. Hinrichsen

[11] National Environmental Management: Biodiversity Act 2004 (ACT NO, 10 OF 2004), Alien and Invasive Species Lists, 2014, Government Gazette Vol. 599 Department of Environmental Affairs, 1 August 2014.

Harmful algal blooms

Harmful (toxic) blooms have become a regular seasonal occurrence in the bay since 1994, however, these are transported into the system with exchanges of surface water with the adjacent continental shelf and have not yet been observed to develop in the Saldanha Bay – Langebaan Lagoon system. These blooms pose a risk to both the sensitive ecosystems in the area as well as to beneficial uses, such as aquaculture operations, and recreation and tourism.

Littering

Littering, particularly plastics, has become a major problem associated with urban development, not only in terms of unpleasant aesthetics, but also in terms of the physical harm caused to marine life. Towards improving the quality of South African beaches the Department of Environmental Affairs initiated their Coastcare Programme, involving local communities. The Saldanha Municipality acts as implementing agent for the Coastcare Programme in their region.

Desalination Plants

Other recent developments implemented in and around Saldanha Bay include the TNPA 2 400 m^3/day reverse-osmosis desalination plant constructed at the Iron Ore Terminal in Big Bay, which has been operational since August 2012. Effluents from a further desalination plant proposed by the West Coast District Municipality, and the proposed Frontier Saldanha Utilities (Pty) Ltd regional marine outfall, would be discharged into Danger Bay.

4. IMPACT IDENTIFICATION AND ASSESSMENT

4.1 Identification of Key Issues and Sources of Potential Impact

There is a vast source of literature available on the potential impacts to the marine environment from shellfish, finfish and seaweed aquaculture. The potential impacts identified below are generic, as the nature and intensity of the effects will vary depending on the species being farmed, the location of the farms/precincts, as well as the individual farming practices. Focus is primarily on suspended bivalve cultivation (rafts and long-lines), with cage farming of marine finfish and seaweed cultivation being more briefly covered.

The impacts assessed below relate to the full extent of the proposed ADZ (Figure 1) relative to the total extent of Saldanha Bay, and assume the total potential annual (ungraded) production of ~27 600 tpa for shellfish, as estimated by Heinecken *et al*. (2016), with an additional 40 tons per ha for finfish in those areas identified as suitable for cage culture.

Two alternatives are being considered for the five proposed precincts as part of the ADZ:

Alternative 1	Alternative 2
Five ADZ precincts in Saldanha Bay: Outer Bay - North *(identical for both alternatives)*: This precinct extends from the Marcus Island causeway to the Malgas Island Marine Protected Area (MPA) and from the 10 m depth contour to the 30 m depth contour north of the Port entrance channel	Five ADZ precincts in Saldanha Bay: Outer Bay - North *(identical for both alternatives)*
Outer Bay – South *(identical for both alternatives)*: This precinct extends from the Donkergat Peninsula to the Jutten Island MPA and from the 10 m depth contour towards the Port entrance channel	Outer Bay – South *(identical for both alternatives)*
Big Bay – North *(identical for both alternatives)*: This precinct extends from the 5m contour towards the Port jetty up to the proposed Port of Saldanha LNG and LPG developments, and south to the Mykonos harbour entrance channel	Big Bay – North *(identical for both alternatives)*
Big Bay – South *(this precinct is larger extending to the 5 m contour)*: This precinct extends from the Mykonos harbour entrance channel towards the Langebaan Lagoon MPA, and from the 5 m depth contour towards the Donkergat Peninsula	Big Bay – South *(this precinct is smaller extending to the 10 m contour)*: This precinct extends from the Mykonos harbour entrance channel towards the Langebaan Lagoon MPA, and from the 10 m depth contour towards the Donkergat Peninsula
Small Bay *(identical for both alternatives)*: This precinct encompasses the existing aquaculture allocations in Small Bay	Small Bay *(identical for both alternatives)*

By definition of the ratings, the extent of the impact will in most cases be 'local' (i.e. confined to project or study area of part thereof) regardless of whether an individual farm/precinct or the entire ADZ is considered. Similary, the extent of the impact would not differ between Alternative 1 and Alternative 2. Consequently, from a marine ecological perspective, there would be no difference in the overall significance rating between the two alternatives.

4.1.1 Construction impacts

- Crushing of biota in sediments during placement of anchor blocks

4.1.2 Effects on the seabed (operations)

- Biodeposition of faeces, pseudofaeces and detritus
- Changes to physico-chemical properties of the sediments
- Changes to biological properties of the sediments
- Modification of benthic habitat through accumulation of live and dead shells on the seabed
- Shading from farm structures and crop

4.1.2 Effects on the water column (operations)

- Effects of farm structures on currents and waves
- Effects on seawater nutrient chemistry and clarity
- Depletion of food sources, especially phytoplankton, for other organisms
- Alteration of plankton community structure
- Harmful algal blooms

4.1.4 Wider ecological effects (operations)

- Habitat creation by farm structures
- Effects on fish (and ichthyoplankton)
- Effects on seabirds
- Effects on marine mammals: seals, dolphins and whales
- Biosecurity risks relating to the spread of diseases, parasites and biofouling pests
- Genetic interactions with wild populations, and effects of escapees (fish culture)
- Effects of therapeutants and trace contaminants (fish culture)

4.1.5 Effects on other users (operations)

- Pulse disturbances during harvest practices
- Conflict with other users
- Landscape considerations

The potential ecological effects from suspended bivalve cultivation (rafts and long-lines) and from marine finfish farming are summarised in Figures 10 and 11, respectively, and discussed in more detail in the assessments below. The literature available on shellfish, finfish and seaweed culture is considerable, and the objective of this report was not to provide an extensive review. The relevant descriptions provided below are thus drawn largely from Landry *et al*. (2006), Forrest *et al*. (2007), Keeley *et al*. (2009), McKindsey *et al*. 2011 and the very comprehensive recent review by the New Zealand Ministry for Primary Industries (MPI 2013).

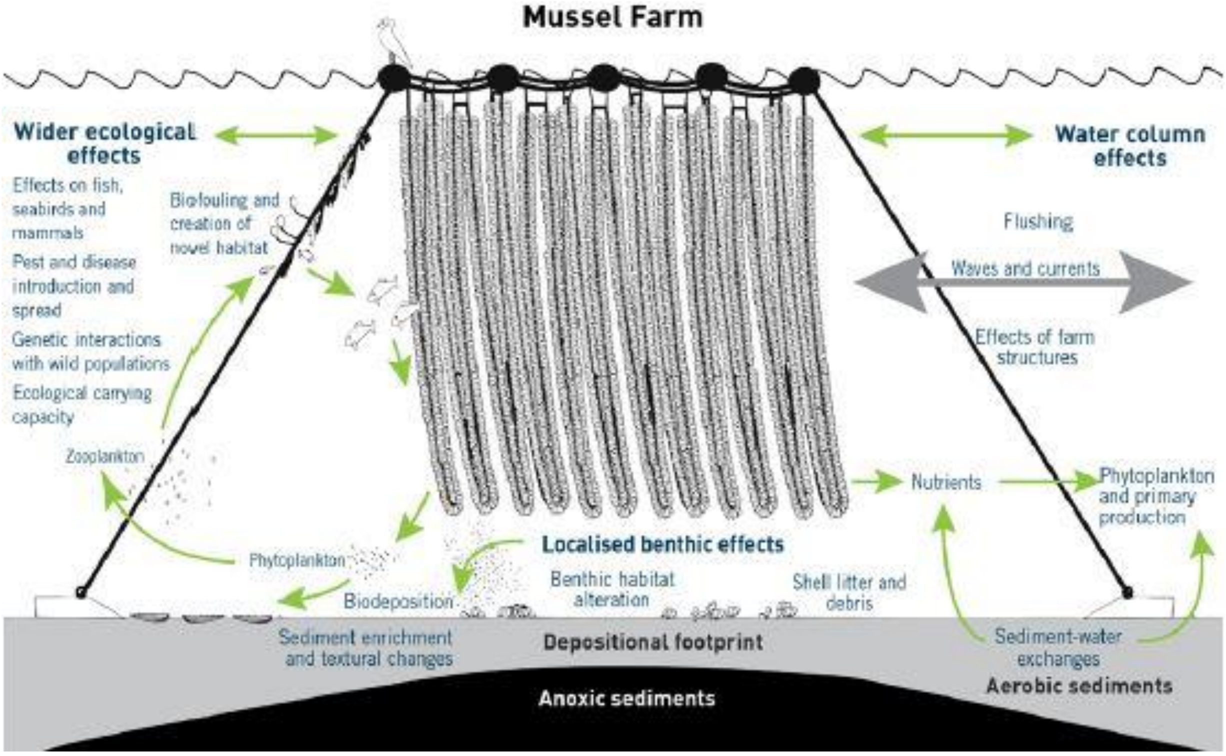


Figure 10 : Schematic of potential ecological effects from continuous long-line mussel cultivation (Keeley *et al*. 2009). This would apply also to oyster cages suspended on long-lines.

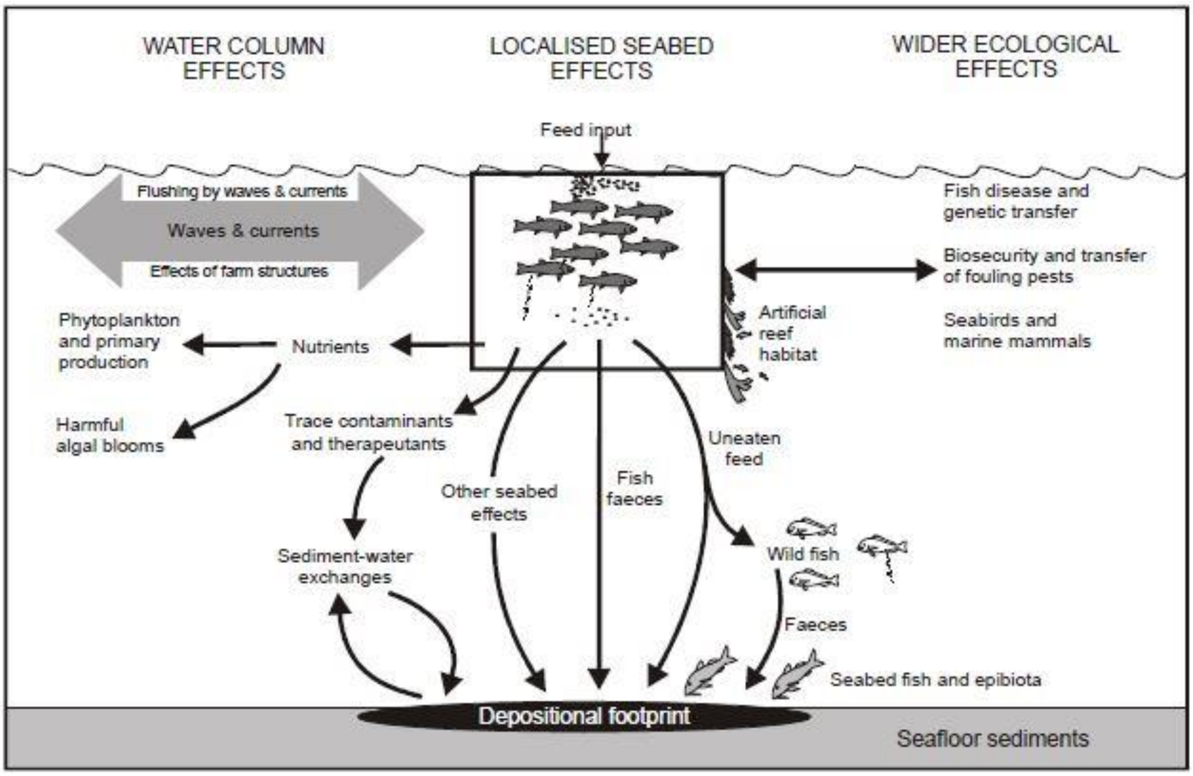


Figure 11 : Schematic of potential ecological effects from marine finfish farms (Source: Forrest *et al*. 2007).

4.2 Assessment of Construction Impacts

Impacts on the marine environment during the construction phase would be limited to those caused by the placement of fish cages on the sites and mooring infrastructure on the seabed for longlines, rafts, oyster stacks and cages. The mooring blocks, anchors, chains and ropes will result in crushing of biota directly within the footprint of anchors or mooring blocks, and the subsequent movements of mooring chains and ropes may cause further mortalities and or disturbance to benthic communities. However, the installation of anchor blocks will concurrently provide an alternative hard substrate to other mobile and sessile benthic species. The impact would, however, be highly localised and of low intensity, and is assessed as having **LOW** overall significance.

Table 6 : Impact: Benthic impacts during the construction phase

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Low 1	Long-term 3	**Low** 5	Definite	**LOW**	**- ve**	High
Essential mitigation measures: • Select sites avoiding potentially sensitive and valuable habitats such as conservation areas (Malgas Island, Jutten Island, Langebaan Lagoon MPAs), biogenic habitats (e.g. kelp beds) and reefs (e.g. Lynch Blinder, North Bay blinder) • Ensure mooring system is well designed to prevent/limit movement of anchors and chains over the sea floor • Leave mooring anchors or blocks in place when undertaking cage net maintenance or fallowing sites to avoid repetitive impacts of the same activity at each site								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Definite	**LOW**	**- ve**	High

4.3 Assessment of Direct Impacts from Shellfish Farming

4.3.1 Effects on the seabed

Seabed effects from shellfish culture (mussel long-lines or suspended oyster cages) result from the sedimentation of organic-rich, fine-grained particles (faeces and pseudo-faeces), and the deposition and accumulation of the live bivalves, shell litter and other biota attached to the ropes, floats and the mussels/oysters themselves. The main effect on the seabed results from the deposition of faeces and pseudo-faeces, which leads to enrichment of the seabed sediments beneath the farms due to the high organic content of the deposited particles, with concomitant effects on the benthic communities.

Biodeposition

Being filter feeders, mussels and oysters remove plankton (phytoplankton and zooplankton), organic detritus and inorganic particulate materials from the water column. The digestive wastes are expelled as faecal pellets, whereas inedible or excess particulate material is bound in mucous and expelled as pseudo-faeces. These biodeposits have greater sinking velocities than their constituent particles, and in combination with reduced water movements below the rafts (see later), shellfish farms are typically characterised by increase sedimentation rates under the culture sites (Hatcher *et al*. 1994; Dame 1996; Newell 2004; Callier *et al*. 2006; Giles *et al*. 2006). The degree to which biodeposits accumulate in the vicinity of a farm is a function of four factors, namely 1) the rate of biodeposit production, 2) initial dispersal, 3) the redistribution on the sediment surface *via* creep, saltation and/or resuspension, and 4) the rate of biodeposit decay (Giles 2009).

Detritus originating from fouling epibiota attached to the culture structures or the shellfish themselves also contributes to increased sedimentation (Kaiser *et al.* 1998), either where fouling organisms reach high densities on farm structures and fall to the seabed naturally or because of deliberate defouling by farm operators. Sedimentation rates beneath mussel farms are known to vary with season (Giles *et al.* 2006), culture species (Jaramillo *et al.* 1992) and environmental conditions (e.g. tidal currents, water depth, riverine inputs).

The degree to which effects of shellfish farms on the seabed manifest is dependent on the site-specific environmental characteristics (e.g. current speeds and directions, existing benthic habitat, wave climate, phytoplankton abundance), and to a lesser extent on farm management practices (e.g. stocking densities, line orientation, harvesting techniques) (Dahlbäck & Gunnarsson 1981; Mattsson & Lindén 1983; Kaspar *et al.* 1985; De Jong 1994; Chamberlain *et al.* 2001; Grange 2002; Christensen *et al.* 2003; Miron *et al.* 2005). The capacity of the environment to disperse and assimilate the biodeposition associated with shellfish farms is largely determined by water depth and current speeds, as well as seasonal variations in water temperature (Giles 2009; Weise *et al.* 2009). Increased flushing not only reduces localised sedimentation and accumulation of organic matter, but it also increases oxygen delivery to the sediments, allowing for more efficient mineralisation of organic material (Findlay & Watling 1997). Farms located in deep water in areas of strong water currents would therefore have depositional footprints that are less intense and more widely dispersed than shallow, poorly flushed sites.

The majority of environmental issues associated with biodeposition occur in systems where water exchange is restricted (Castel *et al.* 1989). Farms located in well-flushed tidal environments typically result in a favourable increase in macrofaunal biomass rather than the accumulation of pseudo-faeces (Rodhouse & Roden 1987). However, in sheltered embayments or inlet systems where currents are very weak or water depth is shallow, biodeposition would be expected to contribute to sediment hypoxia (Dame & Prins 1997; Chamberlain *et al.* 2001; Grant *et al.* 2005, 2007; Waite *et al.* 2005; Cranford *et al.* 2007). In extreme cases this may lead to the development of an overlying bacterial mat and significantly reduced infaunal biomass and diversity (Dahlbäck & Gunnarsson 1981).

Although biodepositional effects tend to be most evident directly beneath the long-line droppers, a gradient of seabed effects has been demonstrated (Hartstein & Rowden 2004), consistent with patterns of enrichment from other point source discharges (see Pearson & Rosenberg 1978). By contrast, live shellfish, shell material and associated fouling biota settle directly beneath the long-lines and are typically confined within 10 m of marine farming structures (Kaspar *et al.* 1985; Callier *et al.* 2007).

Depositional effects footprints predicting the distance and direction pseudofaeces and faeces could travel before reaching the seabed have been modelled using representative flow patterns and current speeds and an estimated particle-sinking velocity for faeces and pseudofaeces (see for example Giles & Pilditch 2004; Hartstein & Rowden 2004). Results have indicated that in small, shallow, sheltered embayments experiencing low flushing rates, the spatial extent of biodeposition typically does not extend beyond 50 m from the farm boundaries, while depositional footprints of >250 m were modelled for sites in more energetic environments or greater water depth (Hartstein & Stevens 2005; Stenton-Dozey *et al.* 2008). Although the seabed beyond the effects footprint may be exposed to farm-derived materials, the environment is expected to have the capacity to assimilate these without measurable ecological changes.

Research on the recovery rates of seabed communities from deposition-related enrichment effects of mussel and oyster farms is sparse. Recovery rates are assumed to be site specific and relatively rapid once farming ceases. However, accumulated shell material from drop-off is likely to persist in/on the sediment beyond the point of recovery from typical enrichment type effects.

Assuming that farms would be operational over the medium- to long-term, increased biodeposition from suspended shellfish culture facilities is deemed of medium intensity within the immediate vicinity of the farm, with impacts persisting for at least as long as the farm is in operation, and is consequently considered to be of MEDIUM significance without mitigation (Table 5). The implementation of mitigation would reduce the significance to LOW.

Physico-chemical changes to sediment properties

The increased sedimentation and accumulation of biodeposits on the seabed beneath shellfish farms in turn results in changes to the physico-chemical properties of sediments (Dahlbäck & Gunnarsson 1981; Mattsson & Lindén 1983; Kaspar *et al.* 1985; De Jong 1994; Chamberlain *et al.* 2001; Giles *et al.* 2006; Hargrave *et al.* 2008). These include changes in sediment texture (Tenore *et al.* 1982; Kaspar *et al.* 1985; Stenton-Dozey *et al.* 2005), local organic enrichment with an associated increase in oxygen consumption (Christensen *et al.* 2003; Giles & Pilditch 2006; Giles *et al.* 2006; Carlsson *et al.* 2009; Alonso-Pérez *et al.* 2010), increased nitrogen release rates (Hatcher *et al.* 2004), sulphate reduction (Dahlbäck & Gunnarsson 1981) and lowered REDOX potential (Tenore *et al.* 1982; Christensen *et al.* 2003; Grant *et al.* 2005; Wilding 2012). However, several other studies showed that these parameters are often not sensitive enough to detect the effect of mussel aquaculture on benthic sediments (Anderson *et al.* 2005; Miron *et al.* 2005; Callier *et al.* 2007).

Historic studies and the State of the Bay surveys have shown that current shellfish culture operations have lead to organic enrichment and anoxia in sediments under the culture rafts and ropes (Clark *et al.* 2015). Fouling discards from current raft and longline culture operations in Small Bay are estimated at ~11 tons per ha (C. Heinecken, CapMarine, pers. comm.).

Future production in the expanded ADZ will primarily be from longlines, and biofouling discards from these operations was estimated as amounting to ~12.5 tons per ha. Assuming the ADZ is expanded to 1 871 ha, with maximum production of shellfish at 25% of the PCC, this would amount to biofouling inputs to the seabed of around 23 000 tons annually[12]. Whereas some of this would be consumed by predators and scavengers attracted to the shellfish farms, there is an increased risk of the development of more extensive areas of hypoxia or anoxia in the bay sediments as a result of the increased discards, especially in areas of reduced flushing. Other likely effects of these discards are changes in shearstress at the seabed, with concommitant effects on flushing rates, biological changes in response to physico-chemical changes in the sediments and habitat modification.

Physico-chemical changes to sediment properties from suspended shellfish culture facilities are closely linked to the biodepositional environment on the farms, and is deemed of medium intensity within the immediate vicinity of the farm. Impacts would persist for at least as long as the farm is in operation (medium- to long-term) and is considered to be of MEDIUM significance without mitigation (Table 6). The implementation of mitigation would reduce the significance to LOW. Recovery of the sediment properties following removal of the farms are assumed to be site specific and relatively rapid once farming ceases.

[12] 12.5 tons per ha x 1 871 ha = 23 387.5 tons

Table 7 : Impact: Effects of suspended shellfish culture on biodeposition and associated physico-chemical changes to sediment properties

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Medium 2	Long-term 3	**Medium** 6	Definite	**MEDIUM**	**- ve**	High
Essential mitigation measures: • Select sites favouring well-flushed, deep and productive areas (Big Bay North, Outer Bay North, Outer Bay South) and avoiding potentially sensitive and valuable habitats such as conservation areas (Malgas Island, Jutten Island, Langebaan Lagoon MPAs), biogenic habitats (e.g. kelp beds) and reefs (e.g. Lynch Blinder, North Bay blinder). (Note: raft density within each farm, production levels per farm or the number of precincts within the agreed ADZ will also influence the level of mitigation deemed appropriate) • Avoid high density culture (overcrowding)[13] • Implement recommended monitoring of biodeposition and physico-chemical changes in seabed properties at farming sites relative to undisturbed control sites (as per recommended EMP in Appendix II) and compile annual monitoring reports.								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Definite	**LOW**	**- ve**	High

Biological changes

Accumulation of organic matter and associated changes in physico-chemical properties can create suboptimal conditions within the sediment matrix that can result in changes in the abundance and diversity of benthic micro- and macrobiota (Danovaro *et al.* 2004 and references therein). Increased sedimentation beneath mussel farms has been reported to reduce production of microscopic plants (Christensen *et al.* 2003; Giles *et al.* 2006), with concomitant effects on denitrification rates and oxygen conditions in the sediments and overlying water. Similarly, reported significant changes in microbial (Dahlbäck & Gunnarsson 1981; Mirto *et al.* 2000) and meiofaunal (Castel *et al.* 1989; Mirto *et al.* 2000) community composition in response to elevated organic content beneath shellfish farms may occur.

However, macrofauna living within the sediment matrix are the most widely used indicator of sediment enrichment effects. Organically enriched sediments typically exhibit increased macrofaunal abundance, decreased species richness and biomass, and a shift in community structure to favour species more tolerant of low oxygen levels (Tenore *et al.* 1982). Typically, the large-bodied macrofauna (e.g. heart urchins, brittle stars, large bivalves) is displaced by short-lived disturbance-tolerant 'opportunistic' species (Tenore *et al.* 1982; Mattsson & Lindén 1983; Kaspar *et al.* 1985; Christensen *et al.* 2003). The loss of large-bodied burrowing taxa can have potential knock-on effects to sediment health due to a reduction in bioturbation and the associated irrigation of deeper sediments (Christensen *et al.* 2003). Other studies, however, indicated that although changes in community structure were evident, these were not significant (Crawford *et al.* 2003; Stenton-Dozey *et al.* 2004, 2005), and were highly localised and variable among sites, and dependent on environmental conditions such as depth and average current velocity (Hartstein & Rowden 2004; Hartstein & Stevens 2005). Studies on the displacement or destruction of epibiota beneath and immediately adjacent to mussel farms are lacking.

[13] The recommended density is one raft of 800 droppers per ha; 11 longlines of 832 droppers per ha; 11 longlines of 176 oyster stacks/abalone barrels per ha (Heinecken *et al.* 2016).

The significance of ecological effects from shellfish farms will ultimately be related to site-specific values, such as the presence of species or habitats that are sensitive to deposition or of high conservation value.

As with the physico-chemical properties, changes in biological communities associated with the sediments below suspended shellfish culture facilities are closely linked to the biodepositional environment. Impacts are deemed of medium intensity within the immediate vicinity of each farm, persisting for at least as long as the farm is in operation (medium- to long-term) and for a few years beyond, and are thus considered to be of **MEDIUM** significance without mitigation (Table 7). The implementation of mitigation would reduce the significance to **LOW**. Recovery of the sediment properties following removal of the farms are assumed to be site specific and relatively rapid once farming ceases.

Table 8 : Impact: Changes in biological communities in response to changes in sediment properties

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Medium 2	Long-term 3	**Medium** 6	Probable	**MEDIUM**	**- ve**	High
Essential mitigation measures: • Select sites favouring well-flushed, deep and productive areas (Big Bay North, Outer Bay North, Outer Bay South) and avoiding potentially sensitive and valuable habitats such as conservation areas (Malgas Island, Jutten Island, Langebaan Lagoon MPAs), biogenic habitats (e.g. kelp beds) and reefs (e.g. Lynch Blinder, North Bay blinder). (Note: raft density within each farm, production levels per farm or the number of precincts within the agreed ADZ will also influence the level of mitigation deemed appropriate) • Avoid high density culture (overcrowding) • Implement monitoring of infaunal and epifaunal macrobenthic communities at farming sites relative to undisturbed control sites (as per recommended EMP in Appendix II)								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Probable	**LOW**	**- ve**	High

Habitat modification

The most visually conspicuous effect to the seabed from shellfish farming is the modification of the benthic habitat through 1) addition of physical structure (anchor blocks) on the seabed, and 2) the accumulation of live and dead shell material on the seafloor beneath the suspended culture structures.

The installation of anchor blocks will directly alter benthic communities under the blocks through crushing, but will concurrently provide an alternative hard substrate to other mobile and sessile benthic species. Although information on the importance of physical structure associated with suspended bivalve aquaculture on the seafloor is lacking, there is considerable information on the importance of structures used as artificial reefs to enhance specific areas for fisheries species (Jensen *et al*. 2000; Seaman 2000; Brickhill *et al*. 2005). While the provision of food from the fall-off of mussels from culture structures is the most likely cause of the increased abundance of epibenthic macrofauna associated with farms, McKindsey *et al*. (2011) demonstrated that an increase in the abundance of lobsters at a site in eastern Canada was due to the presence of anchor blocks and not to mussel fall-off. Bottom structures also provide surface area[14] for the settlement of sessile organisms not normally found on soft sediment bottoms. Diverse fouling communities may thus develop on these structures (Carbines 1993), thereby increasing the biomass (Ricciardi & Bourget 1999) and productivity (Cusson and Bourget 2005; Cowles *et al*. 2009) of the culture site.

[14] Longlines deployed in Big Bay use three five-ton mooring blocks for every 400 m of surface longline, with a footprint of approximately 8m^2.

The shell material that typically accumulates beneath suspended shellfish culture facilities is produced primarily during harvesting and farm maintenance (Davidson 1998; Davidson & Brown 1999). Leonard (2004), however, demonstrated that an average of 130 g/m of live mussels fell daily to the seabed under mussel lines in eastern Canada. The distribution of fallen mussels ranges from patchy to widespread coverage across the farm site (Forrest & Barter 1999), covering as much as 55% of the seabed at farm sites (Inglis & Gust 2003). In Saldanha Bay, this coverage may at times be exceeded as mussel biomass sloughs off the ropes if they are not harvested timeously, as happens when farms are closed due to red tide toxins following a HAB event (C. Heinecken, CapMarine, pers. comm.). As with the anchor blocks, mussel/oyster clumps and shell litter can potentially serve as a substrate for the formation of reef-type communities (Iglesias 1981; Kaspar *et al.* 1985; De Jong 1994; Freire & González-Gurriarán 1995; Davidson & Brown 1999) and an increase in predators and scavengers such as starfish, crabs and fish (Kaspar *et al.* 1985; Grant *et al.* 1995; McKindsey *et al.* 2011 and references therein), thereby indirectly increasing local benthic diversity and productivity. In other situations, however, mussel clumps and shell litter can remain relatively barren of reef-type communities (Watson 1996).

Alteration of the habitat below suspended culture farms is closely linked to the biodepositional environment on the farms and is deemed of medium intensity within the immediate vicinity of the farm. Impacts would persist for at least as long as the farm is in operation (medium- to long-term) and are considered to be of **MEDIUM** significance without mitigation. Recovery of the habitat would depend on the magnitude of the initial impact, with 'reefs' forming in response to heavy drop-off potentially persisting for some years after removal of the farms. Unless the build-up of material is actively removed, the implementation of mitigation would not be effective in reducing the significance.

Table 9 : Impact: Modification of seabed habitat at suspended shellfish cultivation sites

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Medium 2	Long-term 3	**Medium** 6	Definite	**MEDIUM**	**- ve**	High
Essential mitigation measures: • Select sites avoiding potentially sensitive and valuable habitats such as conservation areas (Malgas Island, Jutten Island, Langebaan Lagoon MPAs), biogenic habitats (e.g. kelp beds) and reefs (e.g. Lynch Blinder, North Bay blinder) • Avoid high density culture (overcrowding) • Implement recommended monitoring of macrobenthic communities at farming sites relative to undisturbed control sites (as per recommended EMP in Appendix II)								
With mitigation	Local 1	Medium 2	Long-term 3	**Medium** **6**	Definite	**MEDIUM**	**- ve**	High

Shading

Direct effects on the seabed from shellfish farms could, under certain conditions, arise through shading from farm structures. This could reduce the amount of light reaching the seafloor, with implications for the growth, productivity, survival and depth distribution of ecologically important primary producers such as benthic microalgae, macroalgae or seagrasses, and a range of associated ecological effects (Everett *et al.* 1995; Crawford 2003; Huxham *et al.* 2006). In a study by Lo *et al.* (2008), it was concluded that the direct provision of physical structure and shading by aquaculture structures best explained an outbreak of jellyfish in Taiwan. The relative importance of shading versus other sources of seabed impact has not been conclusively established, but is conceivable in areas where farms are placed across algal habitats in environments of relatively high water clarity, and in well-flushed systems where the ecological effects from sedimentation and biodeposition are minimal. Shading effects on seagrasses and macroalgae can effectively be mitigated through proper farm placement. It should be noted, however, that water clarity (turbidity) in Saldanha Bay is generally poor, thereby reducing the significance of shading below structures in the proposed precincts of the ADZ.

Shading effects are therefore considered to be of **LOW** significance. No mitigation options are possible without the removal of the structures causing the shading. The impacts of shading are deemed of low intensity, persisting for as long as the farm is in operation. Recovery of any effects following farm removal will be rapid. Impacts are thus considered to be of **LOW** significance both without and with mitigation.

Table 10 : Impact: Shading of the seabed under suspended shellfish cultivation facilities

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Low 1	Long-term 3	**LOW** 5	Definite	**LOW**	**- ve**	High
Essential mitigation measures: • Select sites avoiding potentially sensitive and valuable habitats such as conservation areas (Malgas Island, Jutten Island, Langebaan Lagoon MPAs), biogenic habitats (e.g. kelp beds) and reefs (e.g. Lynch Blinder, North Bay blinder) **Best Management Practices:** • Avoid overcrowding of mussel droppers, oyster stacks and other structures associated with the culture method								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Definite	**LOW**	**- ve**	High

4.3.2 Effects on the water column

The water column is a highly dynamic environment that varies markedly in space and time due to complex hydrodynamics and the chemical and biological processes that occur within. This complexity is further compounded by the way that the physiological processes of filter-feeding bivalves interact with the surrounding water. Therefore, not only can the physical presence of the farming structures influence the current and wave regime in an area, but the composition of water passing through a mussel farm can be altered in a variety of ways, both in terms of the amount and composition of particulate matter as well as dissolved nutrients.

Effects of farm structures on currents and waves

Tide and wind-generated currents play an important role in the transport and delivery of seston and dissolved nutrients and gases into and the flushing of wastes and associated nutrients out of the marine system. Currents also influence seabed habitats and their associated communities through sediment deposition and movement and shell litter deposition, and the flux of nutrients between the benthos and the overlying water column. If currents are not above a critical threshold to allow resuspension of seabed sediments and detrital material from shellfish farming, this typically leads to accumulation of organic wastes and localised enrichment.

Being anchored submarine structures, shellfish farms generate drag forces in their interaction with currents. The extent to which currents are modified depends on the extent to which the structures create drag and attenuate currents (Boyd & Heasman 1998; Grant & Bacher 2001; Plew *et al*. 2005; Morrisey *et al*. 2006b; Grant *et al*. 2008; Stevens *et al*. 2008; Delaux *et al*. 2011; Newell & Richardson 2014). The size, aspect ratio and orientation of suspended culture systems, spacing of ropes, rope diameter, stock biomass and presence of predator nets all contribute to the degree to which water flow through the farm is affected. The two main approaches to assessing the effects of farm structures are: (i) measuring and comparing the differences in currents within and outside of existing farms (Boyd & Heasman 1998; Plew 2005), and (ii) estimating macro-scale changes using hydrodynamic modelling techniques (Grant & Bacher 2001; Stevens *et al.* 2008; see reviews in Giles 2009; Weise *et al.* 2009).

Studies have shown that suspended mussel culture infrastructure may alter hydrodynamics and reduce flow rates at the farm level, in both raft (Pérez Camacho & Beiras 1995; Blanco *et al.* 1996; Boyd and Heasman 1998; Riethmüller *et al.* 2006a, 2006b; Herman 2007; Duarte *et al.* 2008; Petersen *et al.* 2008) and long line (Gibbs *et al.* 1991; Plew *et al.* 2005; Strohmeier *et al.* 2005; Strohmeier *et al.* 2008;) systems. Furthermore, dropper line diameter (Plew *et al.* 2005) and dropper line and larger-scale spacing (i.e. long-line and raft), as well as farm size and configuration may influence current velocities (Boyd & Heasman 1998; Smith *et al.* 2006; Aure *et al.* 2007; Duarte *et al.* 2008; Stevens *et al.* 2008). Boyd & Heasman (1998) demonstrated that decreases in current speeds within mussel rafts in Saldanha Bay were as little as 10% of the ambient flow, with increased rope density (i.e. decreased porosity) leading to decreased current velocities. Raft designs have, however, changed since this study was undertaken, now being longer and thinner, thereby reducing dead spaces in the centre of the raft. In contrast, Plew *et al.* (2005), found a 38% decrease in current speed at a long-line mussel farm in New Zealand and a reorientation of water flow parallel to the alignment of the mussel lines at peak velocities.

At the "bay" scale, Makita & Saeki (2004) demonstrated that although oyster long-lines increase retention time within farm sites, inflow and outflow volumes in the area as a whole were not affected. However, the long-lines did influence the relative exchange rates of different areas within an embayment, creating areas that were better flushed than others. In contrast, Lo *et al.* (2008) suggest that flushing times for an entire bay in Taiwan were greatly altered by the presence of suspended oyster culture and fish culture, such that flushing rates increased from 3-7 days when structures were absent to 5-13 days when culture structures were present. Similarly, reduction in current speeds of up to 54% were suggested by hydrodynamic models inside an intensively farmed open embayment in China, and a 20% reduction within adjacent navigation channels (Grant & Bacher 2001; Morrisey *et al.* 2006b), with concomitant reduced flushing rates in the bay.

Increased retention and reduced flow rates would modify deposition regimes not only within farms but potentially at bay-scales, as the effects of farm drag are cumulative (Plew 2011) and may thus influence communities on the seafloor over a wider area. While alteration of the wave climate shoreward of farms could theoretically affect ecologically important intertidal and shallow subtidal habitats (see for example Davidson & Richards 2005), seabed communities may also be affected as shell deposits due to fall-off may slow flow across the sediments, increasing sedimentation rates (de Jong 1994; Lloyd 2003). Anchor blocks may have similar effects, although their presence may also produce localized scouring and alter bottom sediments (Cusson & Bourget 1997; Guichard *et al.* 2001). Ecosystem function may thus be significantly affected by changes to coastal currents and waves, as aquaculture developments increase beyond critical levels (Grant & Bacher 2001).

Modelling of tidal currents in other parts of the world suggests that despite the comparatively less intensive approach to shellfish farming in South Africa, the suspended culture farms in Saldanha Bay could still have effects on current speeds that might extend over the whole bay, or beyond. At the present ungraded production volume in Saldanha Bay (3 625 tpa) the densities of rafts and longlines per hectare is of little ecological relevance with respect to effects on currents and waves, but if the densities of farming structures per hectare increase so will the risk of significant effects, particularly in Small Bay. In general, the effects of marine farms on hydrodynamics are likely to be small in comparison with the effects on other aspects of the marine ecosystem.

For the planned ADZ the proposed overall expansion of shellfish aquaculture in Saldanha Bay is unlikely to significantly affect bay-wide hydrodynamic characteristics. At the local farm-scale, however, effects on currents may have potential implications for the sustainability of individual shellfish ventures and the local ecosystem. The introduction of additional structures may increase flushing times for an area, and in turn lead to an increase in localised seston depletion, thereby affecting the growth rates of the culture and other organisms in the area that are also dependent on a steady supply of seston. While primarily a farm management issue, potential effects on other filter feeders in the area must be kept in mind.

Alteration of current regimes around and within the proposed farms is deemed of medium intensity within the immediate vicinity of each farm, with potential effects further afield (depending on the location of the precinct and the density and extent of aquaculture therein). Impacts would persist for as long as the farm is in operation (medium- to long-term) and are considered to be of **HIGH** significance without mitigation. The physical effects on hydrodynamic conditions would persist for the duration that the structures and crop are in place, but recovery would be nearly immediate on removal of all structures.

Table 11 : Impact: Effects of farm structures on currents and waves

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Local to Regional
2</td><td>Medium
2</td><td>Long-term
3</td><td>High
7</td><td>Definite</td><td>HIGH</td><td>- ve</td><td>High</td></tr>
<tr><td colspan="9">Essential mitigation measures:
• Select sites favouring well-flushed, deep and productive areas (Big Bay North, Outer Bay North, Outer Bay South)
• Assuming the full extent of the proposed ADZ and maximum ungraded total annual production (27 600 tpa) within the precincts, it is deemed essential that predictive analytical and numerical modelling be undertaken to forecast the effects of shellfish farming structures on local and bay-wide currents, stratification and wave climates (either for specific precincts or for site-specific farms) before authorisation for the ADZ is granted. The results could additionally be used to develop alternative farm designs, and to adjust the orientation of rafts/longlines and submerged structures relative to prevailing currents so as to minimise possible localised hydrodynamic changes. However, if recommended mitigation measures for siting, buffer zones and stocking density of farming structures are implemented, a phased approach is taken for the development of the ADZ and annual ungraded shellfish production remains below 10 000 tpa for the first two years, increasing thereafter, hydrodynamic modelling is not deemed necessary.</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Medium
2</td><td>Long-term
3</td><td>Medium
6</td><td>Probable</td><td>MEDIUM</td><td>- ve</td><td>High</td></tr>
</table>

Effects on seawater nutrient chemistry

The metabolic waste products of cultured filter-feeders are a source of dissolved nitrogen (e.g. ammonium) in the water column. Enhanced benthic remineralisation rates beneath the farm (i.e. the microbial breakdown of mussel biodeposits on the sediment surface and flux of ammonium into the water column) can also result in increased nitrogen concentrations in the water column. This accelerated recycling of organic nitrogen provides a feedback mechanism that can stimulate further phytoplankton production, thus counteracting seston depletion (Prins *et al*. 1998; Ogilvie *et al*. 2003; Carlsson *et al*. 2012). Such localised nutrient enrichment could also stimulate production of algae attached to the mussels and culture lines (Black 2001), which in turn could potentially enhance coastal fish production (Tenore *et al*. 1982). Whether the impact of modified nutrient ratios is a significant factor influencing primary producers will depend on, among many factors, the culture site itself and the stocking density, but may lead to cascading effects that are much greater than simple shifts in nutrient levels (Hatcher *et al*. 1994).

The bivalves and associated fouling organisms on the culture lines remove oxygen from the water column, thereby potentially altering dissolved oxygen concentrations down-current of the farm (Mazouni *et al*. 1998, 2001; LeBlanc *et al*. 2002; Mazouni 2004; Nizzoli *et al*. 2006; Richard *et al*. 2006, 2007b). This could potentially be exacerbated by enhanced benthic oxygen consumption due to deposition and decomposition of particulate organic materials beneath farms. Although development of anoxic zones within the water column is theoretically possible, except for Small Bay, occurrence of these is extremely unlikely, unless farms are established in poorly flushed embayments, or at sites affected by enrichment effects due to other activities (e.g. fish farming; sewage and fish factory effluents).

The magnitude of effects of the alteration of seawater nutrient chemistry around and within the proposed farms will depend on the scale of future proposed operations, their effects on the hydrodynamic regime and the stocking density. The significance of ecological effects from shellfish farms will ultimately be related to site-specific values, but if kept at or below the recommended stocking densities of farm structures (Heinecken *et al.* 2016), is deemed of medium intensity within the immediate vicinity of the farm, with potential effects further afield (depending on location). Impacts would persist for as long as the farm is in operation (medium- to long-term) and are considered to be of **MEDIUM** significance without mitigation. The effects would persist for the duration that the structures and crop are in place, but recovery would be nearly immediate on removal of all structures.

Table 12 : Impact: Effects of farm structures on seawater nutrient chemistry

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local to Regional 2	Medium 2	Long-term 3	**High** 7	Possible	**MEDIUM**	**- ve**	High
Essential mitigation measures: • Select sites favouring well-flushed, deep and productive areas (Big Bay North, Outer Bay North, Outer Bay South) • Provided recommended mitigation measures for siting, buffer zones and stocking density of farming structures are implemented, a phased approach is taken for the development of the ADZ and annual ungraded shellfish production remains below 10 000 tpa for the first two years, increasing thereafter, modelling of changes in nutrient parameters (dissolved carbon, nitrogen and phosphorous) around the precincts is not deemed necessary. **Best Management Practices:** • Implement monitoring of the immediate water column around the precincts or specific farms for nutrient parameters (dissolved carbon, nitrogen and phosphorous)								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Possible	**VERY LOW**	**- ve**	High

Seston removal

Long-line culture of filter-feeding bivalves effectively creates a fixed biological filtration system suspended through the upper portion of the water column. Although the clearance rate of mussels and oysters varies considerably according to body size and seston quantity and quality, rates for mussels of up to 8.6 litres per mussel per hour have been reported (James *et al.* 2001). A substantial proportion of the seawater flowing through a fully stocked farm will thus be "processed" by the bivalves before it moves down-current and beyond the farm boundaries.

During the filter-feeding process, mussels can most efficiently extract particles within an approximate size range of 5-200 μm (Safi & Gibbs 2003), but even particles as large as 6000 μm can be retained (Zeldis *et al.* 2004). Suspended shellfish culture thus places the cultured stock in direct contact with the food web, where the extraction of seston from the water column can include phytoplankton, zooplankton, ichtyoplankton, protozoa, bacteria, detrital organic matter and inorganic sediment (Maar *et al*. 2008).

The extent to which a mussel farm removes seston from the water column is dependent on the ratio of the flushing time (which is affected by influence of structures on currents) to the rate at which the mussels filter and remove seston from the water (Gibbs 2007). The effect of introducing additional shellfish culture to an area will increase the seston removal rate, both through the further reduction in water movement and thus increased time available for the bivalves to effectively extract particulate matter from water. This in turn, could lead to food depletion, which would not only affect the cultured stock, but could limit food availability to other suspension-feeders in the ecosystem, thereby exceeding the ecological carrying capacity of a farmed area (Jiang & Gibbs 2005; Sequeira *et al*. 2008). It could also increase the recruitment potential of naturally occurring invertebrate and vertebrate populations in an area due to the availability of additional settlement surfaces. Various studies on suspended mussel cultivation have found some evidence of phytoplankton depletion (as chl a rather than phytoplankton species composition) within and around existing mussel farms, although temporal and spatial variability was high (Perez Camacho *et al*. 1991; Heasman *et al*. 1998; Strohmeier *et al*. 2005; Grant *et al*. 2008). It was concluded, however, that typical, small mussel farms have relatively little influence on the overall concentration of phytoplankton in the water column, particularly within the context of the wider spatial area surrounding the farms. In contrast, modelled depletion shadows for large-scale farm developments predicted reduced chl a concentrations extending beyond farm boundaries (Stenton-Dozey *et al*. 2008; Morrisey *et al*. 2006; Newell & Richardson 2014). The considerable variation in food depletion associated with environmental conditions (e.g. hydrodynamic patterns, background chl a concentrations etc.) suggested that adverse ecosystem effects over bay-wide scales were unlikely. The recent assessments by Olivier *et al*. (2013) and Probyn *et al*. (2015) for Saldanha Bay suggest that the proposed development of expanded aquaculture management areas would be unlikely to significantly alter the ecological structure of the food web.

Seston removal by cultured bivalves has been considered by some to be an example of top-down control that could have beneficial environmental effects through amelioration of eutrophication effects and improvement in water clarity (Officer *et al*. 1982; Gottlieb & Schweighofer 1996). Others dispute this, because most of the ingested organic material would be rapidly recycled into the water column as inorganic nutrients to stimulate further phytoplankton production. Therefore, the net effect on phytoplankton dynamics could be to increase turnover and overall production, rather than limit phytoplankton biomass (Nizzoli *et al*. 2005).

In summary, the magnitude of effects of the removal of seston by suspended shellfish culture will depend on the scale of future proposed operations, their effects on the hydrodynamic regime and the stocking density at each precinct. The significance of ecological effects from shellfish farms will therefore ultimately be related to site-specific values, but is deemed of medium intensity within the immediate vicinity of each precinct, with potential effects extending beyond the location of each site (scaling effects expected to diminish with increasing distance from the site). Impacts would persist for as long as the farm is in operation (medium- to long-term) and are considered to be negative and of **HIGH** significance without mitigation. The effects would persist for the duration that the structures and crop are in place, but recovery would be nearly immediate on removal of all structures.

Table 13: Impact: Removal of seston from the water column by suspended shellfish cultivation

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local to Regional 2	Medium 2	Long-term 3	**High** 7	Definite	**HIGH**	**- ve**	High
Essential mitigation measures: • Select sites favouring well-flushed, deep and productive areas (Big Bay North, Outer Bay North, Outer Bay South) • Assuming the full extent of the proposed ADZ and maximum ungraded total annual production (27 600 tpa) within the precincts, it is deemed essential that predictive analytical and numerical modelling be undertaken to forecast seston depletion shadows (either for specific precincts or for site-specific farms) before authorisation for the ADZ is granted. However, if recommended mitigation measures for siting, buffer zones and stocking density of farming structures are implemented, a phased approach is taken for the development of the ADZ and annual ungraded shellfish production remains below 10 000 tpa for the first two years, increasing thereafter, biophysical modelling of plankton depletion zones around the precincts is not deemed necessary. **Best Management Practices:** • Implement monitoring of the immediate water column around the precincts or specific farms for key plankton (chl a, phytoplankton abundance and species composition) parameters								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Definite	**LOW**	**- ve**	High

Alteration of plankton community structure

Studies have indicated that food items may be specifically selected by some bivalve species, based on particle size and/or nutritional value (Bourgrier *et al*. 1997; Shumway *et al*. 1997; Saffi & Gibbs 2003). As mussels are unable to efficiently filter out picoplankton (phytoplankton cells <2 µm) (Saffi & Gibbs 2003), the water passing through a farm might be expected to contain a higher proportion of picoplankton compared to the larger size classes that are preferentially removed. Preferential filtering may result in changes to the size structure of the plankton communities in a farmed area, particularly in areas of low flow. Although most zooplankton is considered too large to be utilised by mussels, there have been concerns raised over the ability of shellfish to consume planktonic larvae, and in particular, the larvae of fish, thereby affecting zooplankton population structure.

The removal of particular size classes of the plankton community and the concomitant effects on plankton community structure is deemed of medium intensity within the immediate vicinity of the farm, with potential effects further afield (depending on location). Impacts would persist over the short-term only, as plankton abundance in the area is naturally highly dynamic. Impacts are considered to be of **LOW** significance without mitigation, and **VERY LOW** significance with mitigation. The effects would persist for the duration that the structures and crop are in place, but recovery would be nearly immediate on removal of all structures.

Table 14 : Impact: Preferential feeding by shellfish may alter plankton community structure

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local to Regional 2	Medium 2	Short-term 1	**Low** 5	Definite	**LOW**	**- ve**	High
Essential mitigation measures: • Select sites favouring well-flushed, deep and productive areas (Big Bay North, Outer Bay North, Outer Bay South) **Best Management Practices:** Implement monitoring of the immediate water column around the precincts or specific farms for key plankton (chl a, phytoplankton abundance and species composition) parameters								
With mitigation	Local 1	Medium 2	Short-term 1	**Very Low** **4**	Definite	**VERY LOW**	**- ve**	High

Harmful algal blooms

Harmful algal blooms (HABs) represent a particular risk in shellfish growing waters. There is no evidence from other parts of the world, however, to indicate that localised farm-generated enrichment or alteration of phytoplankton communities have resulted in an increased incidence of HABs, although in eastern Canada various species of toxic phytoplankton have been reported to grow associated with algae growing on farmed mussels (Lawrence *et al*. 2000; Levasseur *et al*. 2003). In areas where nutrient enrichment may trigger an increase in the occurrence of HABs, bivalve stocking may in fact improve water quality and reduce the chances of HABs developing. Toxic algae blooms are a natural phenomenon along the South African West Coast, occurring irregularly in regions along the coast that do not have established shellfish farm when environmental conditions are optimal for such events.

The development of HABs as a result of suspended shellfish culture is deemed of medium intensity within the immediate vicinity of the farm, with potential effects further afield (depending on location). Impacts would persist over the short-term only, as plankton turn-over rates are rapid and abundance in the area is naturally highly dynamic. Impacts are considered to be of **VERY LOW** significance both without and with mitigation. Any observed effects would persist only for the duration that the structures and crop are in place, but recovery would be nearly immediate on removal of all structures.

Table 15 : Impact: Increased incidence of HABs as a result of suspended shellfish cultivation

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Medium 2	Short-term 1	**Very Low** 4	Improbable	**INSIGNIFI-CANT**	**- ve**	High
Essential mitigation measures: • No mitigation is possible or feasible								
With mitigation	Local 1	Medium 2	Short-term 1	**Very Low** **4**	Improbable	**INSIGNIFI-CANT**	**- ve**	High

4.4 Assessment of Wider Ecological Impacts

4.4.1 Habitat creation

Compared to the natural rocky or soft-sediment habitats over which shellfish farms are located, such structures can provide a substantial three-dimensional surface area for colonisation by fouling organisms and associated biota (Costa-Pierce & Bridger 2002; Gutiérrez *et al.* 2003). The dominant biota on such structures includes macroalgae and sessile filter-feeding invertebrates (Heasman 1996; Hughes *et al.* 2005; Braithwaite *et al.* 2007) that typically have a range of other non-sessile macroinvertebrates and fish associated with them (Tenore and González 1976; Khalaman 2001*a*, 2001*b*; LeBlanc *et al.* 2003*b*; Murray *et al.* 2007). The assemblages that develop on artificial structures can be quite different to those in adjacent rocky areas (Glasby 1999; Connell 2000).

Artificial structures also provide novel foraging habitat, detrital food sources, breeding habitat, and refuge from predators for many species (Dealteris *et al.* 2004). Although the functional role of the associated fouling community is not well understood, it contributes in some way to the water column and seabed effects described above.

The creation of hard substratum habitats below and within suspended shellfish culture is deemed of medium intensity, with impacts persist for as long as the structures are in place, and (in the case of benthic 'reefs') beyond the life-time of the farm. Impacts are considered to be positive and of **MEDIUM** significance both without and with mitigation. Any observed effects would persist beyond the duration of the farm as recovery could take years.

Table 16 : Impact: Creation of habitat by farm structures

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Local 1	Medium 2	Long-term 3	**Medium** 6	Definite	**MEDIUM**	**+ ve**	High
Essential mitigation measures: • No mitigation is feasible or possible other than the no-project alternative								
With mitigation	Local 1	Medium 2	Long-term 3	**Medium 6**	Definite	**MEDIUM**	**+ ve**	High

4.4.2 Effects on fish

Studies describing how shellfish farms affect wild fish assemblages are sparse, reflecting a general lack of concern over the potential for adverse effects. Shellfish farming involves introducing a complex three-dimensional structure, which can be colonised by a diverse and productive fouling community (most aquaculture operations are situated over sandy or muddy substrate, reef areas are avoided). Such alterations to the existing habitat in turn alter the environments suitability to fish (Caselle *et al.* 2002; Dempster *et al.* 2006). Hence, it is commonly believed that marine farms have the propensity to enhance fish abundances (Brooks 2000; Brehmer *et al.* 2003; Dealteris *et al.* 2004). The overall fish assemblages may, however, be quite different to those found in adjacent habitats. The farm structures need also not necessarily provide habitat for significant numbers of commercially or recreationally important fish (Morrisey *et al.* 2006), with any effects likely to be site- and region-specific.

Wild fish abundances can also be affected by changes in the way the area is subjected to fishing pressure. Whereas shellfish farms may essentially serve in creating a commercial 'no-take' area (Dempster *et al.* 2006), removing commercial fishing pressure may be offset by changes in the way the area is utilised by recreational fishers, as marine farms are often viewed as good fishing locations, particularly when crop is being harvested and the fouling organisms that are being cleaned from the mussels are being discharged back into the water.

Cultured shellfish populations may also have the potential to directly reduce recruitment into fishery populations through the consumption of eggs and larvae (Davenport *et al.* 2000; Lehane & Davenport 2002; Gibbs 2004). A desktop study undertaken in Admiralty Bay, New Zealand, where mussel culture occupied about 10% of the total bay area, concluded that the impact on Blue Cod recruitment was equivalent to additional mortality of less than 10% (Gibbs 2004). The study also noted that this reduction could be negated by allowing a further 1.1% of the female spawning stock to remain unfished. The magnitude of the potential grazing influence of shellfish farms on recruitment in fisheries will largely be governed by the extent of the culture, behaviour of larvae and flow dynamics of the region in question.

Clark (2015) notes that there is a downward trend in fish abundance since 2010/11 "*and it is somewhat concerning that the estimated abundance of some key species is decreasing in the areas of maximum anthropogenic disturbance within Small Bay, whilst they are stable or increasing in other less disturbed areas of Big Bay and Langebaan Lagoon*". There are, however, no described fish spawning locations in Saldanha Bay although 'bays' and estuaries are known to serve as nursery areas for many juvenile fish species around the South African coast. For the ADZ it is anticipated that the expansion of aquaculture and increase in structures will act as aggregating devices for fish for both shelter and as a food source. The creation of hard substratum habitats below and within suspended shellfish culture is deemed of medium intensity, with impacts persist for as long as the structures are in place, and (in the case of benthic 'reefs') beyond the life-time of the farm. Impacts are considered to be positive and of **MEDIUM** significance both without and with mitigation. Any observed effects would persist beyond the duration of the farm as recovery could take years.

Conversely, the effects could potentially be negative if they result in regional fish populations becoming displaced from other habitats or more vulnerable to recreational fishing pressure. Any observed effects would persist beyond the duration of the farm as recovery of artificially created reefs could take years. It is unlikely the current or future level of shellfish farming in Saldanha Bay would have significant knock-on effects on the sustainability of wild fish populations.

Table 17 : Impact: Effects of suspended shellfish cultivation on fish

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Medium 2	Long-term 3	**Medium** 6	Definite	**MEDIUM**	**+ ve/ -ve**	High
Essential mitigation measures: • The whole of Saldanha Bay (particularly the shallower areas) is an important spawning and nursery habitat for a number of fish species (houndsharks, white stumpnose, elf), which can potentially spawn anywhere within the bay in summer where/when conditions are suitable. There is thus no mitigation is feasible or possible other than the no-project alternative								
With mitigation	Local 1	Medium 2	Long-term 3	**Medium** **6**	Definite	**MEDIUM**	**+ ve**	High

4.4.3 Effects on seabirds

Effects on food supply

Saldanha Bay, Langebaan Lagoon and the associated islands provide important shelter, feeding and breeding habitat for at least 53 species of seabirds, 11 of which are known to breed on the islands (Clark 2015). Further, the islands of Malgas, Marcus, Jutten, Schaapen, Caspian and Vondeling support breeding populations of African Penguin (a red data species), Cape Gannet, four species of marine cormorants, Kelp and Hartlaub's Gulls, and Swift Terns. Saldanha Bay and its islands support substantial proportions of the total populations of several of these species (Clark 2015).

The attraction of certain seabird species to aquaculture structures has been noted from different parts of the world, suggesting that the birds benefit from increased foraging success on fish and biofouling associated with shellfish farms (Brown 2001; Lalas 2001; Ross *et al*. 2001; Butler 2003; Roycroft *et al*. 2004), and even on the cultured mussel stock itself (Kirk *et al*. 2007). The consequences of this attraction will likely depend on the species' dietary preferences and response to both direct and indirect ecosystem changes induced by shellfish cultivation.

The potential effect to breeding and feeding seabirds, however, also includes reduced habitat for feeding and from the smothering of the seabed by farm-derived biodeposition and shell litter. The physical presence of farm structures can reduce the habitat available for surface-feeding seabirds, such as gulls, terns and shearwaters.

Human disturbance

Certain seabird species are relatively sensitive to human presence and disturbance. Day-to-day maintenance, harvesting and other activities taking place on shellfish farms located near breeding or roosting sites therefore have the potential to adversely affect bird populations, possibly in tandem with other sources of disturbance (e.g. recreational vessel activities). During certain times of the year, seabirds may use farm structures as perching sites for look-outs (i.e. to spot fish) or to evade shore predators and avoid human disturbance on shore. In Ireland, Roycroft *et al*. (2004) found evidence of shorebirds, such as oystercatchers and plovers, using farm structures rather than more traditional land sites. Overall, the potential disturbance of seabirds from nearby shellfish farms appears to be dependent on the bird species, farm location in relation to nesting or breeding sites, and the relative disturbance of farm operations (e.g. noise and boat traffic) in comparison to other local forms of disturbance (e.g. recreational boating, casual or commercial use of nearby beaches).

A potential beneficial effect to seabirds of aquaculture farms includes the provision of roost sites closer to foraging areas, thus saving energy and enabling more efficient foraging (particularly for cormorants, gulls and terns). Likewise, the attraction and aggregation of small fish to the farm to feed on fouling organisms and/or shelter under the farm structures may become potential prey of birds.

Entanglement

No entanglements of seabirds in shellfish farm lines have been reported. A potentially greater risk within the shellfish aquaculture industry is poorly managed operational by-products of farms, including lost lines and plastics (Weeber & Gibbs 1998), particularly after stormy weather (Page *et al*. 2000). Other potential effects include collision with farm structures, and the attraction of seabirds to artificial lighting.

The scale and magnitude of the effect of suspended shellfish culture on seabirds would depend largely on the location of a farm within the range of the seabirds in question, the bird species, its conservation status, and the duration of the effect. Of particular concern are negative interactions with species that are threatened, endangered and vulnerable or have restricted ranges. The species most likely to be affected by the ADZ are the African Penguin, and the Bank Comorant (both threatened or endangered), although the declines of these species are attributed to reduction in prey availability (sardine mostly) (Clark 2015) and not anthropogenic effects associated with developments in Saldanha Bay. The effects are therefore deemed of high intensity due to the proximity of nesting sites of endangered species. Impacts would persist for as long as the structures are in place and are thus considered to be of **MEDIUM** significance without mitigation. Any observed effects would persist only for as long as the farm is operational.

Indirect effects

The potential for wider, more indirect ecosystem effects on seabirds due to shellfish aquaculture include food-web interactions (Black 2001; Kaiser 2001; Würsig & Gailey 2002; Kemper *et al*. 2003), biotoxin and pathogen outbreaks (Geraci *et al*. 1999; Kaiser 2001). While these potential indirect interactions have been considered in the literature (Würsig & Gailey 2002; Kemper *et al*. 2003), no actual research on any indirect effect has yet been documented.

Table 18 : Impact: Effects of suspended shellfish cultivation on seabirds

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	High 3	Long-term 3	**High** **7**	Possible	**MEDIUM**	**- ve**	High
Essential mitigation measures: • The Saldanha Bay islands and their surrounding marine habitat serve as home ranges, and critical breeding and foraging habitats for a number of threatened, endangered or protected bird species. Siting of precincts to avoid MPAs, and implementation of a buffer zone between an MPA and an adjacent precinct will mitigate impacts to some extent. However, as seabirds forage over a wide area there is no universal mitigation feasible or possible other than the no-project alternative • Minimise the potential for litter entering the marine environment (particularly plastic wastes) • Install visual deterents for birds (e.g. tori line type deterents) **Best Management Practices:** • Ensuring that minimal non-navigational lighting occurs at night and using downward-pointing and shaded lights								
With mitigation	Local 1	Medium 2	Long-term 3	**Medium** **6**	Possible	**LOW**	**- ve**	High

4.4.4 Effects on marine mammals: seals, dolphins and whales

Interactions between marine mammals and aquaculture usually result from an overlap between the spatial location of the facilities and the breeding, feeding and/or migrating habitat of the marine mammal species. Interactions include competition for space (habitat exclusion or modification), underwater noise disturbance, potential for entanglement and knock-on effects due to alterations in trophic pathways. Potential risks are best identified and managed on a case-by-case basis; for example by selecting farm locations to minimise the likelihood of overlap with marine mammal migration routes and/or known habitats.

Habitat exclusion

Mussel farm droppers typically extend vertically from floats at the surface through the water column to within a short distance above the seabed (see Figure 3). Oyster and scallop farms only occupy the top half of the water column. Such vertical structures may appear as visual or acoustic three-dimensional barriers that can potentially exclude marine mammals from habitats previously used for feeding, calving and/or migration activities (Markowitz *et al*. 2004). Studies in New Zealand have observed significantly fewer dusky dolphins (*Lagenorhynchus obscurus*) inside mussel farms Marlborough Sounds than outside (Markowitz *et al*. 2004, Vaugh & Wursig 2006, Duprey 2007, Pearson *et al*. 2007, but see also Heinrich 2006), suggesting that, while not completely displaced from the region as a whole, they did not appear to be utilising habitats occupied by shellfish farms in the same manner as prior to the farms' establishment.

The nature of habitat exclusion, however, greatly depends on the type of culture method and the particular species of marine mammal present in the cultivation area. In Australia, a humpback whale (*Megaptera novaeangliae*) and southern right whale (*Eubalaena australis*) travelled straight through finfish farm structures situated on their traditional migration route, destroying the cages and/or entangling themselves while following (Kemper & Gibbs 2001; Kemper *et al*. 2003; Lloyd 2003). The presence of farms may, however, also exclude marine mammals from foraging or feeding areas, or resting or nursery area. The nature of the exclusion greatly depends on the type and scale of the farming method and the particular marine mammal species affected. Seals are perhaps the one marine mammal species that will not be excluded from habitats by shellfish farming, potentially utilizing the farm structures as a source of food and as haul-out areas (Forrest *et al*. 2007).

Underwater noise

Aquaculture activities could also result in habitat degradation in the form of underwater noise disturbance e.g. use of motor boats, knocking of structures with wave disturbance, clanging of anchors and buoys. The level and persistence of any underwater noises associated with shellfish farming would be negligible relative to other underwater noise sources in Saldanha Bay, such as commercial vessels, but will vary according to farm features (e.g. type, size), habitat characteristics (e.g. location, depth, type of bottom sediments, shape of coastline) and compounding factors, such as the number of farms and/or other noise sources in nearby regions.

Entanglement

Shellfish farming structures occupy a large portion of the water column, effectively creating a three-dimensional obstacle that resident marine mammals have to navigate around (Würsig & Gailey 2002; Markowitz *et al*. 2004). In addition, many species of marine mammals are known for their curious nature and are often attracted to novel objects, such as floating debris and/or lines. Most entanglements occur in loose, thin lines and as such, potential entanglement risks at shellfish farms are likely to be low, since backbone and anchor lines are under considerable tension. Fouling of large mammals (southern right and humpback whales) on lobster trap lines is known to occur seasonally off the South African coast. The likelihood of this occurring inside Saldanha Bay is low, although incidents of entanglement in Outer Bay might occur but is considered improbable.

Indirect effects

The potential for wider, more indirect ecosystem effects on marine mammals due to shellfish aquaculture include food-web interactions (Black 2001; Kaiser 2001; Würsig & Gailey 2002; Kemper *et al*. 2003), biotoxin and pathogen outbreaks (Geraci *et al*. 1999; Kaiser 2001), and antibiotic use (Buschmann *et al*. 1996; Kaiser 2001). While these potential indirect interactions have been considered in the literature (Würsig & Gailey 2002; Kemper *et al*. 2003), no actual research on any indirect effect has yet been documented.

The scale and magnitude of the effect of suspended shellfish culture on marine mammals would depend largely on the location of a farm within the range of the species in question (i.e. does the aquaculture area overlap with migration paths, breeding habitats or feeding areas), the conservation status of the potentially affected species, and the duration of the effect. Of particular concern are negative interactions with species that are threatened, endangered and vulnerable or have restricted ranges.

Those species that are likely to occur in the ADZ (Humpback, Southern Right, Minke and Bryde's whales, Orcas, Dusky and Heavisides dolphins) are all listed as "least concern" or "data deficient". All these species occur over a wide range and none have restricted feeding areas within the project area.

The probability of interaction is species dependent. Interaction with whales and dolphins are unlikely within the bay, but possible in Outer Bay. Although no longer breeding on the Saldanha Bay islands, Cape fur seals forage widely throughout inshore waters along the southern African West Coast and over the continental shelf, being attracted to fishing vessels and harbours. Interaction by the ADZ with seals would thus be definite across the extent of the ADZ area.

Overall, the effects are deemed of medium intensity, would persist for as long as the structures are in place and are thus considered to be of **MEDIUM** significance without mitigation. Any observed effects would persist only for as long as the farm is operational.

Table 19 : Impact: Effects of suspended shellfish cultivation on marine mammals

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Local
1</td><td>Medium
2</td><td>Long-term
3</td><td>Medium
6</td><td>Probable</td><td>MEDIUM</td><td>- ve</td><td>High</td></tr>
<tr><td colspan="9">Essential mitigation measures:
• Ensure debris and waste material does not enter the water to minimise the risk of attraction and entanglement
• Keep a log of all cetaceans, seabirds and predators recorded in the vicinity of fish farms, including behavioural observations
• Monitoring by farm personnel of presence (and absence) of marine mammal species in the vicinity or general region of the farm sites, as well as observations of any time spent under or around the farm structures. These data should be periodically compiled and analysed by experts

Best Management Practices:
• Develop and enforce strict maintenance and operational guidelines and standards in relation to potential entanglement risks on the farm including loose ropes, lines, buoys or floats
• Ensure all mooring lines and rafts are highly visible (use thick lines and bright antifouling coatings)
• Keep all lines taught through regular inspections and maintenance
• Develop disentanglement protocols in collaboration with DAFF, DEA and the SA Whale Disentanglement Network and establish a rapid response unit to deal with entanglements
• Adopt appropriate maintenance and operational guidelines and standards for minimising noise in noise-generating equipment</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Low
1</td><td>Long-term
3</td><td>Low
5</td><td>Possible</td><td>VERY LOW</td><td>- ve</td><td>High</td></tr>
</table>

4.4.5. Biosecurity risks and biofouling pests

Internationally, the role of aquaculture in the spread of fouling pests has long been recognised (Perez *et al.* 1981; Bourdouresque *et al.* 1985; Wasson *et al.* 2001; Leppäkoski *et al.* 2002; Hewitt *et al.* 2004). Properties that allow the establishment and spread of invasive species include rapid growth under a range of environmental conditions, great physiological tolerances, and great reproductive output (Ruiz *et al.* 2000), and these are among the same attributes that are sought out for aquaculture species (Branch & Steffani 2004). Fouling of the shellfish farms and culture stock has also become recognised as a significant threat to the aquaculture industry, as population explosions of biofouling species can result in substantial crop losses (Coutts & Forrest 2007; Gust *et al.* 2007; Grant *et al.* 1998). Many of these pest organisms also have the potential to be highly invasive in natural habitats (Bullard *et al.* 2007).

Spread of fouling pests *via* aquaculture

Suspended cultivation methods are implicated in the introduction of a great proportion of exotic species in coastal waters around the world (Carlton 1992; Ruiz & Carlton 2003), as their associated structures and materials (e.g. ropes, floats, pontoons) provide ideal habitats that allow fouling pests to proliferate at high densities (Clapin & Evans 1995; Floc'h *et al.* 1996; Carver *et al.* 2003; Lane & Willemsen 2004; Coutts & Forrest 2007; McKindsey *et al.* 2007). From a biosecurity perspective, ecological risks arise because the infested farms act as a 'reservoir' for the further spread of the pest.

At local scales (e.g. within bays), spread from infested reservoirs is facilitated by dispersal of microscopic life-stages or *via* the drift of reproductively viable fragments (Forrest *et al.* 2000; Bullard *et al.* 2007). The establishment of the pest on adjacent structures such as other marine farms, jetties and vessel moorings, which offer settlement substrates, can act as 'stepping stones' for the spread of pest species (Bulleri & Airoldi 2005; Forrest *et al.* 2008). For many fouling organisms, however, spread across large areas or between regions occurs *via* inadvertent transport with aquaculture and other human activities (e.g. vessel movements). Inter-regional transfer of infested structures (e.g. ropes, floats), farm vessels or seed stock as part of routine operations increases the likelihood of spreading the pests to other localities if stringent management measures are not taken to reduce such biosecurity risks (Forrest & Blakemore 2006; Forrest *et al.* 2007).

The development of new shellfish farm operations, especially in regions where no marine farming exists, raises the likelihood that biosecurity risks will arise. Risks will be most significant when: (i) pest organisms are spread by imported shellfish spat (e.g. oysters) into regions or habitats that are optimal for their establishment and where they do not already exist; and (ii) mussel farming activities are the primary mechanism for the spread of the pests. If a pest organism is already present in the new habitat, or is likely to spread there regardless of mussel aquaculture activities, for example *via* natural dispersal or *via* non-aquaculture vectors (e.g. recreational and commercial vessels), then the incremental risk posed by mussel farm operations may be negligible. Determination of such risks is situation-specific and must be evaluated on a case-by-case basis. Provided there is knowledge of the biological attributes of pest organisms (e.g. natural dispersal capacity and habitat requirements) and human-mediated pathways of spread (Dodgshun *et al.* 2007), various assessment procedures can be used to assist with identification of relative risks and the extent to which they can be managed (Forrest *et al.* 2006).

It is important to consider biosecurity risks because of the potential far-reaching and irreversible implications if there is an outbreak or incursion of a pest or disease. The introduction, proliferation and spread of risk organisms on the southern African West Coast could lead to significant effects on marine habitats and their associated values. Once established in marine environments, pests and diseases are typically difficult and costly to manage and the ongoing effects are often permanent.

Heinecken *et al.* (2016) note that:

Currently all C. gigas spat are imported. The National Environmental Management: Biodiversity Act (2014) (NEMBA) provides guidelines on the processes to be followed regarding the intentional introduction of potentially invasive species. However, NEMBA has limited relevance to unintentional introductions of blacklisted species that may be introduced on fouled oyster spat. NEMBA (DEA 2014) report also notes that four previously unrecorded species were found to be associated with oyster spat introduced into South Africa, in particular the black sea urchin, Tetrapygus niger; the European flat oyster, Ostrea edulis; Montagu's crab, Xantho incisus, and the brachiopod Discinisca tenuis. There is also the risk that diseases and/or parasites may be introduced with the import of oyster spat into the bay. The Biodiversity Risk and Benefit Assessment (BRBA) report on the C. gigas (DAFF 2015), provides a list of some of the diseases which commonly infect C. gigas, and these may provide a potential problem with increased densities in the culture of the species into the ADZ.

To mitigate against this risk, the BRBA report has emphasised that the most critical need with regards to future culture of C. gigas is the development of a South African bivalve hatchery, at Saldanha or elsewhere, to reduce the reliance on imported spat, and hence the risk of introduction of associated alien species and diseases (DAFF 2015).

The prevalence of pests and diseases occurring in South Africa's aquaculture industry is low compared to other countries. As a vector pathway for the introduction of non-native marine species, mariculture contributes only 6%, compared with the 86% introduced through ship fouling and ballast water (Mead *et al*. 2011). The authors note that as a vector for the introduction of alien species, mariculture is likely to increase in prominence in future.

The risk of a disease outbreak or incursion, however, is generally considered serious to the industry given the potential consequences, both in terms of the environment and the operations of the industry. Oyster stacks are brought ashore for cleaning, and biofouling organisms are thus not returned to the water. However, the biofouling on mooring ropes or mussel droppers is dumped on site during cleaning, thus potentially re-introducing non-native fouling species not detected by inspections of farm structures for invasive organisms.

As mussel and oyster farming has been underway in Saldanha Bay for a number of years, expanded production is unlikely to pose a higher risk, unless increased demands for seed stock require imports from new localities, or new mollusc species are introduced that are sourced from elsewhere, in which case a risk analysis would need to be conducted as part of the import permit. The potential effects of biosecurity risks from suspended shellfish culture are deemed of high intensity, would potentially persist beyond the duration of the aquaculture activities themselves and are thus considered to be of **VERY HIGH** significance without mitigation. Suitable management would reduce the significance to **MEDIUM**.

Table 20: Impact: Introduction of alien invasive species or spread of fouling pests

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Regional
2</td><td>High
3</td><td>Long-term
3</td><td>Very High
8</td><td>Probable</td><td>VERY HIGH</td><td>- ve</td><td>High</td></tr>
<tr><td colspan="9">MPI (2013) notes that there are three components to biosecurity management, namely:
• Prevention of incursions is the most effective approach to biosecurity and should focus on the management of high-risk pathways, including from international source regions, new pathways, and regional sources known to be infected by recognised high-risk pests.
• Surveillance (detection) focussing on passive surveillance (screening at airports and ports), routine surveillance (undertaken on and around marine farm structures and associated vessels and infrastructure by farm operators) or targeted surveillance of high-risk areas.
• Control of populations and outbreaks requiring coordination with, and support from, all marine stakeholders (whose activities can spread unwanted organisms) and agencies at local, regional and national scales. Eradication measures and/or application of therapeutants are only advised if the risk of re-invasion can be managed and pests can be detected before they become widespread.

Essential mitigation measures:
• Ensure a high level of biosecurity management and planning is in place to limit the introduction of pests and diseases and to be able to respond quickly and effectively should biosecurity risks be identified
• Farm operators should undertake routine surveillance on and around marine farm structures and associated vessels and infrastructure for indications of non-native fouling species
• Maintain effective antifouling coatings and regularly inspect farm structures and vessels for pests; clean structures and hulls regularly to ensure eradication of pests before they become established
• If spat import cannot be avoided, culture facilities should only be permitted to use spat sourced from biosecure certified hatcheries and/or quarantine facilities.
• Ensure that veterinarian protocols to eliminate any pests, parasites and diseases are strictly adhered to

Best Management Practices:
• Develop South African bivalve hatcheries to reduce the reliance on spat import, and hence the risk of non-intentional introduction of associated alien species and diseases</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Medium
2</td><td>Long-term
3</td><td>Medium
6</td><td>Probable</td><td>MEDIUM</td><td>- ve</td><td>High</td></tr>
</table>

4.4.6 Disease

The risk of transmission of indigenous pathogens or parasites from cultured stock to wild populations and to other species can be considered minimal. The effects of disease on the farmed mussels themselves are of importance with regard to farm management and can be economically significant. This is a possibility only if the endemic species are susceptible and if appropriate intermediate hosts (if required) are available. The possibility that potential intermediate hosts could be part of the suite of fouling organisms should not be overlooked, both in life cycle studies and as possible control measures.

There is international evidence that mytilids might harbour viruses with consequent threats to susceptible fish. For example, *Mytilus galloprovincialis* was identified as a reservoir host for infections of the aquatic birnavirus (ABV) in the Japanese flounder *Paralichthys olivaceou* (Kitamura *et al*. 2007), and subsequently also detected in healthy King salmon (*Oncorhynchus tshawytscha*) returning to the east coast of South Island, New Zealand (Diggles *et al*. 2002). Similarly, the aquabirnavirus infectious pancreatic necrosis virus (IPNV) detected in *Mytilus edulis* (VPS 2000) is a common virus of salmonids and is also a suspected clam pathogen in Taiwan.

As with biosecurity risks, the potential effects of the spread of diseases from suspended shellfish culture are deemed of high intensity, would potentially persist beyond the duration of the aquaculture activities themselves and are thus considered to be of **HIGH** significance without mitigation. Suitable management would reduce the significance to **VERY LOW**.

Table 21 : Impact: Transmission of diseases from cultured stock to wild populations

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Regional
2</td><td>High
3</td><td>Long-term
3</td><td>Very High
8</td><td>Possible</td><td>HIGH</td><td>- ve</td><td>High</td></tr>
<tr><td colspan="9">MPI (2013) notes that there are three components to biosecurity management, namely:
• Prevention of incursions is the most effective approach to biosecurity and should focus on the management of high-risk pathways, including from international source regions, new pathways, and regional sources known to be infected by recognised high-risk pests.
• Surveillance (detection) focussing on entry surveillance (screening at airports and ports), routine surveillance (undertaken on and around marine farm structures and associated vessels and infrastructure by farm operators) or targeted surveillance of high-risk areas.
• Control of populations and outbreaks requiring coordination with, and support from, all marine stakeholders (whose activities can spread unwanted organisms) and agencies at local, regional and national scales. Eradication measures and/or application of therapeutants are only advised if the risk of re-invasion can be managed and pests can be detected before they become widespread.

Mitigation measures:
• Ensure biosecurity management and planning is in place to limit the introduction of parasites and diseases and to be able to respond quickly and effectively should biosecurity risks be identified.
• If spat import cannot be avoided, culture facilities should only be permitted to use spat sourced from biosecure certified hatcheries and/or quarantine facilities.
• Ensure that veterinarian protocols to eliminate any pests, parasites and diseases are strictly adhered to
• The use of chemicals in disease management is discouraged due to negative impacts on the aquatic environment, consumer reluctance, and because the frequent use of traditional therapeutics may trigger the emergence of disease-resistant strains of pathogens (MPI 2013). Use only prescribed veterinary chemicals.

Best Management Practices:
• Develop South African bivalve hatcheries to reduce the reliance on spat import, and hence the risk of non-intentional introduction of associated alien species and diseases</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>High
3</td><td>Short-term
1</td><td>Low
5</td><td>Possible</td><td>VERY LOW</td><td>- ve</td><td>High</td></tr>
</table>

4.4.7 Genetic interactions with wild populations

There is potential for aquaculture to affect genetic profiles of wild populations of the same species. Any factor that reduces the overall genetic variability may compromise the capacity of that species to adapt to environmental change, and may even compromise the long-term survival of the species (Landry *et al.* 2006). If the genetic variation within a given population is reduced, the population will be less able to adapt to change. Loss of variation among populations will result in convergence of populations towards one type and a narrower range of options for the species. The problem stems mainly from shifting significant numbers of individuals of a single species and establishing them elsewhere. Inbreeding from culture-based production of seed is also possible. Potential for altering genetic profiles of wild populations is largely determined by the pre-existing level of genetic structuring within that species. With the exception of *Chromytilus meridionalis*, most of the culture species under consideration are non-native to the West Coast, although *Mytilus galloprovincialis* is now widespread on rocky shores along most of the southern African West Coast. Their success as an invasive alien suggests that they have adapted well genetically to their natural environment and hybridisation with cultured stocks is unlikely to reduce their genetic variation. The spat used by the industry is allowed to settle naturally onto the culture ropes. As such genetic profiles are not expected to be affected by mussel culture at all.

The risks of genetic effects are species specific and need to be managed on a case-by-case basis. Important factors to consider include:

- the distance of the farm from viable habitat;
- the distance to natural populations;
- the dispersal range of genetic material (gametes) from the species concerned;
- source of stock; and
- an understanding of the genetic structuring of wild populations.

If the oyster, abalone or scallop farming industry increases its dependence on hatchery-supplied spat, particularly with the advancements in selective breeding, this would require the development and implementation of genetic management protocols.

The potential effects of genetic interactions with wild populations of mussels are deemed of low intensity, which would potentially persist beyond the duration of the aquaculture activities themselves and are thus considered to be of **LOW** significance without mitigation.

In the case of oysters, scallops and abalone, however, where there is a dependence on hatchery supplied seed, the potential effects of are deemed of medium intensity and are thus considered to be of **MEDIUM** significance without mitigation. Suitable management would reduce the significance to **LOW**.

Table 22 : Impact: Risks of Genetic interactions with wild mussel populations - mussels

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Regional 2	Low 1	Long-term 3	**Medium** 6	Improbable	**LOW**	**- ve**	High
Essential mitigation measures: • No mitigation is feasible or possible								
With mitigation	Local 1	Medium 2	Long-term 3	**Medium 6**	Improbable	**LOW**	**- ve**	High

Table 23 : Impact: Risks of Genetic interactions with wild oyster, scallop or abalone populations

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Regional 2	Medium 2	Long-term 3	**High** 7	Possible	**MEDIUM**	**- ve**	High
Essential mitigation measures: • Ensure good physical and biological containment to limit the effects of escaped stocks • Follow "Genetic Best Practice Management Guidelines for Marine Finfish Hatcheries" developed by DAFF and ensure adequate genetic monitoring of brood stock rotation.								
With mitigation	Local 1	Medium 2	Long-term 3	**Medium 6**	Possible	**LOW**	**- ve**	High

4.4.8 Contaminant inputs

Operational shellfish farms do not require the ongoing input of materials that could introduce trace contaminants to the marine environment, as can occur for example as a result of antifouling paints or synthetic feed inputs to sea-cage fish farms (Morrisey *et al*. 2000; Easton *et al*. 2002; Schendel *et al*. 2004). Sediment binding of contaminants (should they be present) is likely to reduce the potential for toxic effects on associated biota. This issue is thus likely to be of negligible significance in the case of shellfish culture sites and insignificant relative to observed localised ecotoxic effects in Saldanha Bay sediments. Furthermore, farmed shellfish must adhere to the DAFF permit conditions requiring compliance with the SA Shellfish Monitoring and Control Programme, and are subjected to metals testing as part of the Saldanha Bay water quality and Mussel Watch programs, which would detect unusual accumulation should it occur.

The potential effects of environmental contamination as a result of suspended shellfish cultivation are deemed of low intensity, and are thus considered to be of **VERY LOW** significance both without and with mitigation.

Table 24 : Impact: Contamination of sediments or the water body from suspended shellfish cultivation

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Low 1	Long-term 3	**Low** 5	Improbable	**VERY LOW**	**- ve**	High
Essential mitigation measures: • Do not apply antifoulants on site and use environmentally friendly alternatives where effective **Best Management Practices:** • Establish and adhere to guidelines around the use of anti-fouling products in the mariculture industry								
With mitigation	Local 1	Low 1	Long-term 3	**Low 5**	Improbable	**VERY LOW**	**- ve**	High

4.4.9 Other potential shellfish species considered for the ADZ

Although suspended culture of mussels and oysters has been practiced for many years in Saldanha Bay, a number of other molluscs have recognised aquaculture potential in sea-based cages. Experimental research has been conducted with abalone (*Haliotis midae*) and scallops (*Pecten sulcicostatus*). However, the size, scarcity and relative newness of these industries typically means that any associated environmental effects have not been described or are not yet fully expressed; hence, related literature is sparse or non-existent. It is assumed that many of the environmental effects that arise from cultivation of these other molluscan species would be common among farming that involves similar cultivation methods (e.g. backbone suspended culture) and/or involves organisms with similar feeding strategies (e.g. filter-feeding bivalves). This is because most of the effects described above stem from both feeding and waste products of the cultured stock, or the physical presence of the structures themselves. Should cultivation of other molluscan species, other than abalone (*Haliotis midae*) and scallops (*Pecten sulcicostatus*) go ahead in Saldanha Bay, it is recommended that the impacts of these operations be assessed as and when required, as environmental effects will be site-specific as their extent and intensity will largely be dependent on local hydrodynamic conditions and stocking density.

Abalone

Published information on the environmental impacts of offshore abalone aquaculture is sparse. Sea-based containment systems typically comprise barrels suspended from conventional long-line systems. The abalone are grown inside the barrels where they are fed brown and/or red macroalgae, and in some instances specially designed feed-pellets (Keeley *et al*. 2009). As suspended culture would be less intensive than land-based production, and likely less intensive than suspended mussel culture, the related environmental issues are consequently expected to be less significant.

The low nutrient content of the feeds, low feeding rate and relatively low stocking densities, growth rate and production, also makes significant adverse impacts on water and sediment quality unlikely (Gavine & McKinnon 2002). Furthermore, abalone are considered to be reasonably efficient feeders, assimilating up to 80% of the ingested food (Yamasaki 1998). Localised impacts on water and sediment quality are possible if waste feed and faeces accumulate beneath the culture unit. However, as abalone require extremely good water quality for growth and survival, it is likely that any accumulation in waste and subsequent deterioration of water quality would impact on the cultured stock (through decreased oxygen concentrations) before serious impacts on water or sediment quality became evident. As with other forms of suspended culture, the extent of the environmental effects would be influenced by both environmental and farming management practices, and it is likely that commercial intensities that would trigger a negative environmental response are impractical due to water quality feedback mechanisms.

Scallops

Arendse (2015) investigated the potential for farming the South African Scallop, *Pecten sulcicostatus* in suspended culture. It was concluded that successful farming was possible only if survival of early life stages can be improved. Should suspended culture go ahead, commercial intensities are unlikely to be of sufficient intensity to trigger negative environmental responses over and above those already discussed for mussels and oysters.

4.5 Assessment of Direct Impacts from Fish Farming

The marine finfish aquaculture industry in South Africa is at a pioneering phase only, focusing primarily on the farming of Atlantic salmon (*Salmo salar*) and rainbow trout (*Onchorhynchus mykiss*), although yellowtail (*Seriola lalandi*), White Stumpnose (*Rhabdosargus globiceps*) and Silver Kabeljou (*Argyrosomus inodorus*) are also being considered. The culture of Coho and Chinook salmon (*Oncorhynchus kisutch* and *O. tshawytscha*) in Saldanha Bay has also recently received authorisation through a risk assessment. In Saldanha Bay, the industry currently is, and would in future be, based primarily around cage (or 'net pen') farming and likely to remain small in comparison with the cultivation of mussels and oysters.

The environmental issues associated with finfish culture are much the same as for shellfish culture, namely:

- Effects of cages on hydrodynamic characteristics
- Seabed and water column effects due to the discharge of organic wastes
- Habitat creation by cages, mooring lines and anchor blocks
- Biosecurity, disease transfer, genetic interactions and effects of escaped fish
- Effects on seabirds, marine mammals and other predators
- Chemical pollution of marine food chains by therapeutants (pharmaceutical medicines) and trace contaminants

Most of these impacts have been discussed in Section 4.3 and 4.4. and for the sake of brevity will not be repeated in detail again here. For the sake of completeness, however, a summary is provided below, with more details provided only for those impacts specific to the farming of fish. This is based heavily on the review provided by Forrest *et al.* (2006) and is by necessity generic in nature given the present unknowns regarding potential species, suitable locations, cage designs, stocking densities, feed types, husbandry practices etc.

Although extensive literature exists on the ecological effects of finfish farming internationally, quantitative data and first-hand experience of such effects are as yet sparse for the South African situation, and based on only a two pilot projects undertaken in Algoa Bay (dusky kob, silver kob, yellowtail) and Gansbaai (Atlantic salmon) (Ismail 2008; Nel & Winter 2009). Nel & Winter (2009) reported no demonstrable impacts above natural environmental variability for the farm outside Port Elizabeth Harbour where stocking densities were low. It must be emphasised, however, that these results cannot simply be applied to other areas where depths, oceanographic conditions, flushing rates and carrying capacities are likely very different, and farmed species and stocking rates may not be comparable.

The implementation of the MOM (Modelling-Outgrowing fish farms-Monitoring) management system (Ervik *et al.* 1997; Hansen *et al.* 2001; Stigebrandt *et al.* 2004) (or similar) is typically deemed essential in the development of an ADZ for finfish farming. The basic concept behind this approach is recognising that certain aspects of the receiving environment are more or less sensitive to the impacts of fish farming, and therefore have different capacities for production. By integrating the EIA, impact monitoring and environmental quality standards, the requirments for analytical and numerical models, and amount of environmental monitoring considered necessary is determined by the degree of the environmental impact. However, as the feasibility and environmental impacts of fish farming in South Africa are as yet unclear, a conservative approach must be adopted during the assessment of commercial scale production as part of the proposed Saldanha Bay ADZ. Furthermore, the dearth of local experience on the potential environmental impacts of proposed finfish culture will by default result in low to medium confidence in some of the significance ratings.

4.5.1 Seabed and water column effects

As the farming of finfish requires the addition of artificial diets, most ecological effects on the seabed and water column relate to the deposition of uneaten feed and faeces and the release of excreted ammonia. Particulate wastes expelled into the water column will settle onto the seabed near the farm. This intense local input of organic matter and nutrients can have pronounced effects on the sediments directly beneath finfish cages by 1) smother benthic communities, 2) creating potential risks of sediment anoxia and related changes in the physico-chemical properties of the sediments, with 3) concomitant alteration of benthic communities. The magnitude and extent of these effects will be site-specific and largely dependent on local hydrodynamic conditions and stocking density. Studies have shown, however, that there is a rapid improvement in environmental conditions with increasing distance (over tens or hundreds of metres) from farm structures (Merceron 2002; Kempf *et al* 2002; Forrest *et al.* 2007), although Sara *et al.* (2004) detected changes up to 1 000 m away. Although these seabed effects are largely reversible, recovery is likely to take many months or years, depending on water flushing characteristics of the site.

Modelling of nutrient and chemical waste dispersal from a single proposed commercial-scale fish farm at Mossel Bay (Mead *et al.* 2009), predicted that depositing wastes would sink to the sea floor within 200 m of the cages. In contrast, elevated levels of dissolved nutrients were predicted to occur up to 2 km from the fish cages, with nitrate levels expected to be above background concentrations as much as 8-12 km from the site under certain oceanographic conditions. Modelling calculations, however, assumed a very efficient Food Conversion Ratio (FCR) of 1.2 (Mead *et al.* 2009), and at more conservative ratios the impact footprint would thus likely be substantially more, implying that the cumulative impacts of organic waste discharge from several commercial-scale fish farms is likely to be significant. However, in comparatively shallow habitats (such as Saldanha Bay), where fish cages would be close to the seabed, depositional footprints are likely to be much reduced.

Expelled particulate wastes will also result in nutrient enrichment in the water column in the vicinity of finfish farms, which can 1) stimulate phytoplankton growth potentially leading to eutrophication and the development of algal blooms, 2) reduce water transparency, thereby affecting the growth of macroalgae and seagrasses, and 3) alter phytoplankton species composition and potentially favouring the development of HABs. These water column effects would be immediately reversible on removal of the farm.

Seabed and water column effects can be reduced by locating farms in well-flushed areas of suitable depth, in areas where species and habitats of special value are not present, or where flushing characteristics alter deposition patterns to a point where adverse effects do not occur. A range of other Best Practice steps to mitigate effects can be implemented (MPI 2013), including:

- selecting sites with good water exchange and sufficient depth to allow the cages to be held at least 5 m above the seabed (Bryars 2003; Beveridge 2004);
- manage stocking densities at levels that ensure the environment health is maintained. Optimum stocking densities and feeding rates, during each season and for different species of fish of different size classes, can only be determined after several seasons of rearing have taken place at each site (Schoonbee & Bok 2006);
- minimising feed wastage and chemical usage thereby optimising fish health and growth (Fernandes *et al.* 2001);
- using ‘high energy’ (i.e. resulting in reduced ammonia-N loading) and ‘low pollution’ (i.e. high digestibility, low phosphorus) diets; and
- destocking, or fallowing, a site after a growing cycle in order to allow seabed recovery prior to restocking.

Assuming that farms would be operational over the medium- to long-term, increased seabed effects from caged finfish culture facilities is deemed of high intensity within the immediate vicinity of the farm, with impacts persisting some years beyond the lifespan of the farm and is consequently considered to be of **HIGH** significance without mitigation. The implementation of mitigation, based on international best practice (e.g. MPI 2013) would reduce the significance to **MEDIUM**. If annual production figures are kept below 1 000 tpa to reach a maximum production of 5 000 tpa over a period of five years, hydrodynamic modelling is not deemed necessary, and the significance of the impact would reduce to **LOW**. The impact of fish farms is considered higher than that of shellfish farms due to the introduction of additional fish feeds.

Table 25 : Impact: Effects of finfish culture on nutrient enrichment, sediment physico-chemical properties and alteration of benthic communities

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	High 3	Long-term 3	**High** 7	Definite	**HIGH**	**- ve**	Low
Essential mitigation measures: • Select sites avoiding potentially sensitive and valuable habitats such as conservation areas (Malgas Island, Jutten Island, Langebaan Lagoon MPAs), biogenic habitats (e.g. kelp beds, seabird breeding and foraging areas) and reefs (e.g. Lynch Blinder, North Bay blinder) • Select suitably deep sites that allow cages to be held at least 5 m off the seabed • The configuration of finfish cages should not exceed a total coverage of 30% of the total area allocated for finfish farming, both within individual licence areas and overall within the portions of the ADZ identified for finfish culture • Prior to the development of finfish culture in Saldanha Bay, undertake analytical and numerical modelling exercises using detailed, site-specific current modelling data to predict the magnitude and extent of waste plumes generated, and to ensure that these do not impact on sensitive habitats such as the Saldanha Bay shoreline, important reefs and MPAs. **However**, if recommended mitigation measures for siting, buffer zones and managing stocking densities are implemented, a phased approach is taken for the development of finfish cage culture within the ADZ and annual finfish production does not exceed 1 000 tpa, reaching a maximum production of 5 000 tpa after five years, increasing thereafter only if monitoring results indicate environment health is maintained and impacts remain managable, analytical and numerical modelling around the precincts or individual farms is not deemed necessary. **Furthermore,** should production exceed 5 000 tpa, a precautionary approach must be applied, involving strict and intensified monitoring programmes and adherence to environmental quality standards. Should standards or precautionary limits be approached or exceeded, the monitoring plans should have a response procedure that leads to appropriate downward adjustments of fish production. • Manage stocking densities at levels to ensure that environment health is maintained. • Monitor and manage feeding regimes to minimise feed wastage and chemical usage. Use high digestibility high energy and low phosphorus feeds; species and system-specific feeds maximize food conversion ratios (and minimize waste) • Rotate cages within production areas to allow recovery of benthos • Limit annual increases in finfish production to no more than 1 000 t, and only if monitoring results indicate that environment health has been maintained and impacts remain manageable, up to 5 000 tpa ungraded production. • Only exceed finfish production of 5 000 tpa (after at least 5 years) to a maximum of 10 000 tpa if a precautionary approach is applied, involving strict and intensified monitoring programmes and adherence to environmental quality standards. Should standards or precautionary limits be approached or exceeded, the sampling and monitoring plans must include a response procedure that leads to appropriate downward adjustment of fish production. • Adopt the (relevant aspects of) MOM (Modelling-Outgrowing-Monitoring) management system (or similar) to monitor infaunal and epifaunal macrobenthic communities at farming sites. • Undertake ongoing, detailed benthic and water quality monitoring; including baseline surveys at control and impact sites, and decrease the ADZ carrying capacity should the environmental quality indicator be exceeded outside of the accepted sacrificial footprint								
With mitigation	Local 1	Medium 2	Long-term 3	**Medium** **6**	Definite	**MEDIUM**	**- ve**	Low

Increased water column effects from caged finfish culture facilities is deemed of medium intensity within the immediate vicinity of the farm, with impacts being immediately reversible on closure of the farm and is consequently considered to be of **MEDIUM** significance without mitigation. The implementation of mitigation would reduce the significance to **LOW**.

Table 26 : Impact: Effects of finfish culture on water column chemistry

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Medium 2	Long-term 3	**Medium** 6	Definite	**MEDIUM**	**- ve**	Medium
Essential mitigation measures: • Select sites avoiding potentially sensitive and valuable habitats such as conservation areas (Malgas Island, Jutten Island, Langebaan Lagoon MPAs), biogenic habitats (e.g. kelp beds, seabird breeding and foraging areas) and reefs (e.g. Lynch Blinder, North Bay blinder) • Manage stocking densities at levelsto ensure that environment health is maintained • Monitor and manage feeding regimes to minimise feed wastage and chemical usage • Rotate cages within production areas to allow recovery of benthos • Use high digestibility high energy and low phosphorus feeds; species and system-specific feeds maximize food conversion ratios (and minimize waste) • Limit annual increases in finfish production to no more than 1 000 t, and only if monitoring results indicate that environment health has been maintained and impacts remain manageable, up to 5 000 tpa ungraded production. • Only exceed finfish production of 5 000 tpa (after at least 5 years) to a maximum of 10 000 tpa if a precautionary approach is applied, involving strict and intensified monitoring programmes and adherence to environmental quality standards. Should standards or precautionary limits be approached or exceeded, the sampling and monitoring plans must include a response procedure that leads to appropriate downward adjustment of fish production. • Adopt the (relevant aspects of) MOM management system (or similar) in monitor water quality at farming sites								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Definite	**LOW**	**- ve**	Medium

4.5.2 Habitat creation and biosecurity

Finfish farms provide a three-dimensional suspended reef habitat for colonisation by fouling communities and the aggregation of wild fish. Cage structures therefore play an important role in the pelagic ecosystem through enhancement of local biodiversity and productivity. Wild fish in the vicinity of fish farms may be attracted to the cages to feed on waste feed or the fouling community, or to seek shelter from predators. The role of aquaculture structures as reservoirs for the establishment of pest organisms (e.g. fouling pests) is also recognised. The development of finfish farming in Saldanha Bay therefore has the potential to exacerbate the domestic spread of pest organisms, although various management approaches can be implemented to reduce such risks.

The creation of three-dimensional habitats in the water column by finfish caged culture facilities is deemed of medium intensity, with impacts persisting over the lifetime of the farm but being immediately reversible on farm closure. Consequently the impacts are considered to be of **MEDIUM** significance without mitigation. As there is no feasible mitigation for habitat creation other than the ‘no-project’ alternative, the significance would remain **MEDIUM**.

Table 27 : Impact: Effects of finfish culture on habitat creation

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Medium 2	Long-term 3	**Medium** 6	Definite	**MEDIUM**	**+ ve**	Medium
Essential mitigation measures:								

• No mitigation is feasible or possible other than the no-project alternative								
With mitigation	Local 1	Medium 2	Long-term 3	**Medium 6**	Definite	**MEDIUM**	**+ ve**	Medium

The potential effects of biosecurity risks from finfish cage culture are deemed of high intensity, would potentially persist beyond the duration of the aquaculture activities themselves and are thus considered to be of **VERY HIGH** significance without mitigation. Suitable management would reduce the significance to **MEDIUM**.

Table 28 : Impact: Introduction of alien invasive species or spread of fouling pests

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Regional 2	High 3	Long-term 3	**Very High** 8	Probable	**VERY HIGH**	**- ve**	High
MPI (2013) notes that there are three components to biosecurity management, namely: • **Prevention of incursions** is the most effective approach to biosecurity and should focus on the management of high-risk pathways, including from international source regions, new pathways, and regional sources known to be infected by recognised high-risk pests. • **Surveillance (detection)** focussing on entry surveillance (screening at airports and ports), routine surveillance (undertaken on and around marine farm structures and associated vessels and infrastructure by farm operators) or targeted surveillance of high-risk areas. • **Control of populations and outbreaks** requiring coordination with, and support from, all marine stakeholders (whose activities can spread unwanted organisms) and agencies at local, regional and national scales. Eradication measures and/or application of therapeutants are only advised if the risk of re-invasion can be managed and pests can be detected before they become widespread. **Essential mitigation measures:** • Ensure a high level of biosecurity management and planning is in place to limit the introduction of pests and diseases and to be able to respond quickly and effectively should biosecurity risks be identified • Farm operators should undertake routine surveillance on and around marine farm structures and associated vessels and infrastructure • Maintain effective antifouling coatings and regularly inspect farm structures and vessels for pests; clean structures and hulls regularly to ensure eradication of pests before they become established • Fouling organisms removed from farm structures must not be discharged back into the marine environment thereby ensuring that any introduced non-native fouling species not undetected previously, are not released into the wild • Ensure that veterinarian protocols to eliminate any pests, parasites and diseases are strictly adhered to								
With mitigation	Local 1	Medium 2	Long-term 3	**Medium 6**	Probable	**MEDIUM**	**- ve**	High

4.5.3 Seabirds and marine mammals

Potential effects on seabirds and marine mammals (seals, dolphins and whales) relate mainly to habitat modification, entanglement in structures, habitat exclusion, noise and human disturbance. On the southern African West Coast (and in Saldanha Bay) seals would be a problematic species around fish farms, leading to need for predator exclusion nets around sea-cages. Exclusion of marine mammals from critical habitat by finfish farms is at present negligible in Saldanha Bay given the current small scale of the industry. Risks from future development of both finfish and shellfish aquaculture are recognised, but could be minimised by appropriate site selection.

The potential for wider, more indirect ecosystem effects on seabirds and marine mammals due to finfish cage culture include food-web interactions (Black 2001; Kaiser 2001; Würsig & Gailey 2002; Kemper *et al*. 2003), biotoxin and pathogen outbreaks (Geraci *et al*. 1999; Kaiser 2001), and antibiotic use (Buschmann *et al*. 1996; Kaiser 2001). While these potential indirect interactions have been considered in the literature (Würsig & Gailey 2002; Kemper *et al*. 2003), no actual research on any indirect effect has yet been documented.

The scale and magnitude of the effect of finfish cage culture on seabirds, marine mammals and predators would depend largely on the location of a farm within the range of the species in question, its conservation status, and the duration of the effect. Of particular concern are negative interactions with species that are threatened, endangered, vulnerable or have restricted ranges. The probability of interaction is species dependent, with interaction with whales being unlikely, interaction with smaller cetaceans being possible and interactions with seals, diving seabirds and large predatory fish (particularly sharks) being definite. In particular, the area around Malgas Island has a high abundance of seals, who prey regularly on both adult and juvenile gannets, which nest on the island. Heavisides dolphins are also reported to frequent North Bay (DEA, pers. comm. 2016).

Overall, the effects are deemed of high intensity (due to the high threat status of some species involved), would persist for as long as the structures are in place and are thus considered to be of **HIGH** significance without mitigation. The impact of fish farms is considered higher than that of shellfish farms as most of the seabirds, as well as dolphins and seals are piscivores and thus more likely to be attracted to and affected by finfish farms. Suitable mitigation should reduce the significance to **LOW**. Any observed effects would persist only for as long as the farm is operational.

Table 29 : Impact: Effects of finfish cage culture on seabirds, marine mammals and piscivorous predators

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	High 3	Long-term 3	**High** 7	Definite	**HIGH**	**- ve**	High

Essential mitigation measures:

- The Saldanha Bay islands and their surrounding marine habitat serve as home ranges, and critical breeding and foraging habitats for a number of threatened, endangered or protected bird species. Siting of precincts to avoid MPAs, or implimentation of a buffer zone between an MPA and an adjacent precinct will mitigate impacts to some extent. However, as seabirds forage over a wide area and marine mammals and piscivorous predators occur throughout bay, there is no universal mitigation feasible or possible other than the no-project alternative.
- Ensure debris and waste material does not enter the water to minimise the risk of attraction and entanglement
- Remove any injured or dead fish from cages promptly
- Do not release any blood and/or offal (organic waste) from finfish into the bay
- Keep a log of all cetaceans, seabirds and predators recorded in the vicinity of fish farms, including behavioural observations
- Monitoring by farm personnel of presence (and absence) of marine mammal species in the vicinity or general region of the farm sites, as well as observations of any time spent under or around the farm structures. These data should be periodically compiled and analysed by experts
- Use predator exclusion nets as necessary; enclose nets at the bottom to minimise entanglement, keep nets taut, use mesh sizes of < 6 cm (Kemper *et al*. 2003), and keep nets well maintained (e.g. repairing holes)
- Install visual deterents for birds (e.g. tori line type deterents)
- Develop disentanglement protocols in collaboration with DAFF, DEA and the SA Whale Disentanglement Network and establish a rapid response unit to deal with entanglements

Best Management Practices:

- Develop and enforce strict maintenance and operational guidelines and standards in relation to potential entanglement risks on the farm including loose ropes, lines, buoys or floats
- Ensure all mooring lines and nets are highly visible (use thick lines and bright antifouling coatings)

<table>
<tr><td colspan="9">• Keep all nets and lines taught through regular inspections and maintenance
• Ensuring that minimal non-navigational lighting occurs at night and using downward-pointing and shaded lights
• Adopt appropriate maintenance and operational guidelines and standards for minimising noise in noise-generating equipment</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Low
1</td><td>Long-term
3</td><td>Low
5</td><td>Probable</td><td>LOW</td><td>- ve</td><td>High</td></tr>
</table>

4.5.4 Genetics, disease transfer and effects of escaped fish

Escape from fish farms is a common problem globally and can be expected from sea cage farming in Saldanha Bay. Given the exposed nature of the South African coast and the abundance of large piscivores, regular escapes, possibly of large numbers of stock as a result of cage failure or breach, is highly likely.

Potential interactions between escapees from fish farms and wild fish populations include:

- competition for resources with wild fish and related ecosystem effects from escapee fish,
- alteration of the genetic structure of wild fish populations by escapee fish, and
- transmission of pathogens from farmed stocks to wild fish populations.

These risks have been highlighted in international studies (primarily in relation to salmon farming), but at present levels of cage farming on the southern African West Coast are likely to be relatively minor issues. Effects from escapee salmonids are likely to be minimal given the small scale of the industry, the fact that only female fish will be farmed, and the absence of salmonid species in wild populations within the grow-out region. In the case of endemic linefish species, some of which would likely be trialled in Saldanha Bay cage farming, the risk of genetic contamination is accentuated by the collapsed status of many of the stocks. Ecosystem effects from escapees or significant genetic influences on relatively small wild stocks may occur, resulting in potential further loss of genetic diversity. For the culture of endemic species, this would, need to be considered further on a case-by-case basis as and when required).

The key factors that determine the likelihood that wild stocks will be affected by escapees are:

- The extent to which the stocks have been selectively bred from a limited brood stock
- The rate of escape or release
- Fish harvest size in relation to reproductive maturity and the ability of gametes to survive and develop in the wild
- The ability of escapees to survive and reproduce in the wild, as determined by their ability to feed successfully and interbreed with wild stocks
- The state (size, distribution, health) of the wild population

DAFF has developed “Genetic Best Practice Management Guidelines for Marine Finfish Hatcheries in South Africa” that recommend maintaining an effective broodstock population size of 30-150 individuals sourced from the area in which grow-out will take place, and also that broodstock are rotated between hatcheries and regularly replaced to ensure an effective population size of >100 (DAFF undated). The Marine Finfish Farmers Association of South Africa Environmental Impact Information Document includes similar recommendations, but also recommends reproductive sterility as the future key to eliminating the genetic impact of escaped fish on wild stock (MFFASA 2010).

The potential genetic impacts of escapees to wild stocks will remain a threat until reproductively sterile fingerlings are available for fish cage farming in South Africa. Genetic effects are almost certainly species- and location specific, as they will vary according to the abundance, distribution and behaviour of wild stocks. As such, the potential for escapee endemic stock to influence local ecosystems would need to be assessed on a species- and location-specific basis, and be based on knowledge of the ecological and fishery values at specific farm locations in relation to the species in question. The issues regarding the genetic contribution from farms to wild population *via* gametes from farm fish will also only apply if the farmed fish achieve reproductively mature size before reaching harvest size. The impact to endemic species would, however, extend across the natural range of the affected species, and as it would essentially be irreversible (within the foreseeable future but not over evolutionary timescales), is considered to be of high intensity, resulting in an overall **HIGH** significance without mitigation. Maintaining a large effective population size and genetic homogeneity between cultured and wild stock is potentially an effective mitigation measure, which would reduce the significance to **LOW** with the successful implementation of mitigation. In the case of salmonids, genetic interactions are improbable and are thus considered to be of low intensity and **LOW** overall significance.

Confidence in the prediction is low, as effects will be species- and location specific, and monitoring would be required to determine any changes in genetic diversity in wild stocks due to the influence of escaped culture stock. Negative impacts of reduced genetic diversity would only be reflected in the demographics of wild stocks should the population face a threat and reduced environmental fitness is exposed.

Table 30: Impact: Risks of genetic interactions of endemic culture species with wild populations

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Regional 2	High 3	Long-term 3	**Very High** 8	Possible	**HIGH**	**- ve**	Low
Essential mitigation measures: • Ensure suitable management and planning measures are in place to limit the possibility of genetic interactions • Implement the "Genetic Best Practice Management Guidelines for Marine Finfish Hatcheries" developed by DAFF and ensure adequate genetic monitoring of brood stock rotation • Use appropriate spawning regimes in the hatchery to maintain genetic diversity in the offspring • Use all female or triploid salmonids in the farms • Use robust, well-maintained containment systems • Maintain cage integrity through regular maintenance and replacement, and training of staff • Develop and implement recovery procedures should escapes occur **Best Management Practices:** • Develop the technology to create sterile fry for stocking of cages								
With mitigation	Regional 2	Low 1	Long-term 3	**Medium** **6**	Improbable	**LOW**	**- ve**	Low

The higher frequency and prevalence of diseases in cultured species compared to wild fish results primarily from the high density of fish within the net pen and therefore the increased likelihood that a pathogen will find a new susceptible host. Stress caused by adverse temperature and salinity levels, low oxygen or high carbon dioxide levels, poor diet, overcrowding, presence of predators, or high suspended solids will predispose fish to disease by raising blood cortisol concentration, which compromises the function of the immune system (Forrest *et al.* 2006).

There are many known diseases and parasites associated with finfish (Blaylock & Whelan 2004), and the spread of parasites, viruses and bacterial infections between caged and wild fish populations (from wild to farmed, or vice versa) is a significant concern for the fish farming industry worldwide (Pearson & Black 2001), with the estimated losses from sea lice (genus *Caligus*) infections of salmon stock alone amounting to hundreds of millions of dollars annually (Staniford 2002; Heuch *et al.* 2005). The parasites and diseases infecting the endemic species being considered for cage culture in Saldanha Bay are not well studied, although kob at least are known to be infected by sea lice of the same genus (*Caligus*) that caused serious problems amongst salmonids, as well as other copepod, trematode, Acanthocephalan (parasitic worm) monogean (specifically the gill fluke *Diplectanum oliverii),* dinoflagellates (*Amyloodinium ocellatum*) and myxozoan species (DEAT undated Grobler *et al.* 2002, Christison & Vaughan 2009, Joubert *et al.* 2009). Intensive sea bass and sea bream culture in the Mediterranean has also resulted in severe disease problems in fish farms; problem diseases include *Pasteurellosis* and *Nodavirosis*, and parasitic infections include *Ichtyobodo* sp., *Ceratomyxa* sp., *Amyloodinium ocellatum, Trichodina* sp., *Myxidium leei, and Diplectanum aequans* (Agius & Tanti 1997 cited in Staniford 2002).

Yellowtail are regarded as nomadic, white stumpnose are migratory within Saldanha Bay (Attwood *et al.* 2007; Kerwath *et al.* 2008), whilst silver kob within the vicinity (10-100 km) of future sea cages will also likely come into contact with farmed stock (Mann 2000). All three of these species (and any others with nomadic or migratory movement patterns) would therefore be at an increased risk of contracting diseases and or parasites from stocked fish and spreading them through wild populations, both locally within the bay and regionally. Potential negative effects on wild stocks are particularly concerning, as all three of these species are important in the commercial and recreational line fisheries and wild kob in the area is assessed as collapsed (Grifitths 2000).

Diseases and parasites can detrimentally affect both cultured and wild stocks, thereby adversely affecting production (e.g. reduced growth rates, unmarketable fish, and mass mortalities). Disease has been an issue within the Saldanha Bay salmon industry, and further issues may arise with other salmonids or endemics, depending on the location of the farms and the water quality in the area as a whole. This could lead to the use of therapeutants to manage disease risks, with concomitant indirect effects on ecosystem health.

The potential effects of the spread of diseases from finfish cage culture are deemed of high intensity, would potentially be irreversible, thereby persisting beyond the duration of the aquaculture activities themselves, and are thus considered to be of **HIGH** significance without mitigation. Suitable management would, however, reduce the significance to **VERY LOW**.

Table 31 : Impact: Transmission of diseases from cultured stock to wild populations

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Regional 2	High 3	Long-term 3	**Very High** 8	Possible	**HIGH**	**- ve**	High

There are three components to biosecurity management, namely:

- **Prevention of incursions** is the most effective approach to biosecurity and should focus on the management of high-risk pathways, including from international source regions, new pathways, and regional sources known to be infected by recognised high-risk pests.
- **Surveillance (detection)** focussing on entry surveillance (screening at airports and ports), routine surveillance (undertaken on and around marine farm structures and associated vessels and infrastructure by farm operators) or targeted surveillance of high-risk areas.
- **Control of populations and outbreaks** requiring coordination with, and support from, all marine stakeholders (whose activities can spread unwanted organisms) and agencies at local, regional and national scales. Eradication measures and/or application of therapeutants are only advised if the risk of re-invasion can be managed and pests can be detected before they become widespread.

Essential mitigation measures:

- Ensure biosecurity management and planning is in place within hatcheries, holding tanks and sea cages to limit the introduction of pests and diseases and to be able to respond quickly and effectively should biosecurity risks be identified
- Ensure all fry undergoes a health examination prior to stocking in sea cages
- Regularly inspect stock for disease and parasites as part of a formalised stock health monitoring programme and take necessary action to eliminate pathogens through the use of approved therapeutic chemicals or improved farm management
- Maintain comprehensive records of all pathogens and parasites detected as well as logs detailing the efficacy of treatments applied
- Locate cages stocked with different cohorts of the same species as far apart as possible; if possible stock

different species in cages successively • Treat adjacent cages simultaneously even if infections have not yet been detected. • Have good house-keeping practices in place at all times i.e. keep nets clean and allow sufficient fallowing time[15] on sites to ensure low environmental levels of intermediates hosts and or pathogens • Regularly inspect stock for disease and/parasites as part of a formalised stock health monitoring programme **Best Management Practices:** • Restrict stocking densities to below 15-20 fish per m^3 to limit the spread of diseases and parasitic infections								
With mitigation	Local 1	High 3	Long-term 1	**Low** **5**	Possible	**VERY LOW**	**- ve**	High

4.5.5 Therapeutants and trace contaminants

Therapeutants (pharmaceutical products, or 'medicines'), disinfectants, anti-fouling paints and feed are all potential sources of chemicals to the marine environment from finfish farms. Some chemical contaminants have the potential to accumulate and persist in the marine environment, resulting in deleterious effects to biota (Hansen & Lunestad 1992; Kerry *et al*. 1995, Costello *et al*. 2001). Inappropriate use of medicines may lead to resistance in pathogenic organisms. Therapeutant treatments are typically parasite or disease-specific, as many parasites and diseases are location and host-specific. As such, the potential for environmental issues from therapeutant use will need to be assessed on a case-by-case basis. In general, however, most therapeutants are water soluble and break down readily and therefore have limited environmental significance. Those administered as feed additives, however, can be deposited on the seabed or taken up by other animals feeding on the feed-waste.

Internationally, increased levels of trace metals (zinc and copper) have been reported in sediments beneath fish cages. Zinc is a nutritional supplement necessary for maintaining fish health, and copper comes from antifouling paints used to minimise the build-up of fouling organisms. Both zinc and copper are likely to bind with sediments and organic material, which will naturally mitigate their risk to the environment. Other chemical contaminants such as dioxins, polychlorinated biphenyls (PCBs) and heavy metals like mercury, are globally ubiquitous compounds that accumulate in animal tissue (including humans) *via* the food chain.

Global bodies, (e.g. WHO and GESAMP), have highlighted the environmental and public health threats of chemical use on fish farms. Consequently, the salmon farming industry has moved away from the use of antibiotics and organophosphates, but numerous other potentially hazardous chemicals such as synthetic pyrethroids, artificial colorants, antifoulants, and antiparasitics are still a serious concern (Staniford 2002).

The future South African finfish aquaculture industry will almost certainly need to use chemicals to protect infrastructure and treat stock. In line with the DAFF Marine Aquaculture Code of Conduct, which stipulates that no chemicals and treatments procedures are be used unless approved by the governing authorities, the MFFASA code of conduct recommends avoiding hazardous chemical use, minimizing the use of agricultural, veterinary and industrial chemicals and adherence to legal requirements when these are required (MFFASA 2010). Contaminant inputs to the environment should thus be minimise to ensure contaminant loads remain within acceptable limits in the future, as if not managed wider natural processes may be affected or altered if chemicals used in fish cage operations bio accumulate up food chains.

[15] "Fallowing" as a parasite and disease mitigation measure refers to leaving all cages within an ADZ area (or bay) un-stocked for a period of at least two months. "Pseudo-fallowing" in this respect can be achieved by stocking all cages with a different species therefore lowering the environmental load of species-specific pathogens

The potential effects of therapeutants and trace contaminants resulting from finfish cage culture are deemed of medium intensity, would potentially persist beyond the duration of the aquaculture activities themselves and are thus considered to be of **MEDIUM** significance without mitigation. Suitable management would, however, reduce the significance to **LOW**.

As the tendency for bioaccumulation of many of the chemicals used in fish cage culture is not well understood, the level of confidence in the assessments is low-medium. Furthermore, the biological availability and ecotoxicity of these contaminants in the environment would be site, species and even population specific.

Table 32 : Impact: Chemical use

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Medium 2	Long-term 3	**Medium** 6	Probable	**MEDIUM**	**- ve**	Medium
Essential mitigation measures: • Use only approved veterinary chemicals and antifoulants • Reduce levels of nutritional therapeutants and trace contaminants in feed using only the lowest effective doses • Use the most efficient drug delivery mechanisms that minimises the concentrations of biologically active ingredients entering the environment • Establish and adhere to guidelines around the use of anti-fouling products in the mariculture industry • Do not apply antifoulants on site and use environmentally friendly alternatives where effective								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Probable	**LOW**	**- ve**	High

4.6 Assessment of Impacts from Seaweed Farming

Beds of *Gracilaria verrucosa* occur naturally in Saldanha Bay; in Small Bay, in the mouth of Langebaan Lagoon and patchily distributed over the sandflats (Rothman *et al*. 2009; Clark *et al*. 2015). As beach-cast yields of this species have varied substantially since the construction of the Marcus Island Causeway and the iron ore jetty (Rothman *et al*. 2009), experimental open-water cultivation of the species was investigated at several sites in Saldanha Bay and in St Helena Bay. This proved unsuccessful, however, due to unfavourable growth conditions and overgrowth of suspended ropes by mussel spat. Nonetheless, the demand for algae both as an abalone feed and for fertilizer may provide incentive for new ventures in the cultivation of seaweeds in the future.

International studies generally conclude that the cultivation of seaweeds would typically have minor ecological effects on the water column and seabed (MPI 2013). The effects of suspended subtidal ropes growing *Gracilaria* on the hydrodynamics of the water column (currents, waves, stratification) would be similar to other suspended aquaculture activities (long lines and cages), as discussed previously. Local farm-scale changes in current flow are almost certain, although they would be immediately reversible on removal of all structures (MPI 2013). The typically large surface area required for viable seaweed culture, however, implies that the physical impact of sea-based systems may have more extensive effects. For example, the careful siting of large farms are reported to help protect coastal areas from erosion or can be used to shelter areas where more fragile and sensitive culture species and systems (e.g. scallop culture) are located (Phillips 1990).

As with shellfish and finfish farms, the introduction of seaweed culture rafts, ropes, anchors and other structures can change the characteristics of the seabed, thereby functioning as artificial reefs and enhancing production of other marine organisms in open waters or otherwise barren areas. For example, farms in Republic of Korea, Japan and China have effectively utilized the seabed below seaweed farms for the culturing of abalone, scallops and sea cucumber, thus maximising the production and profit per unit area (UNDP/FAO 1989; Phillips 1990). Otherwise, seabed effects resulting from algae culture are expected to be relatively minor or even negligible (MPI 2013).

Most other potential environmental effects reflect those discussed above for shellfish and finfish culture. These include:

- shading and its associated potential localised effects on primary productivity (Eklöf *et al.* 2005a);
- localised enhancement of invertebrate and vertebrate herbivores and their predators in response to an increase in available habitat and food supply (Phillips 1990; Eklöf *et al.* 2005b; Zemke-White & Smith 2006; MPI 2013);
- risks of entanglement in farm structures, habitat exclusion, changes in prey abundance and disturbance of marine mammals and seabirds (MPI 2013);
- introduction of alien species in cases where the cultivated seaweed is non-native. In Saldanha Bay this would not be an issue as any *Gracilaria* stock used in the farms would most likely be sourced locally;
- transfer of diseases as a result of seaweed culture has not been documented internationally (Phillips 1990). In Saldanha Bay, the biosecurity risks arising from commercially farming *Gracilaria* would be minimal as the species occurs there naturally;
- the use of chemicals for the prevention and control of disease, water treatment, removal of predators and prevention of fouling organisms and epiphytes has only been documented for isolated cases of intensive and semi-intensive seaweed aquaculture (Santelices & Doty 1989; North 1987; Phillips 1990);
- sloughing off or storm-induced removal of algae from a farm may result in accumulation of drift weed on nearby coastal margins where it may smother the benthos, decompose and cause sediment anoxia (MPI 2013). However, drift macroalgae also comprises an important habitat and food source for sandy beach macrofauna and other coastal invertebrates, and is used as nesting material by cormorants.

As algae function at a lower trophic level and use dissolved nutrients (mainly nitrates, phosphates, silicon) for growth, the only potential water column effect is nutrient extraction, with a possible knock-on effect of reduced nutrient availability for natural phytoplankton populations and other algae species thereby potentially affecting patterns of nutrient recycling and secondary productivity. In areas of high density seaweed culture, the removal of nutrients not only has implications for the long-term viability of seaweed farming itself, but over-production is thought to result disease outbreaks and production losses (Phillips 1990). However, the effect of acting as nutrient sinks has led to extensive research into the bioremediation potential of culturing algae in integrated systems, particularly in conjunction with finfish farms (Troell *et al.* 1997; Troell *et al.* 1999; Zhou *et al.* 2006; Blouin *et al.* 2007; Kang *et al.* 2008; Xu *et al.* 2008). Troell *et al.* (1997, 1999) specifically studied the potential for reducing environmental impacts of salmon cage farming by integrated marine cultivation of *Gracilaria chilensis*. Results indicated that by integrating seaweeds with fish farming the nutrient assimilating capacity of the aquaculture area increased and that the seaweed production and assimilation of dissolved ammonia released from the salmon farm was more than twice that of a *Gracilaria* monoculture. The uptake of nutrients by seaweeds also offers scope for improving the quality of the receiving water in areas where effluents are discharged from land-based aquaculture operations.

Experimental cultivation of *Gracilaria* in Small Bay has proven unsuccessful, primarily due to the periodically warm and nutrient-poor conditions of surface waters in the bay. This indicates the importance of balancing seaweed production with natural nutrient availability for production. Farming of this macroalga in the proposed ADZ would thus only be appropriate in areas of the bay that remain well mixed, or in conjunction with an artificial nutrient source such as a shellfish or finfish farm.

Gracilaria has been successful as a co-culture species for use in Integrated Multi-Trophic Aquaculture (IMTA) in other parts of the world, suggesting that in the proposed ADZ consideration should rather be given to its use in integrated culture systems than as a monoculture. Selection of sites in this case would depend on the location of existing or proposed shellfish and/or finfish activities, and the hydrodynamic conditions in their immediate vicinity.

As a monoculture, the overall effects of seaweed cultivation are deemed of low intensity, would persist for as long as the structures are in place and are thus considered to be of **LOW** significance without mitigation. By integrating successfully seaweed cultivation with shellfish or finfish culture the impacts would reduce to **VERY LOW** significance. Any observed effects would persist only for as long as the farm is operational.

Table 33 : Impact: Effects of seaweed culture

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Local
1</td><td>Low
1</td><td>Long-term
3</td><td>Low
5</td><td>Definite</td><td>LOW</td><td>- ve</td><td>High</td></tr>
<tr><td colspan="9">Best practice mitigation measures:
• Select sites avoiding potentially sensitive and valuable habitats such as conservation areas (Malgas Island, Jutten Island, Langebaan Lagoon MPAs), biogenic habitats (e.g. kelp beds, seabird breeding and foraging areas) and reefs (e.g. Lynch Blinder, North Bay blinder)
• Use only locally sourced Gracilaria for stocking the ropes
• Use as a co-culture species for use in Integrated Multi-Trophic Aquaculture (IMTA) rather than as monoculture
• Strict maintenance and operational guidelines and standards in relation to potential entanglement risks on the farm including loose ropes, lines, buoys or floats
• Avoid the use of fertizers or chemicals and use only approved chemicals and antifoulants
• Ensure debris and waste material does not enter the water to minimise the risk of attraction and entanglement
• Monitoring by farm personnel of presence (and absence) of seabirds and marine mammal species in the vicinity or general region of the farm sites, as well as observations of any time spent under or around the farm structures. These data should be periodically compiled and analysed by experts
• Adopt appropriate maintenance and operational guidelines and standards for minimising noise in noise-generating equipment
• Undertake ongoing, detailed water quality monitoring</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Low
1</td><td>Long-term
3</td><td>Low
5</td><td>Possible</td><td>VERY LOW</td><td>- ve</td><td>High</td></tr>
</table>

4.7 Assessment of Cumulative Impacts

With the development of the ADZ, and as the number of farms in Saldanha Bay (and in other suitable sheltered sites along the coast) increases, it will become increasingly important to consider wider-ecosystem issues due to the cumulative environmental effects that could arise from expanded or multiple farms in combination with additional anthropogenic stressors affecting the marine environment. Environmental sustainability of maritime industries requires an understanding of the cumulative effects on the environment and the ability to measure environmental change in response to multiple stressors. Saldanha Bay and its surrounding coastal waters are the receiving environment for a range of contaminants derived from land- and sea-based industries. Furthermore, activities such as fishing, tourism, shipping, and coastal development present multiple stressors that cumulatively interact with natural processes and affect the health of the marine ecosystem. Many of these activities (and their effects) operate on different spatial and temporal scales. The coastal marine environment is physically dynamic and conditions are inherently variable in response to topography, weather and climate-related processes. Climate change will therefore also contribute to long-term environmental change and could influence the extent to which various human activities impact on the marine environment.

Aquaculture can lead to a range of effects on the marine environment and, at some level, contribute to cumulative environmental change. There are various ways in which aquaculture developments could result in cumulative effects, namely:

- The additive effects of an increasing number of marine farms in a relatively localised area like Saldanha Bay (e.g. multiple local scale benthic footprints),
- Additive effects of a single stressor from multiple sources in addition to marine farms (e.g. dissolved nitrogen from marine farms adds to point source inputs from fish factories or sewage works),
- Additive and synergistic effects of multiple stressors from a single source (e.g. organic enrichment of the seabed under a farm in combination with potential ecotoxic effects of contaminants from feeds or antifouling products), and
- Additive and synergistic effects of multiple stressors from multiple sources.

Assessing the contribution of aquaculture to environmental change resulting from the cumulative effects associated with multiple developments in the bay, is beyond the scope of this study as it would depend on the accessibility and co-ordination of multiple datasets from multiple user groups. Such cumulative issues would best be addressed by government agencies. The cumulative effects discussed here will focus on the additive effects of an increasing number of marine farms in a relatively localised area, keeping additive and synergistic effects to an already compromised environment in mind.

At the local (bay-wide) scale the main cumulative effects to consider are:

- The effect of additional suspended culture farms on the flushing rates within Big Bay and Small Bay. Construction of the iron ore jetty has already reduced the flushing rates in Small Bay leading to the accumulation of organic muds in isolated areas. Further reduction of flushing rates through the introduction of multiple farms in Small Bay may aggravate current regimes in Small Bay thereby further compromising water and sediment quality. Depending on the extent of future expansions of farms in the ADZ, these effects may also manifest in Big Bay, with potential knock-on effects on Langebaan Lagoon. Numerous farms situated along the coast could also have cumulative effects on nearshore currents and waves, potentially changing the wave exposure of the shoreline, with concomitant responses by intertidal communities or changes to important processes such larval transport and nutrient exchange. Bio-physical models should be used, to gain a better understanding of the magnitude of the cumulative effects of an increased number of farms on the hydrodynamics of the bay.
- Changes in current regimes, and the net extraction of plankton by increased filter-feeding biomass of shellfish farms could result in cumulative changes in nutrient conditions and plankton abundance and community composition, both at the farm scale but with knock-on effects on the wider ecosystem. Similarly nutrient emissions to the water column and seabed through feed-added aquaculture and increased biodeposition can have cumulative effects on nutrient conditions and primary production, both at local and bay-wide scales. The potential contribution of different types of aquaculture to these cumulative effects would need to be considered together, since both forms of aquaculture are likely to co-occur in Saldanha Bay and therefore contribute to wider-ecosystem conditions. Additional point source inputs from outfalls would also need to be considered. Application of food web models would assist in estimating and forecasting the range of possible cumulative effects to higher trophic levels.

- An increase in the number and variety of farms within the bay may also effect changes in the abundance and composition of benthic and fish communities in the wider ecosystem due to the alteration of habitat, changes in fishing pressure, and changes in food availability. For example, mussel drop-off and biofouling organisms create reef-like habitats beneath mussel farms thereby altering the composition and abundance of benthic organisms. Although this comprises only a relatively low-level impact at the local scale, high densities of mussel farms or ribbon-like developments would alter a larger proportion of the seabed within the bay from soft sediment habitats to reef habitats thereby leading to cumulative effects on the wider ecosystem. There is also the potential for changes to habitats and/or migration routes of higher-order organisms such as mammals or seabirds.

At the regional scale the main cumulative effects to consider are:

- As aquaculture development intensifies within Saldanha Bay, there will be a concomitant increase in man-made structures and boat traffic, thereby increasing the risk of invasion and establishment of pests. This is not restricted to the aquaculture industry alone, but includes introductions from fishing vessels and other vessels visiting the port. Biosecurity issues surrounding the introduction and spread of pests are probably the highest cumulative ecological risk, especially in areas where proposed farms are located in the vicinity of sensitive habitats such as islands and MPAs.

At the national scale the main cumulative effects to consider are:

- The contracting of diseases and/or parasites from farmed endemic species and their spread to wild populations, and the alteration of the genetic structure of wild fish populations by escapee fish from culture facilities could potentially have cumulative effects at the national scale if the species in question is migratory. Being largely irreversible such impacts are perhaps of greatest concern in the development of the ADZ, particularly considering its proximity to MPAs.

The likelihood of any cumulative effects of shellfish and finfish aquaculture in Saldanha Bay would be dependent on the size of the culture, the sensitivity of the organisms in the receiving ecosystem and the proximity of the system to any perceived “tipping points” (e.g. Langebaan Lagoon or the MPAs).

Spatial modelling tools offer a way of estimating the extent to which the cumulative effects of shellfish and finfish farming may be approaching ecological carrying capacity on “bay-wide” and “regional” scales. However, such models often suffer from knowledge gaps, particularly as regards site-specific hydrodynamic regimes and biological aspects (e.g. feeding behaviour and growth of the stock), and long-term *in situ* monitoring of important ecosystem parameters are typically necessary to refine models to the stage that they can confidently determine how close a development would come to exceeding the ecological carrying capacity.

According to Probyn *et al.* (2015) there is considerable scope for expanding bivalve farming in Saldanha Bay above present levels with minimal threat to the integrity of the ecosystem in the bay. An assessment of the potential cumulative impacts associated with the proposed ADZ development would, however, require further information on the number and types of farms to be implemented, their location and the results of suitable model to determine their cumulative ecosystem effects.

In the development of the ADZ, it is important that consideration be given to the development of a comprehensive environmental code of practice for the industry as a whole. To this end, DAFF has developed the Marine Aquaculture Code of Conduct, which is supplemented by the MFFASA code of conduct specifically for finfish culture. These should be integrated into a combined code of practice covering all potential future mariculture approaches (shellfish, finfish, algae) and setting production limits for individual ADZs relative to the ecological carrying capacity of the receiving environment. Included could be protocols covering the use of antifoulants, maintenance and operational guidelines and standards in relation to potential entanglement risks, monitoring of seabirds, marine mammals and piscivorous predators, monitoring requirements and standards, and compliance reporting etc. Furthermore, at greater scales of development (i.e. where multiple farms or atypically large farms are proposed) it would be appropriate to adopt a staged approach for expansion within an adaptive management and monitoring framework, especially for issues where potential cumulative effects are recognised.

Consideration should be given to the development of Integrated multi-trophic Aquaculture (IMTA) as this can theoretically mitigate some of the potential cumulative effects stemming from aquaculture. IMTA combines, in the appropriate proportions, the cultivation of organic extractive aquaculture species (e.g. shellfish) and inorganic extractive aquaculture species (e.g. seaweeds) in close proximity to fed aquaculture species (e.g. finfish). For example, phytoplankton stimulated by excess finfish farm-derived nutrients can be consumed by mussels, while dissolved nutrients from fish and mussels can be assimilated by adjacent seaweeds at the farm. Co-cultured species could then be harvested to improve the economic performance of the farm.

Such a balanced ecosystem management approach would nonetheless need to take into consideration site specificity, operational limits, and food safety guidelines and regulations.

5 RECOMMENDATIONS AND CONCLUSIONS

5.1 Proposed Mitigation Measures and Management Actions

The most important mitigation measures and management actions to consider during the development of the ADZ are summarised below:

5.1.1 Essential Mitigation Measures

Siting of farms and annual production

The impacts assessed above relate to the full extent of the proposed ADZ as outlined in Figure 1 and Table 1 (see page 6), and the maximum potential annual ungraded production limits for mussels and oysters as estimated by Heinecken *et al.* (2016). During the siting of individual aquaculture farms and expansion of the ADZ, it is important to consider a number of environmental best practices presented in the international literature. These are summarised below:

- Precincts should be carefully selected to favour well-flushed, deep and productive areas (Big Bay North, Outer Bay North, Outer Bay South) and avoid overlap with potentially sensitive and valuable habitats such as conservation areas (Malgas Island, Jutten Island, Langebaan Lagoon MPAs), biogenic habitats[16] (e.g. kelp beds) and reefs (e.g. Lynch Blinder, North Bay blinder).

  To this end a 500 m buffer zone in which no shellfish mariculture development is permitted and a 1 000 m buffer in which no finfish culture is permitted is recommended around the Malgas Island MPA, which has a more sensitive gannet breeding population that could be further affected by seals attracted by fish farms[17], and the entrance to the Langebaan Lagoon. It is understood that a 250 m-wide buffer is deemed sufficient by DEA at Jutten Island. The buffers would in effect reduce the size of the precincts in Big Bay South, Outher Bay North and Outer Bay South (Figure 12).

  Furthermore, a 100 m-wide buffer is recommended around reefs and blinders. The extent of the proposed buffers is based on model results from New Zealand, which indicated that depositional footprints of >250 m were possible for shellfish farm sites in more energetic environments or greater water depth (Hartstein & Stevens 2005; Stenton-Dozey *et al.* 2008). The results of Mead *et al.* (2009) indicated that nutrient effects in the water column could extend several kilometres from commercial-scale finfish farms.

- Assuming the full extent of the proposed ADZ (i.e. no buffer zones) and maximum total ungraded annual **shellfish production** of 27 600 tpa within the precincts (Heinecken *et al.* 2016), it is deemed essential that predictive analytical and numerical modelling be undertaken before authorisation for the ADZ is granted. This is particularly important where proposed shellfish precincts are located adjacent to MPAs. This would include for example, predicting the effects of shellfish farming on local currents, stratification and wave climates and using the results to develop alternative farm designs to minimise possible localised hydrodynamic changes. Such models could also provide an indication of the extent of depositional footprints of biological and feed wastes generated by farms, effects on water column nutrient parameters (dissolved carbon, nitrogen and phosphorous) and seston depletion shadows (chl a, phytoplankton abundance and species composition) in response to the farm structures and stock, to ensure that these do not impact on sensitive habitats such as the Saldanha Bay

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[16] This includes home ranges, critical breeding and foraging habitats and migration routes of threatened, endangered or protected bird and marine mammal species, as well as critical fish spawning grounds and nursery areas.

[17] It is understood that the existing boundaries of the island MPAs have been set so as to protect the island as well as its surrounding kelpbed/reef habitats.

shoreline, important reefs and MPAs. This is particularly important in sheltered bays, where hydrodynamics have been compromised by other developments and where proposed precincts are in the immediate vicinity of potentially sensitive and valuable habitats. This is the approach recommended by the MOM management system, and was also recommended for the Algoa ADZ (Hutchings *et al.* 2013) and for Saldanha Bay by Probyn *et al.* (2015).

However, if a phased approach is taken to the development of the ADZ and ungraded shellfish production is limited to around 10 000 tpa for the first two years, increasing annually thereafter by 5 000 tpa to a maximum of 27 600 tpa ungraded production, as monitoring data becomes available, hydrodynamic modelling is not deemed necessary.

- Prior to the development of **finfish culture** in Saldanha Bay, undertake analytical and numerical modelling exercises using detailed, site-specific current modelling data to predict the magnitude and extent of waste plumes generated, and to ensure that these do not impact on sensitive habitats such as the Saldanha Bay Bay shoreline, important reefs and MPAs.

  However, if recommended mitigation measures for siting, buffer zones and managing stocking densities are implemented, a phased approach is taken for the development of finfish cage culture within the ADZ and annual finfish production does not exceed 1 000 tpa, reaching a maximum production of 5 000 tpa after five years, increasing thereafter only if monitoring results indicate environment health is maintained and impacts remain managable, analytical and numerical modelling around the precincts or individual farms is not deemed necessary.

  Furthermore, should production be expanded above 5 000 tpa, a precautionary approach must be applied, involving strict and intensified monitoring programmes and adherence to environmental quality standards. Should standards or precautionary limits be approached or exceeded, the monitoring plans should have a response procedure that leads to appropriate downward adjustments of fish production.

- Fish cages should be located at suitably deep sites that allow cages to be held at least 5 m off the seabed. The configuration of finfish cages should not exceed a total coverage of 30% of the total area allocated for finfish farming, both within individual licence areas and overall within the portions of the ADZ identified for finfish culture.
- Regardless of final proposed future production figures, a phased approach to expansion of shellfish and finfish farms within the Saldanha Bay ADZ is considered prudent. Should proposed production levels exceed the recommended initial annual ungraded shellfish production of 10 000 tpa and 1 000 tpa production for finfish, or the ADZ be further expanded, a modelling approach to predict the effects of the farms on the marine environment should be applied.
- Ensure mooring systems are well designed to prevent/limit movement of anchors and chains over the sea floor.
- Leave mooring anchors or blocks in place when undertaking cage net maintenance or fallowing sites to avoid repetitive impacts of the same activity at each site

Farm operation

- Avoid high density culture and overcrowding of mussel droppers, oyster stacks and other structures in shellfish farms. The recommended density is one raft of 800 droppers per ha; 11 longlines of 832 droppers per ha; 11 longlines of 176 oyster stacks/abalone barrels per ha (Heinecken *et al.* 2016).
- Implement recommended monitoring of biodeposition and physico-chemical changes in seabed properties, infaunal and epifaunal macrobenthic communities, at shellfish and finfish farming sites relative to undisturbed control sites (Recommended marine monitoring components of an

EMPr for the Saldanha Bay ADZ are given in Appendix II). For finfish farms, adopt the (relevant aspects of) MOM management system (or similar) in monitor infaunal and epifaunal macrobenthic communities at farming sites.

- Manage fish stocking densities to ensure the environmental and stock health is maintained. Optimum stocking densities and feeding rates, during each season and for different species of fish of different size classes, can only be determined after several seasons of rearing have taken place at each site (Schoonbee & Bok 2006).
- Monitor and manage feeding regimes in finfish farms to minimise feed wastage and chemical usage.
- Use species and system-specific highly digestible, high energy and low phosphorus fish feeds to maximize food conversion ratios and minimize waste.
- Rotate cages within production areas to allow recovery of benthos.
- Install visual deterents for birds (e.g. tori line type deterents).
- Ensure debris and waste material does not enter the water to minimise the risk of attraction and entanglement by seabirds, marine mammals and large predators.
- Keep a log of all cetaceans, seabirds and predators recorded in the vicinity of fish farms, including behavioural observations.
- Monitoring by farm personnel of presence (and absence) of marine mammal species in the vicinity or general region of the farm sites, as well as observations of any time spent under or around the farm structures. These data should be periodically compiled and analysed by experts.
- Use predator exclusion nets as necessary; enclose nets at the bottom to minimise entanglement, keep nets taut, use mesh sizes of < 6 cm (Kemper *et al*. 2003), and keep nets well maintained (e.g. repairing holes).
- Remove any injured or dead fish from finfish cages promptly and do not release any blood and/or offal (organic waste) from finfish into the bay.
- Develop disentanglement protocols in collaboration with DAFF, DEA and the SA Whale Disentanglement Network and establish a rapid response unit to deal with entanglements.
- Minimise the potential for litter entering the marine environment (particularly plastic wastes).
- Do not apply antifoulants on site and use environmentally friendly alternatives where effective.

Biosecurity, genetics and disease

- Ensure a high level of biosecurity management and planning is in place within hatcheries, holding tanks and sea cages to limit the introduction of pests and diseases and to be able to respond quickly and effectively should biosecurity risks be identified.
- Have good house-keeping practices in place at all times i.e. keep nets clean and allow sufficient fallowing time on sites to ensure low environmental levels of intermediates hosts and or pathogens.
- Farm operators should undertake routine surveillance on and around marine farm structures and associated vessels and infrastructure for indications of non-native fouling species.
- Maintain effective antifouling coatings and regularly inspect farm structures and vessels for pests; clean structures and hulls regularly to ensure eradication of pests before they become established.

- Fouling organisms removed from oyster stacks, abalone barrels and finfish cages should not be discharged back into the marine environment thereby ensuring that any introduced non-native fouling species not undetected previously, are not released into the wild.
- Develop South African bivalve hatcheries to reduce the reliance on spat import, and hence the risk of non-intentional introduction of associated alien species and diseases.
- If spat import cannot be avoided, culture facilities should only be permitted to use spat sourced from biosecure certified hatcheries and/or quarantine facilities.
- Ensure that veterinarian protocols to eliminate any pests, parasites and diseases are strictly adhered to.
- Ensure suitable management and planning measures are in place to limit the possibility of genetic interactions.
- Ensure good physical and biological containment to limit the effects of escaped stocks.
- Implement the "Genetic Best Practice Management Guidelines for Marine Finfish Hatcheries" developed by DAFF and ensure adequate genetic monitoring of brood stock rotation.
- Use appropriate spawning regimes in the hatchery to maintain genetic diversity in the offspring.
- Develop the technology to create sterile fry for stocking of cages.
- Use robust, well-maintained containment systems to reduce the likelihood of escapes.
- Develop and implement recovery procedures should escapes from finfish farms occur.
- Ensure all spat and fry undergo a health examination prior to stocking in sea cages.
- Take necessary action to eliminate pathogens through the use of therapeutic chemicals or improved farm management.
- Regularly inspect stock for disease and/parasites as part of a formalised stock health monitoring programme.
- Maintain comprehensive records of all pathogens and parasites detected as well as logs detailing the efficacy of treatments applied.
- Locate cages stocked with different cohorts of the same species as far apart as possible; if possible stock different species in cages successively.
- Have good house-keeping practices in place at all times i.e. keep nets clean and allow sufficient fallowing time on sites to ensure low environmental levels of intermediates hosts and or pathogens.
- Treat adjacent cages simultaneously even if infections have not yet been detected.
- Use only approved veterinary chemicals and antifoulants.
- Reduce levels of nutritional therapeutants and trace contaminants in fish feed using only the lowest effective doses.
- Use the most efficient drug delivery mechanisms that minimise the concentrations of biologically active ingredients entering the environment.
- When farming seaweeds, use only locally sourced *Gracilaria* for stocking the ropes.
- Use seaweeds as a co-culture species for use in Integrated Multi-Trophic Aquaculture (IMTA) rather than as monoculture.

5.1.2 Best Management Practices

- Implement monitoring of the immediate water column around the precincts or specific farms for nutrient parameters (dissolved carbon, nitrogen and phosphorous).
- Implement monitoring of the immediate water column around the precincts or specific farms for key plankton (chl a, phytoplankton abundance and species composition) parameters.
- Ensuring that minimal non-navigational lighting occurs at night and using downward-pointing and shaded lights.
- Develop and enforce strict maintenance and operational guidelines and standards in relation to potential entanglement risks on the farm including loose ropes, lines, buoys or floats.
- Ensure all mooring lines and rafts are highly visible(use thick lines and bright antifouling coatings).
- Keep all lines taught through regular inspections and maintenance.
- Develop disentanglement protocols in collaboration with DAFF, DEA and the SA Whale Disentanglement Network and establish a rapid response unit to deal with entanglements.
- Adopt appropriate maintenance and operational guidelines and standards for minimising noise in noise-generating equipment.
- Establish and adhere to guidelines around the use of anti-fouling products in the mariculture industry.
- Restrict stocking densities to below 15-20 fish per m^3 to limit the spread of diseases and parasitic infections.
- Avoid the use of fertizers or chemicals in the culture of seaweeds.

5.2 Recommended Monitoring Requirements

Over and above the mitigation measures and management actions proposed above, international best practice (e.g. MPI 2013) recommends certain monitoring requirements for aquaculture licence areas, and these should be adopted for any licences issued as part of the Saldanha Bay ADZ. These include:

- Routine monitoring at specific intervals should be undertaken once the site is operational.
- For finfish farms, adopt the (relevant aspects of) MOM management system (or similar) in monitor infaunal and epifaunal macrobenthic communities at farming sites. The basic concept behind this approach is recognising that certain aspects of the receiving environment are more or less sensitive to the impacts of fish farming, and therefore have different capacities for production. By integrating the EIA, impact monitoring and environmental quality standards, the requirments for analytical and numerical models, and amount of environmental monitoring considered necessary is determined by the degree of the environmental impact. However, as the feasibility and environmental impacts of fish farming in South Africa are as yet unclear, a conservative approach must be adopted during the establishment of commercial scale production as part of the proposed Saldanha Bay ADZ.
- Submission of annual monitoring reports to the authorities should form part of the permit conditions for individual farms. Reporting requirements are detailed in the recommended EMP in Appendix II.

Monitoring requirements for any future sites or production volumes, in addition of those applied for in this process, should include:

- Baseline studies should establish the physical, chemical and biological conditions of the sediments and the water column in the licence area prior to construction, in order to quantitatively assess the degree of disturbance in subsequent years. Protocols for sample collection, analysis and reporting for these parameters should be developed as part of the Environmental Management Plan for the farm operation.
- A bathymetric map should be submitted along with a sketch of the important habitats in the lease area as well as adjacent potentially sensitive and valuable habitats (conservation areas, biogenic habitats and reefs).
- Incorporate any additional information inclusive of all available information from analytical and hydrodynamic studies undertaken for Saldanha Bay or for ecologically comparable locations in other parts of the world. If this available information is not considered scientifically appropriate to the specific site or for the scale of the proposed operations (for example predicting changes in current patterns, the extent of depositional footprints and phytoplankton depletion shadows in response to the farm structures and stock), then site-specific modelling studies should be undertaken to beter determine the ecological impacts before permitting any expansion of activities beyond the precautionary levels specified.

5.3 Statement of Acceptability

Judgements as to the ecological significance and environmental acceptability of additional shellfish and finfish farming in Saldanha Bay should ideally be made in relation to other sources of environmental risk to marine ecosystem within the bay, and in relation to knowledge of its ecological carrying capacity. Recent assessments by Olivier *et al.* (2013) and Probyn *et al.* (2015) for Saldanha Bay suggest that the proposed development of expanded aquaculture management areas would be unlikely to significantly alter the ecological structure of the food web. The potential maximum ungraded ECC production of 27 600 tpa for the expanded ADZ with a total area of 1 871 ha (Heinecken *et al.* 2016), is suggested by Probyn *et al.* (2015) to be the upper limit (25%) of the estimated production carrying capacity for Saldanha Bay.

Although the total expanded area for the ADZ as recommended in the PD would likely be reduced due to implementation of buffer zones, or due to user conflicts in some areas, Heinecken *et al.* (2016) recommend that the upper limits for ECC can be applied as the ecologically safe parameters for the ADZ regardless of the final area available for development. However, considering the biophysical constrains likely to be experienced by farm structures in some precincts, the recommended limits on longline and raft densities per hectare, and the likely development to full capacity over the medium-to long-term only, the estimated upper limit can be considered the worst-case scenario and the associated assessment would thus likely be conservative.

Nonetheless, it is recommended that a phased approach be adopted in the development of the ADZ and the upper limit for annual shellfish production be realised over at least a five-year period. Likewise for finfish cage culture, a maximum production volume of 5 000 tpa is recommended, achieved by ramping annual production up by 1 000 tpa over a five-year period. The recommended annual increase in production could be split equally between Big Bay and Outer Bay.

Based on these conclusions and the results of this assessment, and provided all the appropriate management actions and mitigation measures are in place, there is no reason to suggest that the proposed development of the ADZ not go ahead.

5.3 Conclusions

This assessment of the potential impacts of the development of an ADZ in Saldanha Bay highlights that the significance of ecological effects will depend largely on the amount of annual ungraded production of bivalves, with site-specific hydrodynamic conditions, the cultured stock in question and the proximity of the farm to valued habitats (e.g. MPAs, rocky reefs) and sensitive species (e.g. nesting shorebirds) also playing a role. Finfish farming, which requires the addition of food, would lead to more pronounced enrichment effect on the benthos than those associated with shellfish farming, which in turn potentially has a greater effect on the water column through seston depletion.

As there is a high degree of uncertainty regarding many of the potential environmental impacts of finfish cage culture on the proposed precincts (e.g. cumulative nutrient loading and waste plume dimensions), especially those adjacent to MPAs, it is suggested that initial development of the ADZ focus primarily on bivalve culture. Should finfish cage culture be included as part of the ADZ, it is recommended that it be authorised at an initial pilot phase level in a few selected locations only, with maximum production limited to 5 000 tpa achieved over a five year period.

The ability of the environment to assimilate wastes produced by commercial-scale shellfish and finfish farms is unknown and difficult to predict or model and a precautionary approach to fish farming in Saldanha Bay is thus recommended. Should the decision making authority (DEA) decide to grant environmental authorisation for the development of the Saldanha Bay ADZ, a comprehensive Environmental Management Programme (EMPr) must be developed and implemented for each permit holder within the ADZ. These EMPrs would require on-going, comprehensive independent monitoring of sufficient indicators to detect and quantify any of the environmental impacts described in this assessment, and must specify thresholds of concern which require remedial action. It is strongly advised that development of the ADZ is phased in over at least a five year period so that cumulative impacts can be detected as they arise, and adaptive management implemented concurrently.

Only once monitoring has revealed acceptable impacts as defined by the environmental quality objectives, indicators and performance measures, should further expansion be considered. Any future expansion should likewise be phased in over at least a five-year period, provided ongoing monitoring has indicated that resource quality objectives are maintained.

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APPENDIX I: CONVENTION FOR ASSIGNING SIGNIFICANCE RATINGS TO IMPACTS

Step 1 - The **consequence** rating for the impact was determined by assigning a score for each of the three criteria (A-C) listed below and then **adding** them.

Rating	Definition of Rating	Score
A. *Extent* *– the area over which the impact will be experienced*		
Local	Confined to project or study area or part thereof (e.g. site)	1
Regional	The region, which may be defined in various ways, e.g. cadastral, catchment, topographic	2
(Inter) national	Nationally or beyond	3
B. *Intensity* *– the magnitude of the impact in relation to the sensitivity of the receiving environment, taking into account the degree to which the impact may cause irreplaceable loss of resources*		
Low	Site-specific and wider natural and/or social functions and processes are negligibly altered	1
Medium	Site-specific and wider natural and/or social functions and processes continue albeit in a modified way	2
High	Site-specific and wider natural and/or social functions or processes are severely altered	3
C. *Duration* *– the timeframe over which the impact will be experienced and its reversibility*		
Short-term	Up to 2 years (i.e. reversible impact)	1
Medium-term	2 to 15 years (i.e. reversible impact)	2
Long-term	More than 15 years (state whether impact is irreversible)	3

The combined score of these three criteria corresponds to a **Consequence Rating**, as follows:

Combined Score (A+B+C)	3 – 4	5	6	7	8 – 9
Consequence Rating	Very low	Low	Medium	High	Very high

Step 2 –The **probability** of the impact occurring is assessed according to the following definitions:

Probability– the likelihood of the impact occurring	
Improbable	< 40% chance of occurring
Possible	40% - 70% chance of occurring
Probable	> 70% - 90% chance of occurring
Definite	> 90% chance of occurring

Step 3 –The overall **significance** of the impact is determined as a combination of the **consequence** and **probability** ratings, as set out below:

		Probability			
		Improbable	Possible	Probable	Definite
Consequence	Very Low	**INSIGNIFICANT**	**INSIGNIFICANT**	**VERY LOW**	**VERY LOW**
	Low	**VERY LOW**	**VERY LOW**	**LOW**	**LOW**
	Medium	**LOW**	**LOW**	**MEDIUM**	**MEDIUM**
	High	**MEDIUM**	**MEDIUM**	**HIGH**	**HIGH**
	Very High	**HIGH**	**HIGH**	**VERY HIGH**	**VERY HIGH**

Step 4 - The **status** of the impact is noted as being either negative or positive.

Step 5 -The level of **confidence** in the assessment of the impact is stated as high, medium or low.

Step 6 - Practical **mitigation** and **optimisation** measures that can be implemented effectively to reduce or enhance the significance of the impact are identified and described as either:

- **Essential**: best practice measures which must be implemented and are non-negotiable; and
- **Best Practice**: recommended to comply with best practice, with adoption dependent on the proponent's risk profile and commitment to adhere to best practice, and which must be shown to have been considered and sound reasons provided by the proponent if not implemented.

Having inserted *Essential* mitigation and optimisation measures, the impact is then re-assessed assuming mitigation, by following Steps 1-5 again to demonstrate how the extent, intensity, duration and/or probability change after implementation of the proposed mitigation measures. *Best practice* measures are also inserted into the impact assessment table, but not considered in the "with mitigation" impact significance rating.

APPENDIX II: RECOMMENDED MARINE MONITORING COMPONENTS OF AN EMPR FOR THE SALDANHA BAY ADZ

The recommended marine monitoring components of an EMPr for the Saldanha Bay ADZ are based heavily on the EMPr compiled for the Algoa Bay ADZ (Hutchings *et al*. 2013), but taking shellfish farming as well as finfish farming into account.

As part of the Environmental Authorisation process, an essential component is the submission of an Environmental Management Programme (EMPr). The objective of the EMPr would be to document and plan the management approach that would best achieve the avoidance and minimisation of potential environmental impacts in the construction, operation and decommissioning phase of the ADZ. The Environmental Impact Assessment Guideline for Aquaculture in South Africa provides a framework for such an EMPr and highlights relevant components required for monitoring of aquaculture facilities (National Environmental Management Act, 1998 [Act No. 107 of 1998]: General Notice 101 of 2013).

An Environmental Management Programme should be developed for the ADZ in its entirety, as well as for each individual farming operation within the ADZ. The EMPr for the ADZ will allow for the management of the cumulative effects of all farms holistically. This EMPr should include all recommendations listed in the Environmental Impact Assessment Report and conditions outlined in the Environmental Authorisation. As part of the ADZ development, detailed site-layout plans should be compiled, for the ADZ as a whole, for the lay out of farms within precincts and for the layout of longlines/rafts/cages within each individual farm.

Individual EMPrs for each farm will allow for more efficient and precise management at the scale of individual farms, thereby providing farmers with the opportunity to custom-manage their facilities and allow designated authorities to better manage compliance. EMPrs for each farm should be formulated so that they are compatible, supportive and facilitative of the EMPr for the ADZ within the limits of the Environmental Authorisation. Environmental objective limits and indicators would need to be developed and specified for each EMPr.

A key component of the proposed project and its associated EMPrs is the management and monitoring of potential impacts on the environment as a result of shellfish and finfish culture. As discussed in Chapter 5, it is recommended that the proposed development be phased in, thereby allowing for an adaptive management strategy that can be formulated and adjusted based on real-time environmental monitoring data as the project evolves and production increases in accordance with acceptable environmental thresholds and South African aquaculture guidelines (NEMA, 1998 [Act No. 107 of 1998]: General Notice 101 of 2013).

An efficient and detailed monitoring programme that will guide and inform an adaptive management strategy is therefore an essential requirement for the proposed development of the Saldanha Bay ADZ. To manage the programme, a Monitoring Forum that comprises stakeholders from DAFF, the mariculture industry, Cape Nature, the Saldanha Bay Water Quality Forum, independent scientists and community members should be established. An independent company(s) should then be managed and tasked by the Monitoring Forum to conduct environmental monitoring at each individual fish farm within the ADZ, for the ADZ itself, and for the Saldanha Bay area at large. This will ensure objectivity and transparency, and facilitate the requirements and goals of the individual EMPrs.

Section 21 of the EIA guidelines for aquaculture in South Africa is of particular relevance in isolating relevant components for an aquaculture monitoring programme (NEMA, 1998 [Act No. 107 of 1998]: General Notice 101 of 2013). These guidelines emphasise that production volumes are often limited by in situ environmental constraints (as opposed to market & technological constraints) and that the activity must be accommodated sustainably in accordance with the capacity and abilities of the natural resources and ecological services of the receiving environment (NEMA, 1998 [Act No. 107 of 1998]: General Notice 101 of 2013). Operations must conduct themselves within sustainable production capacities to prevent environmental degradation (NEMA, 1998 [Act No. 107 of 1998]: General Notice 101 of 2013).

Monitoring data may therefore be collected (FAO 2009):

- as part of an EIA generated Environmental Management Programme (EMPr);
- in compliance with some form of code of practice;
- for the information of the farmer in support of husbandry;
- by regulatory authorities as part of enforcement;
- by regulatory authorities as part of monitoring in the wider environment.

It is recognised that components of a monitoring programme for each EMPr may vary and overlap, depending on whether the EMPr is for an individual farm or for the entire ADZ, or depending on the individual characteristics and requirements of each individual farm. In essence, each farm within an ADZ should have their own monitoring programme for their respective EMPr that is project specific and is compiled as and when they develop their operations. This should include for example farm specific monitoring and record keeping of animal husbandry, stock health, feeding programmes, water quality within and adjacent to farms, sediment sampling in the immediate vicinity of the farm and, in the case of finfish farms, plans to deal with escapees and predators.

Components of a monitoring programme for an ADZ EMPr, however, would include monitoring for wider spatial and cumulative impacts of farms including monitoring further afield and at control sites so that the overall ADZ footprint can be determined. In addition, monitoring for the ADZ EMPr would include studies of disease and parasites and genetic variability within wild stocks, and status of ecosystem indicators further afield (e.g. bird nesting success on islands, cetacean use of important feeding and breeding habitats, habitat use by fish, cetaceans and sharks via telemetry studies). Many of these programmes will need to be collaborative with existing studies in Saldanha Bay. All farmers should contribute to an ADZ monitoring trust that provides funding for the monitoring component of the ADZ EMPr, with assistance from the state (DAFF & DEA, Provincial Nature Conservation Department etc).

Based on the EIA aquaculture guidelines for South Africa (NEMA, 1998 [Act No. 107 of 1998]: General Notice 101 of 2013), and the Basic Assessment Report compiled for Irvin & Johnson's Proposed Aquaculture Project, Mossel Bay (CCA Environmental 2008), Algoa Bay (Anchor Environmental 2013) recommended components for monitoring that would provide the necessary information for an EMPr are provided in Table AII.

Table AII: Recommended monitoring components required by an EMPr for individual farms and/or for an ADZ. Should the proposed standard or target be regularly exceeded, an investigation by an independent EMPr committee is recommended and the efficacy of mitigation measures should be objectively assessed. If no other effective mitigation can be implemented, a reduction in stocked biomass is recommended until targets are consistently achieved.

Component and method for monitoring	Environmental objectives	Proposed Standards/targets	Frequency of Monitoring
• Each operator must appoint an Environmental Control Officer (ECO) during the construction phase, whose responsibility it will be to ensure that the mitigation measures and recommendations made in the Environmental Authroisation are implemented, and to ensure compliance with the EMPr	Implementation of mitigation measures and management actions	Ensure compliance with Environmental Authorisation and EMPr	Ongoing throughout the construction, operation and decommissioning phases
• Establish an effective monitoring protocol to ensure that longline/raft/net integrities and supporting infrastructure are maintained. Each individual farmer should ensure that: - The primary longline/raft/net is secured appropriately so that it is kept taut and rigid at all times; nets of fish cages should be weighted. - Ropes and anchor lines are taut, especially after rough seas; - Ropes are routinely inspected for wear, especially after rough conditions, and replaced as and when required, and - There is adequate separation between rafts and longlines, even during strong currents and rough seas; or - There is adequate separation between the primary and secondary nets of fish cages, even during strong currents and rough seas.	Prevent entanglement of cetaceans and piscovores. Prevent escape of finfish stock.	Zero system failure resulting in loss of farm structure integrity. Fewer than 10 entanglements of any species per year and zero mortalities.	Surface infrastructure - daily Subsurface infrastructure- weekly or after storm events.
• Establish an effective monitoring protocol at fish farms to ensure culture-fish mortalities are quickly removed to minimise contamination and fluxes in waste production.	Minimise waste production and disease transfer	Zero mortalities left in cages for a period exceeding 24 hours.	Daily
• Establish an effective monitoring protocol at fishfarms to ensure feed waste is limited (i.e. prevent overfeeding by maximising the feed conversion ratio of cultured fish). Feeding regimes must ensure that direct feed wastage and above normal faecal and metabolite releases from fish are limited. Feed types and feeding rates should be recorded daily so that conversion efficiency can be calculated and monitored.	Minimise waste and organic pollution of water column and sediments	Maximum of 1% of feed quantity uneaten (settling below cages)	Feeding rates to be recorded daily, pellet deposition to be recorded monthly.
• If predator deterrents are to be used, individual farmers and the designated independent monitoring authority must closely monitor cetacean, seal, shark and seabird behaviour.	Maximise effectiveness of predator deterrents, minimize harmful effects of deterrents on predators.	Zero predation of cultured stock. Zero cases of physical harm to any predator caused by deterrents.	Daily by farm operator. During all other monitoring activities by independent monitoring authority.

Component and method for monitoring	Environmental objectives	Proposed Standards/targets	Frequency of Monitoring
• Information on cetacean, seal, shark and seabird occurrence (including incidence and behaviour) in Saldanha Bay should be collected before and after the farm structures are introduced.	Avoid alteration of natural feeding, breeding and movement behaviours of wild biota.¤	No detectable changes (outside of natural) in large vertebrate distributions over time that can be attributed to the presence of farm locations and structures	As per existing monitoring and acoustic tracking programmes. A contribution to the running costs of research projects monitoring seals, sea birds, cetaceans and sharks should be made for a period from first development until at least 3 years after ADZ achieves maximum capacity.
• Record all marine vertebrate mortalities resulting either directly or indirectly from the development. The programme should include guidelines for acceptable levels of mortality of non-cultured species (which may only be able to be developed over time) and where appropriate, mitigation measures developed (e.g. modification of gears etc.).	Minimise impacts on high trophic level vertebrates	Target = zero mortalities. Acceptable level to be determined by EMPr advisory committee	Daily by farm operator. During all other monitoring activities by independent monitoring authority
• Firstly, adhere to broodstock management guideline or species specific permit conditions that use precautionary principles to reduce genetic impacts. This should be updated by genetic information gained from a monitoring programme that assesses the genetic status of both farmed and wild populations in terms of genetic variability and compatibility every three to five years. The interval of the monitoring programme can be adjusted based on the actual results and changes within the breeding population (mortalities, replacements, etc.). The monitoring programme would require that appropriate molecular markers and procedures (sampling, etc.) be developed for assessment of the species and populations under consideration. The responsibility for carrying out the monitoring and analysis of wild populations should be that of the resource management authority (DAFF) in collaboration with farmers, as they should be responsible for the profiling of their commercial broodstock/cultured stock.	Avoid reductions in the environmental fitness of wild stocks due to genetic contamination by cultured stock	No detectable change in natural genetic variation within wild stocks. Maintain genetic homogeneity between cultured and wild stock	At initiation of each species stocked, thereafter every 3-5 years

Component and method for monitoring	Environmental objectives	Proposed Standards/targets	Frequency of Monitoring
• Each farmer must maintain a comprehensive and detailed register of the quantities of chemicals, antibiotics, antifoulants and hormones, etc. that are utilised. Environmental concentrations should be measured at the edge of the zone of expected impact (50 m from farm structures) in water and sediment samples – see benthic and water quality monitoring recommendations below.	Maintenance of water quality and aquatic environment. Maintain health of cultured stock. Minimise potential spread of disease threat to native stocks	All concentrations of potentially dangerous chemical additives as measured at the edge of the zone of expected impacts (50 m) to lie within appropriate safety limits for humans & within acceptable levels for non- target organisms such that they are not negatively impacted	Register of chemical use – continuous and ongoing. Measurement of environmental concentrations: as per benthic and water quality monitoring described below
• Establish a traceability protocol of the cultured fish/shellfish and its products	Ensure that cultured fish/shellfish products do not act as a cover for the illegal sale of wild stock (e.g. undersize fish, wild abalone)	100% traceability of cultured fish product	Continuous as required by marine compliance officers, at processing, distribution and retail outlets.
• Undertake regular visual observations beneath each fishcage to assess the extent of pellet and faecal deposition beneath the cages. At the very minimum, cylinders should be suspended below each of the cages, close to the sea bed in order to collect faecal and feed waste. This method allows the cylinders to be raised to the surface and inspected frequently. Should these visual assessments identify excessive pellet accumulation the feeding strategy should be revised accordingly.	Minimise waste and organic pollution of water column and sediments	No standard, data to be used for interpretation of benthic monitoring programme results.	For a two week period each month.
• Develop a detailed benthic monitoring programme prior to commencement of the aquaculture activities (both shellfish and fish culture). The monitoring programme should be initiated prior to stocking (final spatial scale monitoring should take place in the vicinity of each proposed finfish cage development and at at least one shellfish farm development in each precinct) and include the following: **Level 1 monitoring**: Sediment physical and chemical characteristics: Indicators of sediment characteristics and quality (e.g. particle size analysis, organic content, redox, pH, hydrogen sulphide concentration and the concentration of any potentially harmful chemicals that have been used in operations including antifoulant constituents such as copper) should be	Minimise waste and organic pollution of water column and sediments	PH > 7 Redox potential >0 mV Sulphide pore water concentration from top 2 cm of sediment < 1500 µM. Changes in particle size and organic content are expected but records must be kept to monitor recovery with	Level 1 monitoring - biannually at least 1 sampling event within 1

Component and method for monitoring	Environmental objectives	Proposed Standards/targets	Frequency of Monitoring
monitored biannually. Samples should be examined for the presence of macrobenthos. Sediment samples will need to be collected immediately adjacent to at least four cages/rafts/longlines with the highest stocked biomass, on the North, East, South and West at the edge of expected impacts (50 m from cage/raft/longline cluster) and at four control sites at least 1 km from the nearest cage/raft/longline in an area with similar physical characteristics (depth, sediment type etc). Sampling should be conducted using a Van Veen type grab sampler, or (in shallower water) a diver-operated suction sampler. In addition, video or photographic surveys beneath and adjacent to fish cages/ shellfish longlines/rafts should be undertaken biannually to assess accumulation of uneaten pellets(fish cages) and faeces/pseudofaeces beneath the structures, as well as the presence of bacterial mats and black anoxic sediments. These can be conducted using remotely deployed cameras where water depth limits scientific diving. **Level 2 monitoring**: Biological monitoring: Monitoring should be undertaken on an annual basis to record changes to the macro-benthic community structure underlying each farm and the extent of this impact. It is recommended that sampling (using the same methodology as for Level 1 monitoring) be conducted directly adjacent to four of the most densely stocked cages/rafts/longlines and at 50m in four directions (North, East, South and West) from the cage/raft/longline cluster of each farm within the precincts of the ADZ. Macrofauna in the biological samples should be identified, counted and weighed, to allow for quantitative assessments of the benthic biota over time (i.e. k-dominance curves). The same method should be repeated at four suitable control sites at least 1km from the nearest cage/raft/longline in an area with similar physical characteristics (depth, sediment type etc). At least three control sites sufficiently far away from the ADZ yet still within Saldanha Bay and with similar abiotic characteristics to the ADZ (sediment grain size, depths etc) should be sampled at the same time as each biological survey. The number of replicates at each station is determined by the size of grab sampler used: when using a grab sampler with a mouth opening of 0.1 m^2 two replicates per station, when using a smaller grab of 0.02 m^2, 5 replicates per station are required.		fallowing. Macrobenthos must occur in sediments within the zone of expected impacts. At the edge of the zone of expected impacts, in addition to the above requirements macrobenthic communities should not differ from the baseline or control sites as determined by multivariate analysis (MDS. ANOSIM and/PERMANOVA tests, abundance- biomass curves in PRIMER or equivalent) using a Before After Control Impact design (BACI). Shannon-Weiner index of diversity should be equivalent to control sites or remain >3	month of peak biomass being attained. Level 2 monitoring: annually within 1 month of peak biomass being attained. The frequency of level 2 monitoring may be reduced after three years of annual monitoring, provided production rates are stable and benthic environmental health is acceptable.
• If excessive build-up of benthic organic waste is observed, sufficient time for these sites to return to their natural baseline state (i.e. state prior to the ADZ) should be allowed during fallowing of fishcages. If need be, farm structures should be moved periodically, in a rotational scheme, to allow for fallow periods where the bottom can recover and benthic organic waste can be more evenly distributed within the precinct. Sites should be monitored for recovery using physical, chemical and biological indicators.	Minimise excessive organic pollution of sediments.¤	To be based on the limits of the above benthic monitoring program	As for the above benthic monitoring program

Component and method for monitoring	Environmental objectives	Proposed Standards/targets	Frequency of Monitoring
• Develop a detailed water column quality monitoring programme (temperature, pH, dissolved oxygen, ammonia, nitrite, at a minimum) within fish farms, at the edge of expected impacts (50 m from cage) and at control sites at least 10 km from the nearest farm structures.	Maintain water quality at acceptable levels	*Within farms: pH7.5-8.5, dissolved oxygen above 4.5 $mg.L^{-1}$ (above approx. 80% saturation), ammonia (NH_3-N) <0.02 $mg.L^{-1}$, Nitrite (NO_2) <0.1 $mg.L^{-1}$ Between Cages within 50 m: pH 7.8-8.3, Dissolved oxygen above 80% saturation. ammonia (NH_3-N) <0.01 $mg.L^{-1}$, Nitrite (NO_2) <0.05$mg.L^{-1}$ Within ADZ: For Saldanha Bay & Control Sites: Not higher than the 80th percentile of background levels	Within cages: weekly. 50 m from cages and control sites: initially monthly until 1 month after peak biomass is attained and then as per Level 1 benthic monitoring provided peak biomass does not increase(bi annual)
• Develop a detailed water column quality monitoring programme for nutrient parameters (dissolved carbon, nitrogen and phosphorous) and for key plankton parameters (chl a, phytoplankton abundance and species composition) within shellfish farms	Maintain water quality at acceptable levels	Target = equivalent values to control sites	Within farms: monthly. 50 m from farms and control sites: monthly and then as per Level 1 benthic monitoring provided peak biomass does not increase(bi annual)
• Monitor the caged fish daily during feeding to ensure a healthy fish stock.	Pre-emptive loss of stock to allow for adaptive management	Target = Zero loss. Monitoring committee to decide on standard.	Daily during feeding
• Develop a protocol to monitor escapes from finfish farms.	Minimise potential genetic impacts. Minimise disease impacts	Target = Zero escapees. Monitoring committee to decide on standard.	Initiate monitoring when there are escapes

Component and method for monitoring	Environmental objectives	Proposed Standards/targets	Frequency of Monitoring
• Establish an ongoing parasite/stock health monitoring programme of both wild and farmed stock, which includes pathogen identification and quantification. The parasite monitoring programme should be developed in collaboration with DAFF, as they should ultimately be responsible for carrying out the parasite monitoring on representative samples of wild populations.	Minimise and manage potential disease outbreaks & impacts	Target = Zero infections and pathogens of farmed species. persistent/regular outbreaks should be investigated by independent monitoring committee. No increase in disease and pathogens above baseline levels in wild stocks should be acceptable.	Biannually
• Ensure all stock being introduced into the farms undergo a health exam by a suitably qualified veterinarian and are certified as disease free.	Preventative stock loss. Disease control	Zero diseased fish introduced to cages	Whenever stocking
• Facilities should be inspected by an aquaculture veterinarian to allow for monitoring of the health status of cultured stock.	Optimal growth rate. Disease control.	Overall health of stock should be of a suitable quality to promote and ensure efficient growth rates of particular species being cultured	Every two years
• Cages, rafts, longlines must be kept clean and on defouling inspected for alien species	Minimise potential for introduction of alien species	Early identification and elimination of introduced species	Monthly
• Develop effective protocols to report on waste management taking an integrated approach based on waste minimisation, waste reduction, recycling, re-use and where appropriate, disposal. Solid wastes must be disposed of at a licenced landfill site.	Minimise litter and wastes		
• Develop effective protocols to report on stocking densities, mortalities, graded and ungraded production, biofouling discards	Compliance reporting for overall management of ADZ	No standard, data to be used in management of ADZ	
• Develop effective protocols to report on details of farm structures and layout including specific details on positioning of buoys, floatation rings, lighting equipment, noise generating equipment etc to be used on the approved farms.	Compliance reporting for overall management of ADZ	No standard, data to be used in management of ADZ	

*The proposed water quality standard/target values for ammonia and nitrite within cages is based on available published values for salmon.
These values reflect a precautionary approach, although there is generally an inverse relationship between ammonia concentration and fish growth rate. In addition, stressed fish due to elevated ammonia levels are more likely to be affected by disease. The sensitivity of different fish species to these chemicals is likely to vary and the standard/targets should be adjusted depending on the species farmed and the natural background levels in the environment.

APPENDIX III: ADDITION TO THE SALDANHA BAY AQUACULTURE DEVELOPMENT ZONE PROJECT DEFINITION

Determination of Carrying Capacity of Finfish Cage Culture in Saldanha Bay

Capricorn Marine Environmental (Pty) Ltd

16 January 2017

Introduction and Context

This appendix has been added to the Project Definition (PD) after discussions between DAFF, SRK and CapMarine. It is in response to the request for more information by DAFF on the likely carrying capacity of salmon farming in the proposed Saldanha Bay ADZ to provide, as far as possible, scientifically-based advice on the ramping-up rate of fish cage culture in Saldanha Bay.

The PD undertaken by CapMarine aimed to describe the existing aquaculture activities in the Bay as well as identify potential to expand aquaculture. The area ultimately identified in the PD significantly increased the spatial extent of aquaculture and included identifying potential areas for different types of culture (but was not intended to be definitive or final). Critically, the Basic Assessment (BA) process which incorporated all the expert assessments and consolidated the available information reduced the extent of the ADZ (relative to the area identified in the PD), but nevertheless resulted in a significant increase in the areas allocated to aquaculture.

Information available

The spatial separation (bivalves, cage culture etc.) of aquaculture activities was based on broad consultation with the current aquaculture industry and many other interested and affected parties. These consultations included discussions regarding the areas for fish farming, in particular farming for salmon and trout, for which trials with cages were already under way in Big Bay. Historically trials using fish in cages in Outer Bay north were also considered pertinent although the outcome of those trails was largely negative due to anoxic water conditions (target species was both Salmon and endemic species). The trials on salmon in Big Bay were also based on the granting by DAFF of a permit requiring specific monitoring. Information on the monitoring was not provided to CapMarine or SRK other than that the MOM methodology had not been effective as the currents in Big Bay had resulted in difficulties in following this approach (net traps under the cages could not be kept in place due to the current). Similarly, the information from other aquaculture activities in South Africa e.g. Algoa Bay, Mossel Bay and Richards Bay, provided no direct information that could inform the carrying capacity and ramp up of fish farming in Saldanha Bay. Saldanha Bay is a semi-closed Bay abutting both marine protected areas and large scale industrial activities with anthropogenic impacts (ore jetty, fish factories, sewage).

In addition, reports on some current initiatives to develop fish cage culture were reviewed, specifically in the context of determining the potential carrying capacity of fish cage culture in Saldanha Bay. These included the report by Hecht (2016), the monitoring of fish culture cages in Algoa Bay (Nel and Winter, 2009), and the “Final marine specialist report for marine aquaculture development zones for finfish cage culture in the Eastern Cape" undertaken by (Anchor Environmental), 2013 as well as the "aquaculture standard" as determined by the Aquaculture Stewardship Council (ASC).

Ross et. al (2010) in their discussion on the "Carrying capacities and site selection within the ecosystem approach to aquaculture" suggest carrying capacity can be considered in different ways types viz.:

a) Physical Carrying Capacity being the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system;
b) Production Carrying Capacity estimates the maximum aquaculture production and is typically considered at the farm scale. For the culture of bivalves, this is the stocking density at which harvests are maximized. However, production biomass calculated at production carrying capacity could be restricted to smaller areas within a water basin so that the total production biomass of the water basin does not exceed that of the ecological carrying capacity, for example, fish cage culture in a lake;
c) Ecological Carrying Capacity is defined as the magnitude of aquaculture production that can be supported without leading to significant changes to ecological processes, services, species, populations or communities in the environment; and
d) Social Carrying Capacity is defined as the amount of aquaculture that can be developed without adverse social impacts.

Note also that, with the exception of the Social Carrying Capacity, these definitions have largely been considered in this project definition. The application of ecological and social aspects is not the mandate of the PD, but should be considered in the BA process.

Based on this additional information, as well as the discussions held with the DAFF project group (on 12 December 2016), it was agreed to further consider the production levels for finfish (cage culture) in the ADZ , and options for ramping up finfish production. As far as possible we agreed to try and scientifically determine the carrying capacity of the Bay of finfish production and that this should be contextualised in both an ecological and economic sense.

Assumptions

The approach we have followed makes several critical assumptions:

1. The total area allocated to the ADZ is 904 ha, of which 258 ha are allocated to fish farming (see Table 1) and the remainder to shellfish farming;
2. The expected salmon production will average at 40 t per hectare per annum – while this figure will vary it is the best available estimate of likely fish production in the ADZ[18];

[18] This figure was agreed as a reasonable level of the potential production of salmon from cages. Note however this is not definitive and future operations in Saldanha Bay has the potential to upscale from one cage to more than 4 cages per hectare as well as increasing (optimising) stocking densities.

3. The maximum production of fish farming, calculated at 40 tpa across the allocated area, is expected at 10 320 tpa (see Table 1).

Table 1: Extent of identified post-mitigation ADZ areas for fish (ha)

Precinct	Total ADZ area (ha)	Fish area (ha)	Max. fish production (mt per area)
Small Bay	163	-	-
Big Bay North	409	22	880
Outer Bay North	216	140	5 600
Outer Bay South	96	96	3 840
Total	**884**	**258**	**10 320**

4. Each precinct is likely to have different ecological and hydrodynamic characteristics – in particular hydrodynamics, which will affect flushing rates of nutrients (including wastes), and which will vary between these areas;

5. Saldanha Bay (covering approximately 8 960 ha) was divided into two areas for the purpose of this analysis. Note that these areas are for the purpose of calculating the nutrient flux (using Nitrate only as an indicator) as described by Monteiro et al. (1998) in Probyn (2015) :

    a. Inner Bay (includes Small and Big Bay = 44.8 km^2 (after Probyn, 2015)) = 4 480 hectares,

    b. Outer Bay = 4 480 hectares (approx. equivalent to the combined Small Bay and Big Bay area).

6. The nutrient load in Saldanha Bay was then approximated using nutrient levels quoted by Monteiro et al. (1998), cited in Probyn (2015), notably Nitrate (N) physical flux for entrainment in the Bay = 7.94 mmol $Nm^{-2}\,d^{-1}$. This would equate to 0.03335 kg/N/m^2/yr assuming a 300 day upwelling year (Probyn pers. comm.)

7. Based on the above value, the nutrient load in the two defined areas as measured by Nitrate entrained in the Bay following upwelling pulses, was determined. Note that these are approximations that are also subject to seasonal and annual fluctuations, but provide a rough quantification of nutrient loading (using only N), with which to compare the potential production of N from fish waste.

8. There are numerous studies that estimate waste production from fish farming as a proportion of N to 1 mt of fish produced. These numbers vary considerably (Price and Morris, 2013). For the purposes of this assessment (and ease of interpretation) we have used the mean of the upper and lower estimates of Strain and Hargrave (2005), which is 87.5 kg of N per metric ton of fish produced.

Methods

We used a stepwise approach :

1. Calculate the potential fish production in each area assuming 40 t ha/yr. Note that for the total areas allocated to cage culture as given in the post mitigation scenario, this would equate to 10 320 t (Table 1). This is a theoretical maximum only and is used to set an upper limit for fish production for the purposes of this assessment only;

2. Calculate the total potential waste (N) assuming 87.5 kg per t fish produced in each area (as well as in the total area);

3. Calculate the Nitrogen flux for the Inner and Outer Bay areas (as a total);

4. Estimate the waste (N) produced as a proportion of the Nitrogen loading in the Inner and Outer Bays (consolidated); and

5. Apply the production, waste and nitrogen flux proportions to different ramp-up rates. We assumed four different ramp-up rates using a 10-year horizon applied to each area as follows:

    a. Precautionary – this is a ramp up of each area allowing only 50 tpa to be produced for three years in each area i.e. similar to that proposed in the marine ecology specialist assessment, but now applied separately to each area. After three years there is a more rapid ramp up to five years and a tapering off thereafter;

    b. Slow – this assumes ramping up adding 10% of maximum precinct production per annum;

    c. Medium – this assumes ramping up adding 20% of maximum precinct production per annum; and

    d. Fast – this assumes ramping up by adding up of 33% of maximum precinct production per annum.

Results

Note that we do not present all permutations, but focus only on the pertinent outputs.

The different ramp up rates are shown in Figure 1 [total area combined incorporating Small Bay, Big Bay and Outer Bay (North and South]. Note that we have assumed the same ramp up rates for each area.

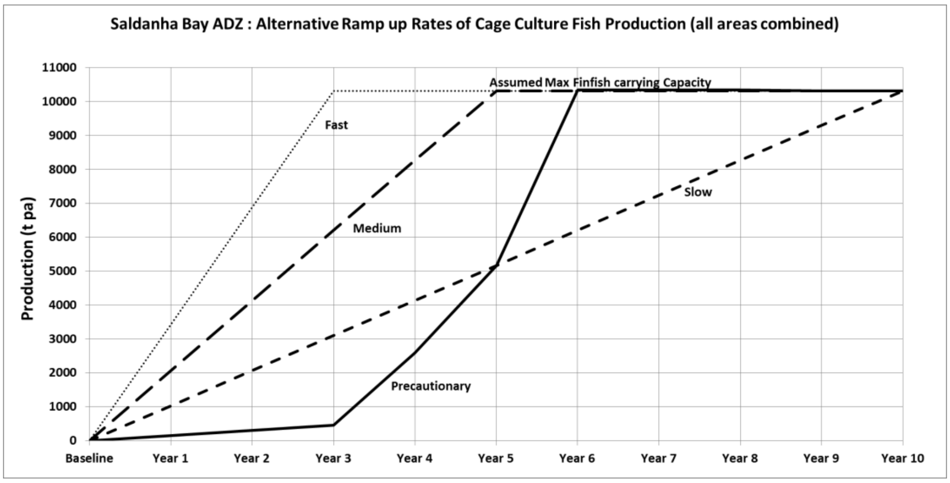

Figure 1. Precautionary Ramp-up rates of fish production by area

Key points to note :

1. The precautionary rate maintains 50 t production in EACH area increasing to 100 t then 150 t pa and is then rapidly ramped up at 25% (year 4) then 50% (year 5) then 100% (year 6) then max production thereafter;
2. The Slow strategy is a 10% increase and reaches maximum production in year 10;
3. The medium rate is a 20% increase and reaches maximum production in year 5;
4. The fast ramp-up is 33% per year reaching maximum production after in year 3.

Fish Waste Production as a Proportion of Nitrogen Flux in the Bay and Ecological Risk

For bivalves carrying capacity levels as suggested by Probyn (2015), is a function of overall primary productivity in the bay. As fish cage culture does not depend on primary productivity in the Bay due to the inputs of artificial feeds, and in consideration of the ecological risk associated with fish cage culture, the following precautionary factors were considered:

1. This assessment assumed waste production of approximately double that used by Sowles (2005) – so nutrient loading as measured using N is likely to be lower than that suggested in Figure 2;
2. We assumed salmon production of 40 t ha – in our view this is very conservative – it is likely that production and stocking densities will be increased over time;
3. The estimates in this assessment do not consider additional anthropogenic inputs;
4. Our estimates are also not cumulative – this would include dumping of mussels and other waste from the bivalve longlines and cages;
5. It does not consider that there may be absorption of nutrients by the bivalve farming (the so-called integrated aquaculture approach).

Site-specific (Saldanha Bay) information for the determination of ecological risk related to fish waste production was not found. Alternatively we considered for example, the results of some international studies such as Sowles (2005) as reported in Price and Morris (2013) who state : "an assessment of nitrogen inputs to Blue Hill Bay, Maine estimated that marine aquaculture discharged 42-49 metric tons of nitrogen to the system annually. This represented less than 10% of the nitrogen loading to the bay and an ecological carrying capacity assessment indicated the area could support additional net pens".

Economic Risk

Depending on the ramp-up rates there is clearly an economic risk. We are not in a position to determine definitive economic risk. In their assessment of the Algoa Bay ADZ, Anchor Environmental (2013) suggest that 3 000 t is the minimum production level for a viable fish cage culture operation. Hecht (2016) is of the view that "the margin between sales price and production cost for salmon is maximised from 1 750 tpa and upwards (per farm)" (information provided by : A. Bernatzeder of DAFF).

Under the scenarios shown in Figure 1 and Table 2 for all areas, economic production levels of about 2 000 t would be reached in Year 1 using the medium ramp up rates and Year 2 using the slow ramp up rates.

Table 2. Total fish Production assuming ramp up strategies and 40t ha.

Ramp-up strategy	Year 1	Year 2	Year 3	Year 4	Year 5
Precautionary	150	300	450	2585	5170
Slow	1034	2068	3102	4136	5170
Medium	2068	4136	6204	8272	10340
Fast	3443	6897	10340	10340	10340

- **Baseline assume a near zero or zero current (2016) production**

Conclusion

After consideration of all the factors presented herein, it was decided that the "Slow" ramp up was likely the best option and provided the best balance between ecological risk (Nitrogen load) and economic returns. This scenario is shown in Figure 2.

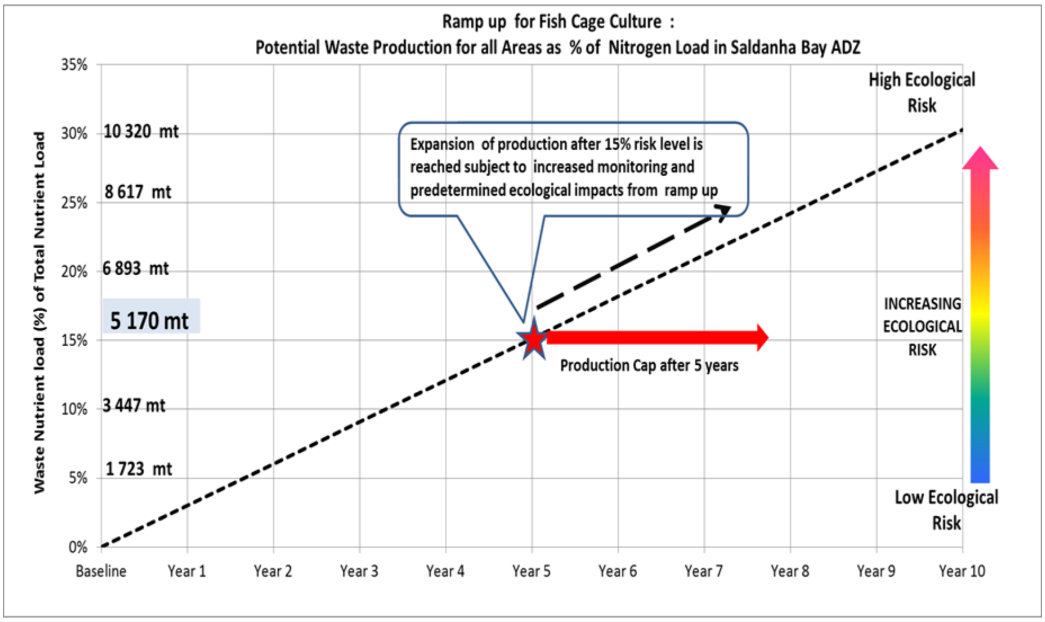

Figure 2. Waste Production (N) as a proportion of Nitrogen Load (all areas) using the slow ramp up strategy.

The rationale for selecting a slow ramp up is as follows :

- A relatively slow ramp-up is precautionary and facilitates proactive decision-making in the event unexpected ecological impacts occur;
- Economically the slow ramp-up accommodates the trade-off between investment and potential returns for prospective aquaculture developers in the ADZ within a reasonable time period i.e. economic yields are possible within 2 years;
- The slow ramp up facilitates monitoring of the expansion of aquaculture, in particular facilitates the understanding of ecological, social and physical impacts;
- The estimates made herein are subject to numerous assumptions and uncertainty. The nutrient loads approximated in this assessment could be highly variable. A slow ramp-up therefore largely accommodates this uncertainty and allows for ongoing verification of the assumptions and estimates used in this analysis.

Further, it was recommended (A. Bernatzeder *pers comm*.) that the production level be capped at an estimated 15% waste nutrient load (as a % of total nutrient load – see Figure 2). This would equate to capping production at 5 170 mt of fish. Any further growth in production would then only be pursued if:

1. Ecological monitoring indicates that at a production level of up to 5 170 mt there are no adverse ecological effects and that there is adequate information to permit further expansion in fish production;
2. Intensified monitoring is applied (a detailed monitoring plan to be implemented) and that expanded production can only occur by following a more precautionary approach; and

3. In the ramp up period, and for any production beyond five years, that a further period of strict monitoring and environmental quality standards is introduced. Should standards or precautionary limits be approached or exceeded, the monitoring plans should have a response procedure that leads to appropriate downward adjustments of fish production.

Further, it is stressed that this assessment is not a concise estimate of the carrying capacity of fish cage production of the proposed ADZ. The limits presented here are therefore "precautionary". Management needs also to consider that at the same time as cage culture is expanding, bivalve production (and expansion) will also be in process. Further, Saldanha Bay is a dynamic oceanographic system – there are many factors that remain uncertain (with respect to the expansion of aquaculture in the Bay). Underpinning the ability of the system to sustain fish and bivalve aquaculture production is the ability of the oceanographic system (hydrodynamics) to not only provide nutrients for aquaculture production, but also the ability of the same system to flush away nutrient build up and waste discharged from the anticipated aquaculture operations.

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