Capricorn Marine Environmental (Pty) Ltd

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

Analysis of information and mapping to determine suitable aquaculture areas, species and methods in Saldanha Bay and land based support activities

Revised : 16 January 2017 to incorporate Appendix 3 on Fish Cage Culture Carrying capacity estimates

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Acronyms

ADZ	Aquaculture Development Zone
ASP	Amnesic Shellfish Poisoning
BRBA	Biodiversity Risk and Benefit Assessment
CC	Carrying Capacity
DAFF	Department of Agriculture, Forestry and Fisheries
DO	Dissolved Oxygen
DPW	Departments of Public Works
DSP	Diarrhetic Shellfish Poisoning
DWT	Deadweight tons
ECC	Ecological Carrying Capacity
EIA	Environmental Impact Assessment
HDPE	High Density Polyethylene
JOD	Juvenile Oyster Disease
MPA	Marine Protected Area
NE	North-east
NEMA	National Environmental Management Act 107 of 1998
NEMBA	National Environmental Management: Biodiversity Act 10 of 2004
NNW	North-north-west
NW	North-west
OVVD	Oyster velar virus disease
PCC	Production Carrying Capacity
PD	Project Definition
PSP	Paralytic Shellfish Poisoning
SAN	South African Navy (Hydrographic Navigation Chart reference)
SANDF	South African National Defence Force
SANParks	South African National Parks
SE	South-east
SEA	Strategic Environmental Assessment
SEDF	Spatial and Economic Development Framework
SSE	South-south-east
SSW	South-south-west
SW	South-west
TNPA	Transnet National Ports Authority
WCRL	West Coast Rock Lobster

Executive Summary

The report was undertaken on behalf of SRK Consulting for the Department of Agriculture, Forestry and Fisheries (DAFF) to define and describe a proposed Aquaculture Development Zone (ADZ) within Saldanha Bay. The current requirements of TNPA for shipping movements were recognised and additional areas for the Saldanha ADZ were selected taking the TNPA expansion planes into account. Studies on the potential carrying capacity, oceanography and other pertinent environmental characteristics of the Bay and the potential to expand bivalve culture and aquaculture in general was reviewed.

Oceanographic conditions are considered key factors in determining the viability of aquaculture in different areas of Saldanha Bay. Wind, sea and swell conditions are likely to be the major determining factor on aquaculture systems that can be deployed within an area and would further influence the potential species that could be farmed in these areas. The review indicates the most exposed areas to prevailing southerly winds and oceanic swell will be in the northern area of the Outer Bay. Big Bay, and the southern half of Outer Bay, although still exposed to the southerly wind, are more protected from the prevailing south west swells and more extreme sea conditions.

The expansion of aquaculture in Saldanha Bay will place greater demand on facilities in the fishing harbour for landing support craft and processing. This may necessitate the harbour authorities reallocating underutilised areas to aquaculture.

The total area currently leased out to aquaculture by TNPA in Big Bay and Outer Bay is 3430 ha. Of this area, 27ha of the areas leased are currently being farmed in Big Bay and Outer Bay (25ha for oysters and 1ha for mussels and 1ha for fish). A total of 1 871 ha of water area is considered suitable for aquaculture for inclusion in an ADZ, increasing the overall (pre-mitigation) area allocated to aquaculture in Saldanha Bay from the current leased area of 430 ha (of which approximately 150 ha are currently farmed). The identified areas considered suitable for the Saldanha ADZ would be in four main areas: 1) Outer Bay – North, 2) Outer Bay – South, 3) Big Bay – North and 4) Big Bay – South. In addition, Small Bay would also be included but with no expansion of the currently allocated aquaculture area.

The three species of bivalves that are currently being farmed within Saldanha Bay are Pacific oysters (*Crassostrea gigas*), Mediterranean mussel (*Mytilus galloprovincialis*) and Black mussel (*Choromytilus meridionalis*). These are likely to remain the main bivalve species of interest in any future expansion into the ADZ. Two additional shellfish species, abalone (*Haliotis midae*) and South African scallop (*Pecten sulcicostatus*) and five finfish species, White Stumpnose (*Rhabdosargus globiceps*), Kabeljou (*Argyrosomus inodorus*), Yellowtail (*Seriola lalandi*), Atlantic salmon (*Salmo salar*) and Rainbow trout (*Oncorhynchus mykiss*) are considered to have potential for future fish farming. One species of seaweed is considered suitable (*Gracila gracillis*) although it is advised that this species has proven not to be commercially viable in Saldanha Bay as it needs large volumes for viable production and is prone to mussel fouling.

Suitable systems for the production of bivalves and finfish include rafts, longlines, fish cages and barrel culture for abalone. The choice of system must however take into account the exposure to weather and sea conditions of each area. Modifications to existing techniques may be required for them to be viable under these conditions.

Given the potential increase in aquaculture in the ADZ the scientifically-determined carrying capacity has been used to estimate the ecologically safe upper and lower limits of the Production Carrying Capacity (PCC). The PCC estimates take into consideration the expected nutrient uptake of the primary aquaculture bivalve species – oysters and mussels. Further considerations would be the likely density and location of the farms and critically, the hydrodynamics of the Bay or alternately at specific locations within the Bay. It is therefore recommended that the ecological impact assessment be informed by the Ecological Carrying Capacity (ECC) using a lower (10% of PCC) and upper (25% of PCC) limit of the estimated Production Carrying Capacity for bivalves. The estimates of ECC for the (ungraded) bivalve aquaculture production based on the areas available for the proposed ADZ are 8 345 t/yr and 27 597 t/yr for the low and high scenarios respectively.

Further, based on these amounts the expected graded production assuming a 70:30 ratio of mussels to oysters for the ADZ would be between 4 603 t/yr and 15 203 t/yr.

Trials for farming of fish in cages and current proposals to expand cage culture of salmon on a much larger scale (than currently done) were difficult to assess as the production estimates are variable and unknown at this point in time. Two current applications for fish farming in both Big Bay (south) and Outer Bay suggest that a likely estimate of production (fish) would be 40 t per hectare per year. However fish farming is not influenced by the ambient carrying capacity of the ecosystem as is the case for bivalve culture. Artificial fish feed is introduced into the system by the farmer which can result in significantly increased nutrient loads into the ecosystem associated with waste products from faeces and unutilised feed as well as biofouling from cage nets and moorings settling in sediments below cages.

Based on likely nutrient inputs from any expansion of fish production using cages it is recommended that any expansion of cage culture be undertaken in a precautionary manner. It is advised that ramping-up fish production is done relatively "slowly" at about 10% per year and is capped at 5017 t after five years. Due to the high levels of uncertainty of the ecological impacts, expansion of fish production should be closely monitored and a site-specific environmental monitoring plan followed.

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

1 Introduction

This report has been undertaken on behalf of SRK Consulting for the Department of Agriculture, Forestry and Fisheries (DAFF)[1] to define and describe a proposed *Aquaculture Development Zone* (ADZ) within Saldanha Bay. Capricorn Marine Environmental (Pty) Ltd were contracted to undertake the *Project Definition* (PD) phase, the scope of which is given in Appendix 1. Broadly, the PD lays the foundation for the Environmental Impact Assessment (EIA) for the development of an ADZ in Saldanha Bay (Figure 1). The PD aims also to identify the critical characteristics of the Bay and the scale (expansion) of any potential aquaculture (incorporated into the ADZ) inclusive of the any potential aquaculture species to be considered.

Figure 1 : Designation of areas within Saldanha Bay

Saldanha Bay has established aquaculture production. The primary driver for this is the unique properties of the Bay conducive for bivalve production. The most important factors affecting bivalve growth, namely water temperature and phytoplankton biomass, are ideal within the Bay. Furthermore, biomass is of the optimal size for bivalve grazing, contributing to growth rates unparalleled by some of the largest bivalve producers worldwide (Pieterse et al, 2012:1068).

[1] The project is being expedited by DAFF under Operation Phakisa – (aquaculture component), a national project investigating the potential for the *Blue Economy* in South Africa

Nevertheless it is generally considered that the current allocation of farming space in Saldanha Bay does not reflect this potential.

As shall be demonstrated in this report, the ecological carrying capacity in the Bay allows for production at scales orders of magnitude greater than current rates. It also makes recommendations for optimal locations of aquaculture farming in the Bay. The EIA process requires the inclusion of key stakeholders prior to the Basic Assessment (undertaken by SRK) and assesses the potential expansion of water areas in Saldanha Bay beyond those currently allocated for aquaculture by Transnet National Ports Authority (TNPA).

1.1 Spatial Extent of the Saldanha Bay ADZ

For the purpose of this report, areas within Saldanha Bay have been named as per the Strategic Environmental Assessment (SEA) of the Port of Saldanha (CSIR, 2013) and shown in Figures 1 and 2. Potential areas for the expansion of aquaculture within a future Saldanha Bay ADZ were broadly identified at a meeting with TNPA on 17th May 2016 and are shown in Figure 2. Note this is a pre-mitigation scenario and does not incorporate changes that might be needed to mitigate the impacts identified by different experts involved in the process.

2 Methodology

A number of factors were taken into account when identifying and demarcating new areas proposed for expansion of aquaculture in Saldanha Bay. These included:

- current requirements of TNPA for shipping movements;
- proposed expansion by TNPA in the bay;
- extent of existing marine protected areas (MPA);
- prevailing and maximum monthly oceanographic conditions in Saldanha Bay; and
- carrying capacity and zoning recommendations for oyster and mussel culture in Saldanha Bay.

2.1 Current requirements of TNPA for shipping movements

The current requirements of TNPA for shipping movements include the extent and depth of the entrance channel to berths and areas required for turning and anchoring Very Large Cargo Carriers (VLCCs), between 150,000 and 320,000 deadweight tons (DWT). The jetty of the Port of Saldanha projects three kilometres into the bay and has two dry bulk berths for loading iron ore and a liquid bulk berth for loading and offloading crude oil at its terminal end. Four general cargo berths are situated on the western side of the jetty in Small Bay. The limits for current shipping are clearly marked on the navigation chart South African Naval Charts SAN 1011.

The aquaculture systems currently deployed in Saldanha Bay are longlines, rafts and floating fish cages, all have surface structures and mooring systems. All of these restrict ship movements and consideration has to be given for safety limits between shipping channels and areas for aquaculture.

Point	Lat S		Long E	
A	33°	2.806′	17°	55.261′
B	33°	1.934′	17°	57.442′
C	33°	3.393′	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°	0.21′	17°	57.71′
J	33°	0.213′	17°	58.03′
K	33°	0.375′	17°	58.028′
L	33°	0.38′	17°	58.575′
M	33°	0.515′	17°	58.573′
N	33°	0.517′	17°	58.702′
O	33°	0.652′	17°	58.7′
P	33°	0.648′	17°	58.379′
Q	33°	0.783′	17°	58.377′
R	33°	0.782′	17°	58.217′
S	33°	0.89′	17°	58.215′
T	33°	0.889′	17°	57.622′
U	33°	0.67′	17°	57.623′
V	33°	0.671′	17°	57.704′
W	33°	1.045′	18°	1.156′
X	33°	2.763′	18°	2.171′
Y	33°	3.031′	18°	0.371′
Z	33°	1.948′	18°	0.89′
AA	33°	1.91′	18°	0.77′
AB	33°	3.47′	18°	0
AC	33°	3.072′	18°	2.278′
AC1	33°	3.212′	18°	1.345′
AD	33°	3.82′	18°	2.193′
AD1	33°	4.036′	18°	1.195′
AE	33°	4.27′	18°	0.089′
AE1	33°	4.17′	18°	0.563′
AF	33°	4.2′	18°	0
AF1	33°	3.95′	18°	0
AG	33°	4.393′	17°	56.961′
AH	33°	4.074′	17°	58.118′
AI	33°	5.117′	17°	58.401′
AJ	33°	5.566′	17°	58.024′
AK	33°	5.662′	17°	57.316′
AL	33°	5.306′	17°	57.316′
AM	33°	5.307′	17°	57.861′
AN	33°	4.706′	17°	57.861′
AO	33°	4.706′	17°	56.961′

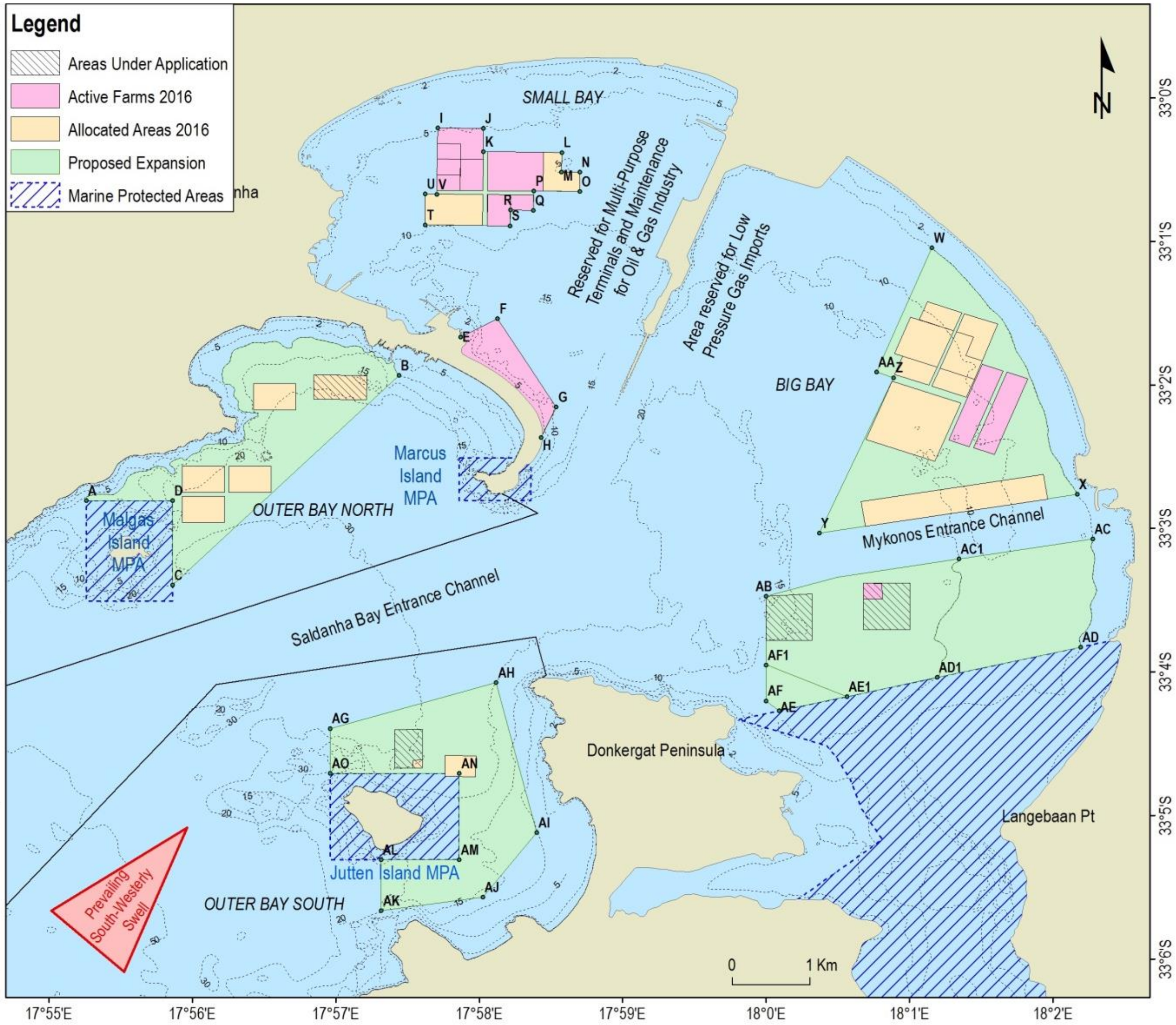


Figure 2. Map showing the proposed Aquaculture Development Zone (ADZ) beyond areas currently allocated (pre- mitigation scenario).

2.2 Proposed expansion by TNPA

The proposed development within Saldanha Bay is provided in the SEA commissioned by TNPA (CSIR 2013). Areas to both the east and west of the jetty were excluded for any possible expansion of the aquaculture area to facilitate the future port development.

2.3 Extent of Marine Protected Areas

Three existing MPAs were taken into account when looking at the proposed areas for the expansion of aquaculture. These are positioned at the entrance to the Langebaan lagoon and around Malgas and Jutten Islands. Three of the proposed aquaculture expansion areas border an MPA (Figure 2)

2.4 Prevailing oceanographic conditions in Saldanha Bay

To assess the potential of proposed areas for aquaculture, available literature covering specifically oceanographic conditions in Saldanha Bay as well as information provided by TNPA were reviewed (Appendix 2), for wind speed and direction and swell height and direction. These were taken into consideration in demarcating the proposed limits for the Saldanha ADZ as well as discussing the proposed aquaculture systems that would be practically viable for each area.

2.5 Carrying capacity in terms of primary production for bivalves culture

Factors specifically affecting carrying capacity for bivalve growth, as presented in the DAFF Saldanha Bay ADZ Concept Document were reviewed (Section 9). These provide the basis for the feasibility of expanding the current area for aquaculture in Saldanha Bay. The review looked specifically at the study undertaken by DAFF on new production and carrying capacity for bivalve aquaculture in Saldanha Bay (Probyn et. al. 2015).

3 Oceanographic conditions

3.1 Oceanographic conditions in Saldanha Bay

Prevailing oceanographic conditions are considered key factors in determining the viability of aquaculture. Wind, sea and swell conditions are likely to be the major determining factor on aquaculture systems that can be deployed within an area and would further influence potential species that could be farmed.

Sea and swell impact directly on the design and mooring of floating structures used in aquaculture, as well as on the vessels that will be required to service these systems. In the more exposed areas, larger and more seaworthy craft will be required and extreme conditions may also limit access to the area at times for feeding fish or harvesting.

Southerly winds (South East to South West) are prevalent for nine months of the year (September to May), with wind speeds ranging between 8 and 19 knots (Appendix 2). The winds from June to August are predominantly from the north and north-west, 8 to 14 knots. The 10-year maximum wind speeds recorded were 58 knots from south-west, south-southwest and north-west and need to be taken into account, as they will create the most extreme conditions that aquaculture productions systems will need to withstand when these occur. The sea conditions in Saldanha Bay vary significantly depending on the wind direction and relative fetch off the adjacent coast. The southerly winds in the northern side of Outer Bay can result in wave heights of 5.5m to 7.5m. On the southern side of Outer Bay around Jutten Island (Figure 2) the area is protected by the island and South Head coastline and is likely to have far calmer sea conditions. Similarly, in the Big Bay area the southerly winds can foreseeably result in wave heights up to 4m in the northern area of the Bay. The prevailing oceanic swells that impact Saldanha Bay are from the South West, up to 7m. The swell is likely to impact mostly the Outer Bay on the northern side. Big Bay east of the iron ore terminal will experience some of the residue swell that passes to the south of Marcus Island and the Jetty projecting into Saldanha Bay.

Table 1: Monthly summary of the prevailing and maximum recorded wind and swell conditions over a ten year review period in Big Bay, Saldanha Bay.

Big bay		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WIND	Prevailing wind speed (knots)	16	16	8	8	8	8	8	8	12	12	12	16
	Direction of prevailing wind	SSW	SSW	S	S	S	N	N	N	S	S	S	SSW
	Maximum wind speed knots)	58	39	39	39	39	39	39	39	39	39	39	58
	Direction	SSW NW	SE NW	N NE	NE	NE	NE	NE	NE	NW	NW	NW	SW NW
SWELL	Height max (m)	4	3.3	4.9	4.9	5.3	6.5	6.2	7.5	5	5.6	5.6	4.6
	Direction	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW

Table 2: Monthly summary of the prevailing and maximum recorded wind and swell conditions over a ten year review period in Outer Bay, Saldanha Bay.

Outer bay		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WIND	Prevailing wind speed (knots)	19	19	14	14	14	14	14	14	14	14	14	19
	Direction of prevailing wind	S	S	SSE	SSE	SSE	NNW	NNW	NNW	S	S	S	S
	Maximum wind speed knots)	39	39	39	39	39	29	29	29	39	39	39	39
	Direction	S	S	S	S	S	SE NW	SE NW	SE NW	SE	SE	SE	S
SWELL	Height max (m)	7	7	7	7	7	7	7	7	7	7	7	7
	Direction	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW

3.2 Environmental factors influencing aquaculture

Two of the most important factors affecting bivalve growth are sea temperature and phytoplankton biomass (Nel et al. 2014:490). Thus, although new production is estimated to be available throughout Saldanha Bay due to water exchange (Probyn et al. 2015:529), temperature conditions may result in some areas of the Bay being more suitable for oysters than for mussels. Understanding the ideal for each organism as well as conditions for various areas in Saldanha Bay will provide an indication of where farms should be situated to maximise production efficiency.

3.2.1 Water Temperature

Sea temperatures vary in different areas of the Bay. In Small Bay, temperatures tend to be warmer by one to three degrees Celsius than in Big Bay (Pitcher & Calder 1998:17). The thermal optimum for the Pacific oyster is 19 degrees Celsius (Nel et al. 2014:485), which suggests the slightly warmer conditions in Small Bay provide an environment consistently closer to this optimum than Big Bay or Outer Bay.

3.2.2 Phytoplankton biomass and current speeds

Biomass concentrations are 10-15% lower in Small Bay than in Big Bay (Monteiro et al. 1998:12). Big Bay exhibits concentrations in excess of 9 mg m^{-3}. Small Bay, as well as the entrance to Langebaan Lagoon, has concentrations below 9 mg m^{-3} (Pitcher & Calder 1998:17). In addition to relatively high biomass concentrations, the stocking density of mussel rafts requires that rafts experience considerable current speeds to move nutrients throughout the farm. Current flow through a mussel farm is 30% of ambient speed, with each row of rafts reducing current flow by 3% (Boyd & Heasman 1998:30). In areas with relatively slower currents and lower biomass, as is typical in Small Bay, food requirements for mussel farms may barely be met (Boyd & Heasman 1998:30). Nevertheless, the more dispersed oyster long-lines would receive adequate through-flow (Olivier et al, 2013).

3.2.3 Wave stress

Mussel culture is recommended for areas with stronger currents, cooler water and higher biomass. Nevertheless, some areas of Saldanha Bay with these characteristics also experience relatively high wave stress. For example, Outer Bay areas near Malgas and Jutten Islands would be suitable for mussel culture in terms of temperature and biomass, but these areas are more exposed to wave stress than areas within Small and Big Bay (CSIR, 2014).

4 Potential areas suitable for the Saldanha Bay ADZ

The extent of the currently leased aquaculture areas are shown in Figure 1, and the proposed new areas for the expansion of the Saldanha Bay ADZ (Figure 2) are summarised in Table 3 and described in more detail in the sections below. The total area currently leased out for aquaculture in Saldanha Bay is 468 ha. At present only 125 ha is farmed in Small Bay and 27ha in Outer and Big Bay combined (25ha for oysters, 1ha for mussels and 1ha for fish). This Project Definition study proposes a further expansion of aquaculture areas in Big Bay and Outer Bay to 18 71 ha. This will increase the total area allocated to aquaculture by 1 404 ha.

Table 3: Proposed area for expansion in hectares for Sea-Based ADZ in Saldanha Bay (pre-mitigation)

Area	Areas currently allocated [ha]	Area currently farmed	New areas [ha][2]	Total future area [ha]
Small Bay	163	125	0	163
Outer Bay - North	37	1	299	336
Outer Bay - South	10	0	317	327
Big Bay - North	254	25	271	525
Big Bay - South	4	1	517	520
Total	**468**	**152**	**1 404**	**1 871**

The individual ADZ precincts are described in more detail below.

4.1 Outer Bay - North of the entrance channel in vicinity of Malgas Island

Currently two areas totalling 37ha have been allocated by TNPA in this area of which one area has been exploited using floating cages stocked with salmon.

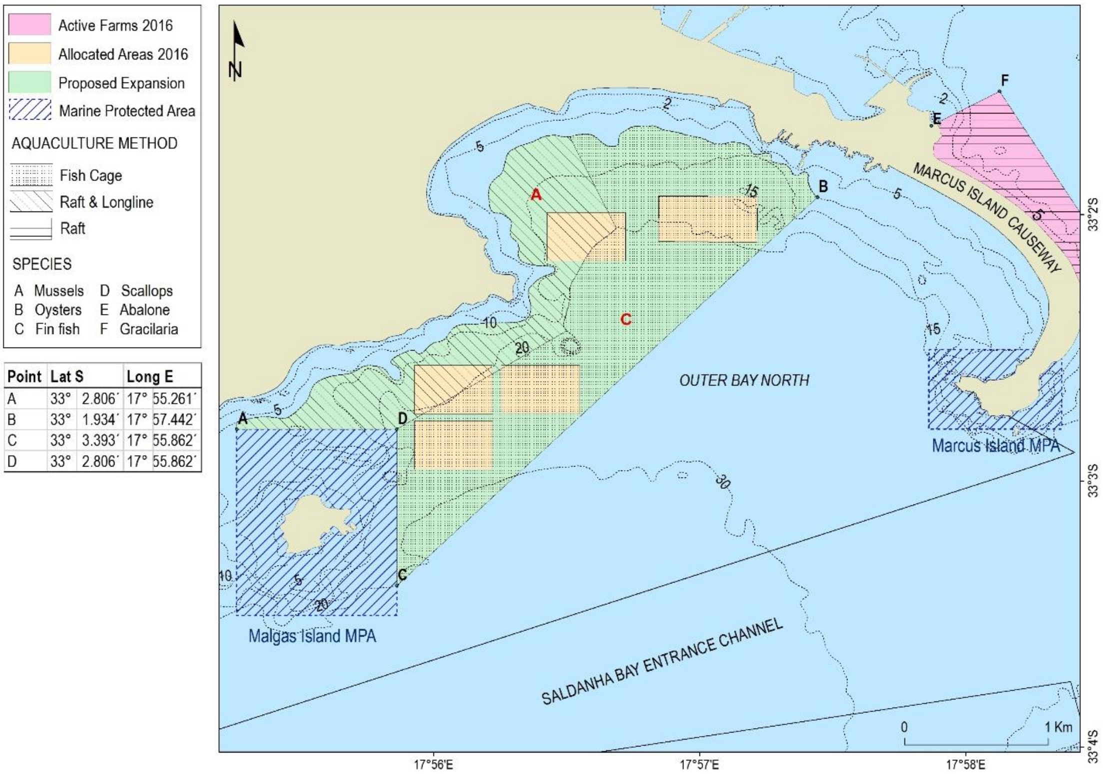
The proposed expansion of 299ha would extend towards Malgas Island, and from the 10m depth contour out to the 30m depth contour north of the entrance channel (Figure 3).

The expansion towards the north inside the 30m contour and up towards Malgas Island is expected to get some limited protection from the extreme swell conditions from the west by the island (Appendix 2). The area would be sheltered from prevailing northerly winds from June to August, but exposed for most of the year to the prevailing southerly winds from September to May (Appendix 2). The maximum wind speeds up to 20m/s could result in sea conditions with wave heights up to 7.5m (Beaufort wind force scale). These conditions would significantly restrict aquaculture production systems that could be used in this region. Expansion eastwards is further likely to be limited by the swell and high wave energy leading up to the spending beach of the causeway between the mainland and Marcus Island.

The area includes optimum depths greater than 15m that would be suitable for finfish cage culture or submerged longlines with the shallower areas still being viable for surface longlines. It is expected that the oceanographic conditions will most likely exclude the use of rafts.

Finfish cage culture has already been trialled in the area. However, periodic events of low Dissolved Oxygen (DO) resulting from upwelling conditions outside the bay have negatively impacted these trials and they were subsequently aborted early in 2016 (Maclachlan and Stander 2016, pers. comm. 03 May 2016). This experience indicates that future finfish farming potential may be limited in this area. However, it was noted that the trial was based on the culture of Salmonid species. It is possible that indigenous finfish species may be more resistant to these natural conditions and still be a viable option in the future.

[2] The expansion includes areas that will be demarcated for navigation between longlines, rafts or fish cages.



Point	Lat S		Long E	
A	33°	2.806´	17°	55.261´
B	33°	1.934´	17°	57.442´
C	33°	3.393´	17°	55.862´
D	33°	2.806´	17°	55.862´

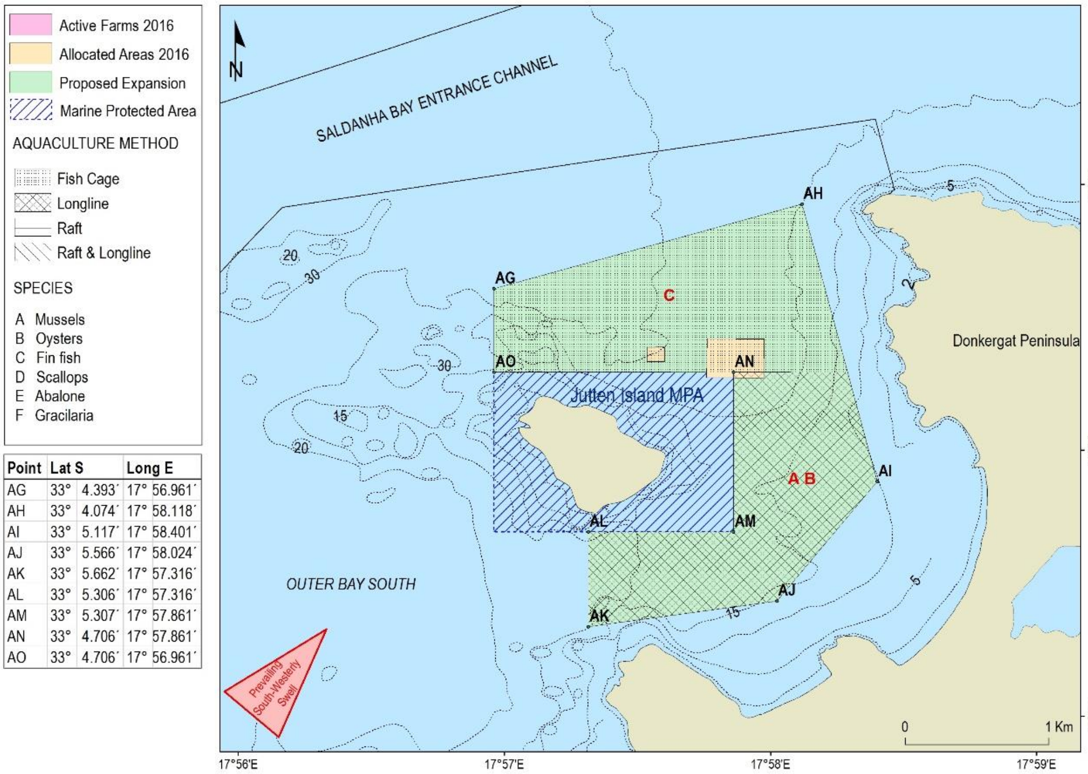
Figure 3. Proposed area for future aquaculture in the Outer Bay north of the entrance channel in vicinity of Malgas Island (pre-mitigation).

The water temperature conditions and exposure make this area suitable for mussel culture and possibly other bivalve species with a colder water tolerance. The proven mooring systems of floating cages in the area has shown that these production units are able to withstanding the oceanographic conditions in the area and it is possible that these may be developed for future bivalve culture systems.

4.2 Outer Bay - South of the entrance channel in vicinity of Jutten Island

Currently two areas totalling 10ha have been allocated in this area and neither has as yet been farmed (Figure 4). The proposed ADZ expansion between Jutten Island and the mainland, from the 10m depth contour northwards to the entrance channel, will add 315ha of aquaculture area. The area excludes South African National Defence Force (SANDF) restricted zone around the mainland and the South African National Parks (SANParks) area around Jutten Island.

The location of Jutten Island to the west and the mainland to the north is likely to afford some shelter to the prevailing swell from the southwest (Section 3.2.3). In addition, the area would be sheltered by the mainland in the south from prevailing southerly winds between September and May. The short fetch from the mainland could result in significantly more favourable sea condition with wave heights well below the maximum 7.5m possible from maximum wind speeds.



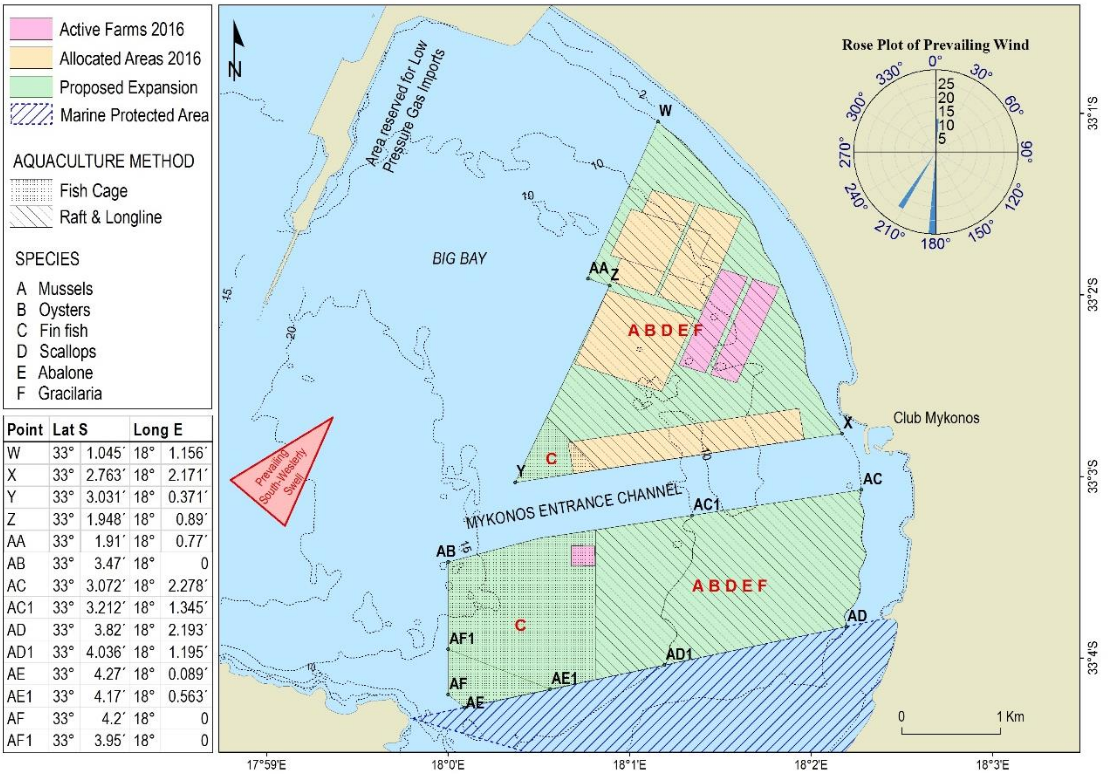
Point	Lat S		Long E	
AG	33°	4.393´	17°	56.961´
AH	33°	4.074´	17°	58.118´
AI	33°	5.117´	17°	58.401´
AJ	33°	5.566´	17°	58.024´
AK	33°	5.662´	17°	57.316´
AL	33°	5.306´	17°	57.316´
AM	33°	5.307´	17°	57.861´
AN	33°	4.706´	17°	57.861´
AO	33°	4.706´	17°	56.961´

Figure 4. Proposed area for future aquaculture in the Outer Bay south of the entrance channel in vicinity of Jutten Island (pre-mitigation).

The area includes depths greater than 15m that would be suitable for finfish cage culture or submerged longlines. However, there is some concern that strong currents through the channel between Jutten Island and the mainland could negatively affect fish cages (Stander 2016, pers. comm. 13 June 2016). Depths greater than 10m prevail in the more protected area between the mainland and Jutten Island and may be suitable for surface longlines for bivalve culture. The strong currents would also benefit the culture of bivalves in this area. It is however expected that the conditions would be too exposed for raft culture using the current raft design being employed in Small Bay.

4.3 Big Bay - North of Mykonos

The entire area falls within the area promulgated for aquaculture in the 1980s and is still demarcated on South African chart SAN1011. This area (Figure 5) was the centre of mussel culture in the second half of 1980s and early 1990s. Both longlines and rafts were previously deployed in the area. The mussel culture was discontinued in mid-1990s due to the economic collapse of the operator. Currently 12 areas totalling 254ha have been allocated in this area, of which one area of 10ha is currently being farmed for oysters using longlines.



Point	Lat S		Long E	
W	33°	1.045´	18°	1.156´
X	33°	2.763´	18°	2.171´
Y	33°	3.031´	18°	0.371´
Z	33°	1.948´	18°	0.89´
AA	33°	1.91´	18°	0.77´
AB	33°	3.47´	18°	0
AC	33°	3.072´	18°	2.278´
AC1	33°	3.212´	18°	1.345´
AD	33°	3.82´	18°	2.193´
AD1	33°	4.036´	18°	1.195´
AE	33°	4.27´	18°	0.089´
AE1	33°	4.17´	18°	0.563´
AF	33°	4.2´	18°	0
AF1	33°	3.95´	18°	0

Figure 5. Proposed area for future aquaculture in Big Bay north and south of the entrance channel to Mykonos (pre-mitigation).

The proposed ADZ expansion extends from an exclusion zone to the west for the gas line development and northwards from the navigation channel leading up to Mykonos harbour (Figure 5), and seawards from the 5m contour in the north.

The position inside the bay east of the oil and iron ore terminals is reasonably sheltered from the prevailing southwest swells and the limited fetch from the mainland in the south is likely to limit wave height. The proximity of the mainland to the north will provide optimum protection from northerly wind and sea conditions during the mid-winter months (Section 3.2).

The influence of tidal currents circulation may also mitigate against low DO conditions that could affect finfish culture. However, the limited area with depth range exceeding 15m is likely to limit opportunities for finfish cage culture to the southwest bounds of this area. The depth profile, currents and the relative protection to extreme oceanographic conditions will favour surface longline and possible future raft production systems for bivalves in this area. Studies on primary production in the area also indicate sufficient carrying capacity to expand bivalve culture in this area (Section 9).

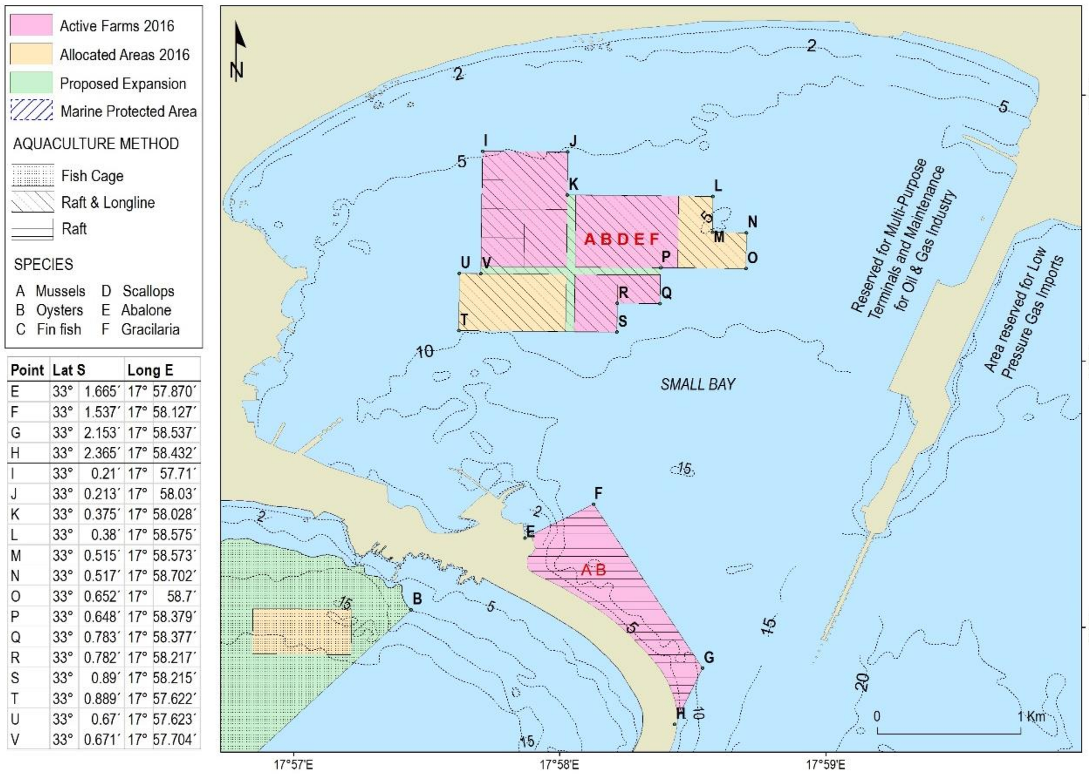
4.4 Big Bay - South of Mykonos

The area is within the previously promulgated zone for aquaculture in the 1980's, and is currently still demarcated on SAN navigation charts SAN1011. One area of 4ha has been allocated in the area and is being used for finfish trials. The proposed ADZ extends southwards from the navigational channel to Mykonos harbour to the limits of the SANParks area (Figure 5), and westwards from the 5m contour in the east to the limit of the exclusion zone required for port operations in the west. An alternative layout has been identified for this precinct that reduces the area to accommodate marine traffic, in particular recreational users (Mykonos area), thereby mitigating potential future interaction between aquaculture installations and other users. This alternative area extends from the 10m depth contour westwards, with more space created adjacent to the Donkergat Peninsula for traffic moving into and out of the lagoon area (Figure 5).

The position inside the Bay provides optimal shelter from the prevailing southwest swells and wind and sea conditions from the south (Section 3.2). The influence of tidal currents circulation and outgoing tidal current from Langebaan lagoon is likely to limit the risk of low DO conditions. However, the depth range is more likely to limit opportunities for finfish cages to the western limits of the area. Analysis of the carrying capacity indicates that this will not be a limiting factor to expansion of bivalve culture in the area (Section 9). The depth profile, currents and the relative protection to extreme oceanographic conditions should favour surface longline and raft production systems for bivalves.

4.5 Small Bay

Currently 163ha (of which 125 ha is under cultivation) have been allocated to farmers in this area (Figure 6 & Table 7).



Point	Lat S		Long E	
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°	0.21′	17°	57.71′
J	33°	0.213′	17°	58.03′
K	33°	0.375′	17°	58.028′
L	33°	0.38′	17°	58.575′
M	33°	0.515′	17°	58.573′
N	33°	0.517′	17°	58.702′
O	33°	0.652′	17°	58.7′
P	33°	0.648′	17°	58.379′
Q	33°	0.783′	17°	58.377′
R	33°	0.782′	17°	58.217′
S	33°	0.89′	17°	58.215′
T	33°	0.889′	17°	57.622′
U	33°	0.67′	17°	57.623′
V	33°	0.671′	17°	57.704′

Figure 6. Proposed area for future aquaculture in Small Bay (pre-mitigation)

Analysis of the carrying capacity (Section 9), taking into consideration protection from both wind fetch and swell, as well as lower current speeds, indicates that further expansion in this area may be limited. The use of raft culture in the area with higher stocking densities, concentrating the biomass of mussels into a limited area, could curtail the food requirements for optimum mussel growth, limiting higher production in the area. Additionally, taking into account harbour development in the area, further expansion for aquaculture is not envisaged in this area.

5 Aquaculture species currently cultivated on commercial scale in Saldanha Bay

At present three species of bivalves are commercially cultivated in Saldanha Bay. These are:

- Pacific oysters (*Crassostrea gigas*)
- Mediterranean mussel (*Mytilus galloprovincialis)*
- Black mussel (*Choromytilus meridionalis*)

While the black mussel (*Choromytilus meridionalis*) is indigenous, Pacific oysters (*Crassostrea gigas*) and Mediterranean mussels (*Mytilus galloprovincialis)* are introduced species into South Africa and are listed by the National Environmental Management: Biodiversity Act (NEMBA) (10 of 2004) regulations, 2014, as Category 2, that exempts for aquaculture in Saldanha Bay. In addition, the Biodiversity Risk and Benefit Assessment (BRBA) report has categorised both *C. gigas* and *M. galloprovincialis* as having a "reduced biosecurity requirements" in areas where there is an existing introduced population (DAFF, 2015).

The established culture methods and ready availability for imported oyster spat and natural settlement of *M. galloprovincialis*, together with their proven commercial viability, make it likely that both will remain the key species farmed in the ADZ in the future in both Big Bay and the Outer Bay.

A constraint to the expansion of bivalve culture that must be taken into consideration will be water quality and the prevalence of bio-toxins (2016, Vos Pienaar pers. comm. July). The bio-toxins currently monitored in Small Bay and Big Bay included Paralytic Shellfish Poisoning (PSP) toxins, Diarrhetic Shellfish Poisoning (DSP) toxins and Amnesic Shellfish Poisoning (ASP) toxins (DAFF, 2014).

In support of the industry and to meet international standards for consumer health and safety, the South African Live Molluscan Shellfish Monitoring and Control Programme, Issue 6: January 2016 provides a clear regulatory framework for the classification of the water areas and required testing to international standards. Bio-toxins are transported into Saldanha Bay and are associated with the upwelling system along the West Coast. It is therefore possible that the areas in the Outer Bay are likely to be first affected by toxic plankton blooms. However, the exposed conditions and rapid water turnover could facilitate the rapid purging of shellfish in the area, while the closed circulation in Small Bay and Big Bay may result in a longer purge time.

5.1 Pacific oysters (*Crassostrea gigas*)

The Pacific oyster (*Crassostrea gigas*) is an introduced species native to the Pacific coast of Asia. Its potential for rapid growth and tolerance to environmental conditions has led to it being the oyster of choice for cultivation in many regions of the world. It is the only commercial species of oyster cultivated in Saldanha Bay and the BRBA report has categorised *C. gigas* as having a "reduced biosecurity requirements" in areas where there is an existing introduced population, such as Saldanha Bay (DAFF,2015). It is therefore envisaged that with the potential ADZ in Saldanha Bay this species will be potentially remain the most economical for future cultivation.

However, the continued and increased production of *C. gigas* does have some potential environmental risk. Currently all *C. gigas* spat are imported. The NEMBA, 2004 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. The BRBA (DAFF, 2015) 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 BRBA report on the *C. gigas* (DAFF,2015), provides a list of some of the diseases which commonly infect *C. gigas* (Table 4), 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).

Table 4: Diseases that commonly infect *C. gigas,* (BRBA DAFF 2015).

Name of disease or parasite	Common symptoms
Denman Island Disease / Bonamiasis	Tissue necrosis (lesions form); mortality (predominantly in older individuals)
Nocardiosis	Mortalities; reduced thermo-tolerance; large lesions
Herpes-type virus disease of *C. gigas* larvae	Mortalities; loss of appetite; lesions
Oyster velar virus disease (OVVD)	Blisters form; Mortality
Juvenile Oyster Disease (JOD)	Reduced growth rate, development of fragile and uneven shell margins, cupping of the left valve; Mortality
Dermo	Reduced feeding, growth, reproduction; Mortality
Vibrio spp	Tissue necrosis; reduced feeding rate; erratic swimming behaviour (larvae); mass mortality.

5.2 Mediterranean mussel (*Mytilus galloprovincialis*)

The Mediterranean mussel (*Mytilus galloprovincialis)* is an introduced species that was first recorded in South Africa in the 1970s (Branch et al., 2004). It is the preferred species for cultivation in Saldanha Bay due to its flesh colour and rapid growth. Natural settlement on grow-out mussel ropes and mooring ropes and cages for finfish ensures its availability for ongoing culture, and it is most likely to remain the main species for cultivation in the ADZ.

M. galloprovincialis is listed as an invasive species in the NEMBA under Category 2. This means that its utilisation is only allowed under conditions within an area specified in the permit issued by DAFF for aquaculture (Department of Environmental Affairs, 2014). The BRBA report has categorised *M. galloprovincialis* as a species with a “low biosecurity risk” in areas where introduced population already exist (DAFF, 2015). The established populations are therefore likely to provide a continuous natural source of spat in Saldanha Bay, and as long as there is no requirement to import or translocate seed mussels from other areas there is no risk of introducing new invasive species from ongoing culture of this species. Due to its current natural distribution in the area, the impact of disease associated with mussel culture has not been assessed, and management of any possible introduced diseases is considered impractical given the prevalence of mussels in the surrounding environment (DAFF, 2012).

A possible constraint to more intensive culture of mussels is the deposition of faecal matter on the sediment below mussel rafts or long-lines. Studies in Small Bay showed that this caused a localised change in the benthic community below rafts, but did not compromise ecosystem function or the health of the mussels (Stenton-Dozey et.al 1998). The concentrated deposition of faecal material is most likely to be more of a problem associated with mussel rafts due to the high density of ropes within the limited area of the raft, and less likely to be a problem with long-lines where the same number of mussel ropes is spread out over a far greater area.

5.3 Black mussel (*Choromytilus meridionalis*)

The Black mussel (*Choromytilus meridionalis*) is indigenous to South Africa. It settles naturally on existing mussel ropes together with *M. galloprovincialis* and seed mussels of both species are bound onto new culture. However, it is not the preferred species for culture due to the dark flesh colour of the female of the species.

6 Recommendation for potential organisms for the expansion of aquaculture in Saldanha Bay

The species that are currently farmed in Saldanha Bay and discussed in Section 5 are likely to remain the key species that will be farmed in the ADZ in the future, as they are well understood and have been shown to be viable both for existing longline and raft culture systems and marketability.

Discussions with industry members highlighted a number of additional indigenous and alien species that could hold potential for future aquaculture development in Saldanha Bay. Some of these have already been farmed under experimental conditions and are discussed in this section. However, the species lists presented below are not exhaustive, and additional species could be identified in future that hold potential for aquaculture in Saldanha Bay as and when aquaculture techniques, conditions in the bay, markets etc. evolve. The potential of the key species are discussed below.

6.1 Potential indigenous aquaculture species

The main indigenous species identified as having possible future potential for aquaculture in the ADZ are:

- Abalone (*Haliotis midae*)
- South African scallop (*Pecten sulcicostatus*)
- Gracilaria (*Gracilaria gracilis*)
- Indigenous fish species.
  - White Stumpnose (*Rhabdosargus globiceps*)
  - Kabeljou (*Argyrosomus inodorus*)
  - Yellowtail (*Seriola lalandi*)

6.1.1 South African indigenous abalone (*Haliotis midae*)

Trials have been conducted in Saldanha Bay using barrel culture and cage culture methods to grow out the South African indigenous abalone (*Haliotis midae)*. These were not considered successful at the time due to infestations of sabellid polychaetes in the abalone shell that reduced growth rates.

However, barrels or cages culture methods, suspended from rafts or longlines, have been well-researched internationally and could easily be adapted for conditions in Saldanha Bay. Abalone hatcheries are already well established in South Africa and abalone seed can readily be obtained. Due to the high market value of abalone, it is foreseeable that future research is likely to continue on how to combat the sabellid worm. Success in this field will most likely result in abalone culture becoming more viable and attractive as a culture species in the ADZ.

It is recommended that *H. midae* is included in the application for the ADZ, due to its potential as an economically viable species, especially for international markets. As an indigenous species it would also likely pose a low ecological risk.

6.1.2 South African scallop (*Pecten sulcicostatus*)

Grow-out studies of hatchery-reared juvenile scallops (*Pecten sulcicostatus*), which are endemic to the South African coast, were undertaken from February 2010 to February 2011 (Arendse & Pitcher, 2012). Growth compared favourably with other commercially cultured species; however, there was some indication that high mortalities were associated with mid-summer temperatures. The possibility of new areas becoming available, especially in North Bay with lower temperatures, may facilitate commercial culture of this species. It is recommended that *P. sulcicostatus* is included in the application for the ADZ. Research in spawning and hatchery reared juveniles is currently underway. Its availability on the market could foreseeably fill current imports and it may also have export potential. As an indigenous species it would also likely pose a low ecological risk.

6.1.3 Seaweeds

Anderson et al. (2010) provides a review on seaweed mariculture potential on the south-west coast of Africa. Luderitz and Saldanha Bay / Langebaan Lagoon were identified as the only large sheltered bays on the temperate southern African coast that support large natural populations of Gracilaria (*Gracilaria gracilis*) and the most obvious sites for the potential development of a local industry. Although there is some limited data on the ecology of the local Gracilaria, nothing is known of reproduction and regeneration in the natural populations.

The potential for Gracilaria harvesting in Saldanha Bay was recognised in the 1980s, where the principal harvesting mechanism was through collection of beach casts. Harvesting was also possible at the main growth depth from 2-6m (at greater depths quality became poor). Gracilaria cultivation was attempted in the 1990s in Saldanha Bay and St Helena Bay; however, these commercial ventures failed (Anderson et al., 1989). Currently, the most-cultivated seaweed species in South Africa is Ulva spp., which is mainly focused on the effluent outflow water in raceways from the abalone industry (Amosu et al., 2013). One of the main problems experienced in suspended rope trials to gracilaria was fouling from mussel settlement. However, the demand for alga both as an abalone feed and for fertilizer may incentivise further research and new ventures in the cultivation of seaweeds.

Research on economically viable southern African seaweeds is therefore very limited, and realizing the potential of this resource will require cooperation between research agencies and industry. Potential production of Gracilaria depends on three primary factors: light intensity, water through flow and suitable nutrients in the water column. Anderson et al (2010) report that beach casts at Saldanha in 1987 approximated 170 tons dry mass, far below the 1 000 tons recovered annually before construction of the Port structures. Christie (1981) reported highest biomass and production of Gracilaria in the Langebaan area at the entrance to Langebaan Lagoon, where there is good water exchange and favourable temperature and nutrient conditions. Pilot studies in Brazil have yielded much higher increases in biomass of cultivated areas of Gracilaria (Camara Neto, 1987).

We conclude that little or no useful economic information exists on the potential for Gracilaria production in Saldanha, and any estimated production volumes are thus associated with a high degree of uncertainty. In the Saldanha ADZ, areas most suitable for Gracilaria production are likely located in Small Bay and Big Bay in areas shallower than 6 m. The fact that Gracilaria was not grown economically to date indicates that the commercial farming thereof may present challenges. Nevertheless, Gracilaria has potential for small scale farmers and is ideal for community projects due to the relative simplicity of the farming. Gracilaria is grown on longlines in relatively shallow water and requires warm water – therefore only the shallow areas of Big Bay are considered suitable (Small Bay has historically been tested for Gracilaria but was found unsuitable). It is therefore recommended that *G. gracilis* is included in the application for the ADZ, but it is advised that it commercial viability is uncertain as it requires high volumes and is susceptible to fouling from mussel settlement.

6.1.4 Indigenous fish species

Several pilot projects have been undertaken for spawning and hatchery rearing of *Argyrosomus Spp.* Dusky kob (*Argyrosomus japonicus*) and Silver kob (*Argyrosomus inodorous*), Yellowtail (*Seriola* *lalandi*) and White stumpnose (*Rhabdosargus globiceps*). Most of these were land-based pump ashore and re-circulatory systems, with pilot sea based cage culture for yellowtail and dusky kob taking place in Mossel Bay, Algoa Bay and Richards Bay. Currently, none of these ventures have been reported to be economically viable, primarily as they compete directly with low cost wild caught stocks and low cost imports of the same species.

Worldwide rising fish prices and supply shortages in traditional fishery products are likely to increase, and cages culture of fish could foreseeably become more cost effective with improved technology and reduce production costs, in parallel with increasing demand and increased prices for fresh fish in South Africa. Finfish culture can thus foreseeably become a focus for future aquaculture in the development of the Saldanha Bay ADZ, together with the growth of marine aquaculture in South Africa.

Some of the constraints raised by stakeholders currently involved with cage culture in Saldanha Bay are low water temperatures associated with upwelling, periodic low levels of DO (such as those experienced in North Bay) and increased costs due to the high level of marine fouling and security of farms against theft (Maclachlan and Stander, pers. comm.).

Advantages of using indigenous species would be the low biodiversity risk and potential to adapt to environment conditions. Fish species native to the West Coast may also be more resistant to water conditions, temperature and DO.

It is recommended that *R. globiceps, A. inodorus* and *S. lalandi* are included in the application for the ADZ, as suitable areas are likely located within the ADZ, they do not require risk assessments as they are indigenous and their commercial viability is likely to increase.

6.2 Potential introduced aquaculture species

6.2.1 Introduced shellfish species

A number of other exotic species of bivalves, besides the Pacific oyster (*Crassostrea gigas*) and Mediterranean mussel (*Mytilus galloprovincialis*) currently farmed in Saldanha Bay, have been proposed by members of the industry to have commercial potential for future farming in Saldanha Bay; these include:

- European flat oyster (*Ostrea edulis*)
- Chilean scallops (*Agropecten purpuratus*)

The European flat oyster (*Ostrea edulis*) is native to Europe and has an established market in that region. *O. edulis* is listed in the NEMBA regulations, 2014, as Category 3 and is currently prohibited in terms of the Act.

However, trials growing out the European flat oyster in South Africa were undertaken in the mid-1980s and 1990s in an enclosed dam to the east of the iron ore stockpile area within the TNPA security area. These were aborted in the mid-1990s with the closure of the farm. However, a self-seeding population is still currently present in the former farmed area. Although the dam has a 2m diameter access pipe to Big Bay, *O. edulis* does not appear to have spread from this current location, with the exception of few isolated individuals that have reportedly been found in Big Bay and Langebaan area (2016, Tonin, pers comm).

Although there is significant economic potential in farming with *O. edulis* in Saldanha Bay, its current NEMBA listing would require a thorough risk assessment to be undertaken to fully evaluate its invasive potential. As seed would have to be initially imported there would be an added risk of introducing diseases that could seriously impact on the current oyster production. The solution to this would be the establishment of a hatchery in South Africa to guarantee disease free spat.

Chilean scallop *Argopecten purpuratus* is currently listed in the NEMBA list of prohibited alien species in terms of section 67(1). However, it has also been reported to be present in imported oyster spat. *A. purpuratus* was successfully spawned and propagated in a closed system hatchery in St Helena Bay in the mid-1990s. Subsequently, the hatchery was closed when the then Department of Fisheries denied a permit for further culture of the species.

However, the ease of propagation and rapid growth of *A. purpuratus* and its suitability for growth in the temperatures in Saldanha Bay makes it a highly attractive species for future culture, also as there is already an existing international market for scallops. Any future consideration of these species would first necessitate a comprehensive risk assessment and reclassification by NEMBA. Currently research effort is directed at the culture potential of the South African scallop (*Pecten sulcicostatus*).

It is recommended that *O. edulis* and *A. purpuratus* are **not** included in the application for the ADZ, as they both require comprehensive risk assessments prior to further consideration for aquaculture.

6.2.2 Introduced fish species

The Salmonids Atlantic salmon (*Salmo salar*) and Rainbow trout (*Oncorhynchus mykiss*) are exempt from the NEMBA list of prohibited alien species in terms of section 67(1), and the BRBA report also categorised *O. mykiss* as being potentially non-invasive. Experimental culture of Atlantic salmon (*S. salar*) was conducted in floating cages in Outer Bay in 2014 to 2015. However, these were aborted due to high mortalities caused by low DO levels in the water following intense upwelling events outside Saldanha Bay. This, together with a concurrent outbreak of a gill pathogen, resulted in high mortalities (Maclachlan and Stander pers. comm.). Trials with Rainbow trout (*O. mykiss*) are currently underway in Big Bay. The high market value of imported salmon and locally produced trout, make both of these species attractive for the cultivation in the ADZ. These species however would need to be cultivated in areas with favourable depth and environmental conditions.

Areas that may hold potential are located in the southern area of the Outer Bay, where water depths and currents may possibly mitigate against low DO. One of the current lease holders in this area has expressed an intention to continue with future trials of farming *S. salar.* It is recommended that *S. salar* and *O. mykiss* are included in the application for the ADZ, as portions of the ADZ are likely to be suitable and both species are likely economically viable.

7 Aquaculture Production Methods

Bivalve production systems currently used in Saldanha Bay involve suspension methods, where seeded mussel ropes or mesh bag racks, or containers for oysters are suspended from either surface longlines (Figure 7) or rafts. Finfish cages generally consist of a flexible collar from which the net cages are suspended.

Key elements common to longlines, rafts and fish cages are the requirement for reliable mooring systems. These will be particularly important for longlines and fish cages that will be deployed in areas exposed to greater sea and swell conditions in Big Bay and Outer Bay. As the Port of Saldanha is South Africa's deepest international port with a restricted entrance channel, the Port Captain has specifically expressed the importance for moorings and surface structures of all aquaculture systems to meet the highest international specifications to prevent the danger of longlines, raft structures or cages from breaking loose and endangering navigation in the bay. In future, lessors will be required to submit in advance their longline or raft designs for approval by Port authorities. Aspects of this are likely to include:

- mooring weight and ground tackle specifications;
- rope thickness and material; and
- buoyancy make and material and attachment systems.

The Port Captain has also indicated that required demarcation of aquaculture areas will include navigation buoys and lighting. Although these will be placed and maintained by Port authorities, the costs will likely be carried over to lessors of water area.

7.1 Longlines

Longlines comprise a surface rope held to the surface with floats and a mooring on each end of the surface rope to fix the line in position. Tension on the line and maintaining it on the surface is provided by the two end buoys and moving the moorings apart. The production ropes for mussels or ouster racks are then suspended from the surface rope (Figure 7).

Figure 7 : Mussel rope suspended from a longline

Further buoyancy is provided by additional flotation attached to the line between the end buoys to compensate for the weight of the mussel rope or oyster racks. Currently in the existing production units in Small Bay these are often made up of low-cost plastic containers that frequently break off and wash up ashore, adding to the pollution from washed up debris.

As longlines are moored (Figure 8), their use is generally limited to depths of not more than 100m, and could, therefore, be deployed in all the proposed areas, including the Outer Bay (Figure 9), where maximum depths will not exceed 30m.Taking into consideration the potential for a robust construction, longlines could foreseeably become the main system used for bivalve production in both Big Bay and the Outer Bay.

It is also the opinion of industry members that robust longlines will be more suited to the proposed ADZ expansion into the more exposed areas in Outer Bay. Modification to longlines can also be made to suspend them at a predetermined depth below the surface to reduce the effect of the sea conditions.

Figure 8: Five ton concrete mooring block used for longlines in Big Bay, Saldanha Bay.

Currently longlines deployed in Big Bay use five ton mooring blocks on each end of their lines with a shared five ton mooring block between two 200m lines laid in a straight line. This equates to three five-ton mooring blocks for every 400m of surface longline. The direct impact on the seabed of the mooring blocks would be approximately 8m^2.

Studies on the carrying capacity in Saldanha Bay also indicate that the lower density of mussel or oysters suspended from longlines promotes better current flow between the lines, providing conditions for optimal growth rates as well as limiting the localised impact of sedimentation on the seabed from mussel faecal deposition (Section 3).

It is recommended that future expansion of longline culture will need to adhere to best practice guidelines that will include specifications on:

- maximum allowable length of lines;
- minimum pacing between lines; and
- open water channels between concession areas for navigation of harvesting and maintenance vessels.
- management of unused or broken mussels or fouling mussels on lines or oyster racks.

The recommended spacing between longlines to allow for vessel movement between lines is approximately 10m (Figure 9). In addition, it is recommended that a clear space of at least to 40m is maintained on the border of each leased area, to allow safe passage for vessels navigating between the farms (2016. Tonnin pers. comm. July, 2016).

Figure 9 : Figure Longlines deployed in Big Bay showing end buoys [Red] and intermediate flotation [yellow]. Spacing between longlines provides access for harvesting and servicing vessels

Oysters grown on longlines are washed on board the vessel, and the resultant silt is washed overboard while the vessel is moving along and between lines. Similarly, mussels grown on longlines are harvested, de-clumped and graded on the vessel, and the broken and undersize mussels, together with any fouling organisms, are washed directly overboard as the vessel is moving along and between lines. This is likely to reduce the localised impact of such waste.

7.2 Rafts

The first rafts for mussel culture in South Africa were launched in Algoa Bay in 1986. The design was based on the raft specification used in Vigo, Spain, and consisted of four large steel pontoons with a robust wooden top structure used for the suspension of mussel ropes. Subsequently, rafts were constructed and deployed for mussel culture in Saldanha Big Bay in 1988 and Small Bay in 1989 (Figure 10). These were initially constructed using fibre cement pontoons with a wooden beam top structure. The sea and swell conditions experienced in Big Bay resulted in the wooden structure breaking up from the continuous flexing movement. However, the rafts in the Inner Bay were not affected in this way. Subsequent developments have led to the current raft design used in the Inner Bay, consisting of two flexible high density polyethylene (HDPE) pontoons with a HDPE piping top structure that provides more flexibility to the overall design.

Figure 10 : Raft moored in Small Bay. Working tables and materials on the raft provide facility for harvesting, de-clumping and binding of new ropes on the raft.

An advantage of a raft is that it provides stable structure on the surface for people to work on. This allows some of the processing of mussels and binding to take place *in situ* and less dependence on larger support vessels for harvesting and processing. It can also reduce the reliance for holding and processing facilities ashore. However, a disadvantage is that debris from processing and faecal material from cultured mussels and fouling organisms, specifically the sea squirt (*Ciona intestinalis*) (Figure 11), results in significant sedimentation below the raft (Stenton-Dozey et.al 1998).

The recommended density of rafts per area is one raft per hectare, which equates to an approximate production of 20 to 30 tonnes of marketable mussels per hectare. The positioning of rafts at these intervals will prevent localised depletion of available plankton from the high density of mussel ropes under the limited surface area of the raft. It will mitigate to the localised sedimentation below a raft. It will also provide adequate space for movement of supporting vessels between rafts.

Figure 11 : Fouling of sea squirts (*Ciona intestinalis*) on oyster racks

7.3 Finfish cages

Internationally, floating fish cages incorporate a wide variety of designs and materials (Figure 12). These are largely influenced by the conditions in which they are deployed and the fish species being cultivated. Typically cages deployed offshore, in more exposed areas to farm salmon and tuna, are constructed of flexible high density polyethylene and are circular in construction. Taking into account the exposed conditions in which off-shore cages are situated, and the requirement for multi-mooring systems, the depth thresholds recommended for sea cages is between 25–100 m (FAO.org). Depth and current also influence water quality, which can be affected from the fallout of faeces and undigested feed below the cage and ammonia excretion of fish.

Figure 12 : Flexible HDPE fish cage currently moored in Big Bay, Saldanha Bay

In Saldanha Bay, these recommended depths would limit the use of cages mainly to the Outer Bay where depths of up to 30m can be found in the proposed ADZ. The design of the fish cages used in the trials in Outer Bay consisted of a flexible HDPE collar from which the net cage was suspended. The mooring system conformed to international standards for the prevailing sea and swell conditions.

The possibility also exists to deploy smaller cages in the Big Bay area where the depth exceeds 13m and relatively strong currents are prevalent (2016, Stander pers. comm). The relatively high fouling rate on the netting of the cages in Saldanha Bay is considered a potential problem and will result in the need to exchange cages regularly, placing a greater dependency on available jetty space in the harbour.

7.4 Barrel culture

Commercial barrel culture systems are still in their infancy in Saldanha Bay, but are a recognised culture method for abalone internationally. This system could easily be deployed from both rafts and longlines, and therefore the basic conditions for the deployment of these systems would be the same as for other shellfish species.

However, a basic difference between culturing bivalves and abalone is that barrel culture requires regular servicing to feed the abalone. Due to the cost of abalone seed, it is foreseeable that barrels will be deployed in areas where they could be easily accessed and monitored, and are therefore likely to be restricted to the currently allocated areas of Small Bay or expansion areas in Big Bay.

8 On-shore infrastructure

Sea-based aquaculture areas and systems, both current and for the proposed Saldanha Bay ADZ, will require some form of support from land based infrastructure. Such infrastructure will vary widely depending on species being cultivated and aquaculture systems used. The basic infrastructure required for both current and any future development in aquaculture are:

- adequate landing quays for safe embarking and disembarking of personnel, loading equipment and offloading product;
- access to landing quays is required for vehicles to transport equipment and or product; and
- mooring space within the protected confines of the harbour for support vessels and processing barges.

Optimal shellfish production, specifically oysters, also needs holding facilities ashore with access to clean seawater. The volumes of seawater needed will vary depending on the holding facilities and the turnover of water through the system, which will be determined by the species and unit size. A rough estimate for approximately 250kg of oysters in a holding facility of $1m^3$, would be a water turnover of twice an hour, therefore a through flow of [$2m^3$/hr] per m^3 of holding tank.

Some of the current producers have installed re-circulating systems for their holding facilities, which allow them to cool the water to optimum temperatures and also use filter systems to enhance water quality, which makes operators less reliant on the quality of the seawater sourced from the harbour.

For most products, a high volume of water is required in the cleaning processes. Onshore processing will therefore necessitate some form of filtration or scrubbing process of the waste water before returning it into the bay. To maintain water quality suitable for basic health and safety standards for processing products for human consumption, there will have to be close monitoring of these processes as well as monitoring of the water outflow from other industries in the harbour or storm water drainage systems.

Currently any land based process that discharges effluent into the coastal environment must be authorised by the Department of Environments Affairs, in terms of in terms of the Integrated Coastal Management Act (2008) Chapter 8, Section 69 Marine and Coastal Pollution Control: Discharge of effluent into coastal waters. In addition the DAFF, South African Live Molluscan Shellfish Monitoring and Control Programme Issue 6: January 2016 provides the regulatory framework for the classification of the water areas and required testing to international standards and other regulatory processes.

Detailed information on additional facilities and operations, as is required for the authorisation of such facilities in terms of the National Environmental Management Act 107 of 1998 (NEMA) and ICMA, cannot be provided as part of this study.

Mussels can largely be harvested, de-clumped and graded either on the raft or accompanying vessel harvesting from longlines, and water is pumped and discharged directly overboard. As mussels are generally not kept in holding tanks ashore, the facilities required for packaging for the market are not reliant on a source of seawater, and this process could be undertaken some distance from the harbour, e.g. at the Saldanha Industrial Development Zone.

DAFF has overall responsibility for the Saldanha Bay fishing harbour and the harbour facilities, while the maintenance and management of the harbour currently falls under the jurisdiction of the National Department of Public Works (DPW). Applicants for processing facilities ashore are required to apply to the DPW for land or available infrastructure.

The Saldanha Bay fishing harbour is divided into two areas (Figure 133): Pepper Bay (Figure 14) and the commercial harbour around the government jetty and commercial slipway (Figure 155). The commercial harbour is currently utilised mainly by larger fishing vessels for lay-up, maintenance and repair. The area is already congested from these activities, and any further allocation of land for aquaculture would require specific re-zoning.

Figure 13: Pepper Bay and Saldanha commercial harbours

Figure 14: Approximate extent of Pepper Bay fishing harbour, landing facilities and existing buildings

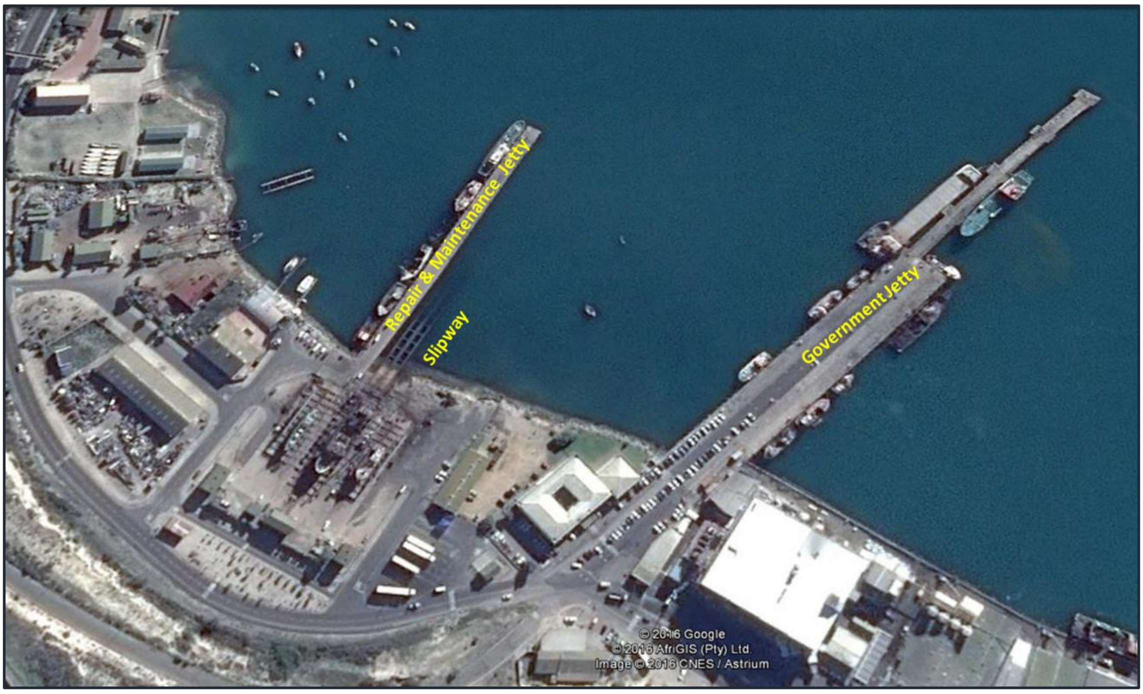


Figure 15: Commercial fishing harbour, slipway and government jetty.

Currently the most practical area suitable for the aquaculture industry is Pepper Bay, which has a land area of approximately 9.7 ha divided into 11 properties. The current infrastructure includes:

- 110m of concrete quay
- 27m and 18m long timber quays; and
- 2 concrete paved boat ramps.

The quay space appears to be adequate at present to accommodate the current aquaculture companies and vessels using them, as well as the processing barges moored off the jetties when not in use. The current infrastructure should be able to accommodate a moderated expansion of the industry. However, a large scale expansion and significantly increase in the number of support vessel is likely to limit overnight mooring and berthing space alongside the jetties for landing product or processing alongside the jetty. One company currently has its own private landing and processing facilities and could foreseeably also lease facilities to a limited number of new operators.

The quay space is also shared with other users in the commercial fishing industry, specifically the West Coast Rock Lobster (WCRL) vessels and commercial line fishermen. There appears little congestion from the WCRL vessels, as these vessels use only the concrete quay to load bait and offload crayfish to the registered DAFF scales on the quay. The vessels then overnight alongside the government quay.

However, there is a concern over short term incidences of congestion with the commercial line fishermen that use the concrete slipways and wooden jetties for the duration of seasonal runs of line fish outside Saldanha Bay. During these periods, more than 100 boats may arrive at the harbour within a day, launching in the early morning and returning during the day to offload their catch and take their boats out the water. There is added congestion of access roadways and parking caused by the fish merchants that purchase the daily catches. Currently, there is an area outside the harbour for the excess vehicles and trailers, but the overall congestion seriously hampers the daily aquaculture activities during those periods. It is possible that this congestion could be effectively controlled by DAFF through stricter coordination of the harbour facilities in these periods.

Detailed information on additional berthing, mooring and landing facilities, as is required for the authorisation of such facilities in terms of NEMA, cannot be provided as part of this study.

The Spatial and Economic Development Framework (SEDF) commissioned by the DPW has identified *inter alia* the need for facilities for future aquaculture in the area and incorporated this into the SEDF that is currently in progress, together with providing facilities for both commercial and recreational fishermen.

Currently, through the Operation Phakisa Delivery Unit, six companies have been able to procure facilities in the harbour, with three currently having access to seawater for processing and holding facilities (Figure 16). The Operation Phakisa Delivery Unit is also negotiating leases that are underutilised to make additional facilities available for companies that already have water areas and are about to start their operations.

Figure 16: Leased areas currently taken up by the aquaculture industry in Pepper Bay fishing harbour.

The availability of more land for processing facilities, with access to seawater for oysters, would thus be necessary for the future expansion in aquaculture, specifically for operators using longlines and vessels with limited space for processing at sea, and is currently be addressed by the Operation Phakisa Delivery Unit.

An alternative option is to undertake a part of such processing on board vessels or barges moored in the bay. On-board processing would require additional regulation to be imposed on these vessels in line with food processing establishments. Although this option could release the pressure on land within the harbour, there would still be a need for access to berthing space for loading and offloading. Further processing and packaging could then be expanded to the industrial areas of Saldanha Bay.

9 Carrying Capacity and Potential Aquaculture Production[3]

9.1 Current aquaculture production rates in Saldanha Bay

The TNPA discussion plan for the Port of Saldanha Bay (20/11/2015) indicates the currently leased areas in Saldanha Bay to be 430 hectares (Figure 2). Recorded figures from 55 farmed hectares (30ha in Small Bay and 25ha in Big Bay) yielded a wet weight (graded) production of 1,042 tons in 2012/2014 (860 tons of mussels from 30 hectares and 182 tons of oysters from 25 hectares) (Table 5). Based on the current production therefore, the marketable production approximates 19 t per hectare in the currently farmed areas.

[3] Subsequent to the finalisation of this report on 5 December 2016, Appendix 3 was added incorporating guidance on estimates of fish production "carrying capacity" for cage culture.

G*raded production volume* is defined as the portion of mussels (or oysters) that are actually marketed / sold. Discussions with the aquaculture industry in Saldanha suggested that approximately 50% of mussel growth at harvest is not marketed (this can vary between 40-60%, hence an average of 50% is used). The portion not marketed is used for re-seeding or is discarded. Ungraded production thus refers to the total production volume (marketed, re-seeded and discarded) of mussels. Oysters, on the other hand, are generally all removed from the water without any discard back into the water. Unlike mussels, oyster spat are imported, and graded volumes are typically equivalent to the entire harvested volumes.

Table 5: Harvest of mussels and oysters in Saldanha Bay

Organism	Tons wet weight	Hectares	Year	Source
Mussels	860	30	2012	Probyn et al. 2015:529
Oysters	182	25	2014	Probyn et al. 2015:529
Total**	**1,042**	**55**		

** This equates to a ratio of 83% mussels and 17% oysters (83:17)

The designation of potential aquaculture areas within a Saldanha Bay Aquaculture Development Zone as proposed in Figure 2 approximates 1871 hectares (see Table 8 for a breakdown of each area). Assuming the current graded production of 19 t/ha and the current ratio between oysters and mussels the scaled up graded production of BIVALVES in this (potential) new area would be about 35 000 t. Note these figures are indicators only and in reality many other factors need to be considered, not least of which is the density of operations, proportional area allocated to lease holders and variability in yields in different areas.

Both mussel and oyster racks and lines also accumulate fouling organisms (Figure 11), as do mooring lines for rafts and other structures associated with the particular farm type. Fouling organisms include many other species, such as tunicates, must also be considered when assessing the availability of nutrients for aquaculture production and should be taken into account when determining the volumes of waste or discarded materials released back into the water.

9.2 Carrying Capacity for aquaculture in Saldanha Bay

Saldanha Bay provides optimal conditions for bivalve production. The delineation of possible ADZ areas in Saldanha Bay has been guided by requirements of the Port of Saldanha as well as oceanographic conditions in the Bay. However, it is acknowledged that additional limiting factors will inform the actual future aquaculture production in Saldanha Bay. These include both the Production Carrying Capacity (PCC) and the Ecological Carrying Capacity (ECC)[4] of the Bay (with regard to

[4] PCC, according to Probyn, depends largely on the physical attributes of the system as related to target species' requirements and, in particular, the primary production occurring there. The ECC is lower, as it takes into account requirements to minimise impacts on the environment, and provides a more conservative, management-orientated estimate of carrying capacity (McKindsey et al. 2006). The ECC can be 2–5 times lower than the PCC (see Probyn et al., 2015)

nutrient uptakes of the primary aquaculture bivalve species – oysters and mussels, the likely density of the farms and critically, the hydrodynamics of the Bay or specific locations within the Bay).

At site specific locations, water dynamics will influence flushing, supply of nutrients and build-up of waste products in sediments below units. Importantly, water flow can also be affected by the density of units which may have an overall negative impact on the economic viability of aquaculture in general in the Bay. Probyn et al. (2015) estimated the Production Carrying Capacity (PCC) for a 5 650 ha area including Big Bay and Small Bay. Based on a sampling station in Big Bay and 12 months of sampling, nutrient flows over a 12 month period were calculated (these results were compared with the previous study of Grant et al. (1998). The Probyn et al. (2015) estimate of total (ungraded) PCC for a lower and higher production scenario **over 1000 ha** was as given in Table 6 below :

Table 6. Estimated production of bivalves (mussels and oysters) from the carrying capacity in Saldanha Bay for a 1000 ha area (scaled down to per hectare in parentheses)

	Mussels	Oysters
Lower Production Level	40 000 t (40 t/ha)	4 600 t (4.6 t/ha)
Higher Production Level	53 000 t (53 t/ha)	6 000 t (6 t/ha)

Note that these upper and lower limits reflect the high and low variability associated with seasonal availability of nutrients (our simplified interpretation – see Probyn et al., 2015 for details). In addition, in this study, the ratio between mussels and oysters was assumed to be 70:30. For the purposes of consistency all calculations made in this report shall assume the same ratio.

Probyn et al. (2015) however advised that these figures were for Production Carrying Capacity (PCC) and did not consider Ecological Carrying Capacity (ECC). McKindsey et al. (2006) and Probyn et al. (2015), in their review of capacity models for bivalve culture, recommended that the ECC should be applied and that this would range between 10 – 25% of PCC.

9.3 Ecological Carrying Capacity and the estimation of potential production

Given an expanded area for aquaculture in the Bay, as suggested in Figure 2 and assuming the upper and lower limits of PCC for the Big Bay / Small Bay area as determined by Probyn et al. (2015) the upper and lower PCC can firstly be converted to a PCC per hectare (see Table 6) and this number then used to derive (by extrapolation) the ECC per hectare for the potential ADZ areas (pre-mitigation). Two ECC levels are then determined : a) lower scenario = 10% of PCC; and b) higher scenario = 25% of PCC for both mussels and oysters (Table 7).

Table 7. Estimates of ECC for Inner and Big bay per hectare for two scenarios (high and low production)

Ecological Carrying Capacity tons per hectare

	Mussels		Oysters	
	10% of PCC	25% of PCC	10% of PCC	25% of PCC
PCC Low Production Level	4.00	10.00	0.46	1.15
PCC High Production Level	5.30	13.25	0.60	1.50

If these numbers are then applied (scaled up) to the proposed ADZ areas as suggested in Figure 2 the following total (ungraded) production volumes for the ADZ can be derived (Table 8):

Table 8. Total production limits (ungraded) for oysters and mussels for all areas as designated in Figure 2. (estimates for graded volumes are given in parentheses)

Location	Area (hectares)	10% ECC Mussel : Oyster (70:30) Low production Scenario tons/annum		25% ECC Mussel : Oyster (70:30) High production scenario tons/annum	
		Mussels	Oysters	Mussels	Oysters
Small bay	163	652 (326)	75	2160 (1080)	245
Big Bay North	525	2100 (1050)	242	6956 (3478)	788
Big Bay South	520	2080 (1040)	239	6890 (3445)	780
Outer Bay North	336	1344 (672)	155	4452 (2226)	504
Outer Bay South	327	1308 (336)	150	4333 (2167)	491
Total Area	**1871**	**7484 (3742)**	**861**	**24791 (12 396)**	**2807**
Combined Mussels		**8 345t (4 603 t)**		**27 597t (15 203 t)**	

Note that these estimates were extrapolated to Outer Bay at the same ratios and ECC per hectare.

Given the above estimates, the lower and upper limits of ECC for ungraded bivalve aquaculture production based on the areas available for an ADZ (as designated in Figure 2) would be 8 345 t/yr (low) and 27 597 t/yr (high). This is equivalent to between 4 603 t/yr and 15 203 t/yr of graded (marketable) production.

These then would be two ecological baselines (high and low limits) for the production of bivalves in the specific areas identified.

The figures provided in Table 8 then allow for ecological baselines that can be applied to each area in the ecological assessments. In practice the area designated is likely to be reduced in size, or, as is currently the case, the entire area allocated is not fully utilised. We suggest that these upper and lower limits for ECC are applied as the ecologically safe parameters for the ADZ. These same numbers would then apply if the area were reduced in size which would accommodate differences in density of lines and rafts on the farms while not exceeding the overall ECC for the ADZ area (as shown in Figure 2).

For seaweed we recommend, as in para 6.1.3 that production level (natural harvests) could potentially be at the level determined by Anderson et al (2010) of 170 tons dry mass (equivalent to approximately to 1 360 tons wet weight) or potentially higher, if intensively cultivated as in Brazil (Camara Neto 1987).

9.4 Application of alternative PCC and EEC estimates for Fish Farming

The estimate for production capacity for farming of fish in fish cages (of which there have been some trials and also ongoing proposals on a much large scale), is problematic in the sense that the production estimates are variable and unknown at this stage. Two current application for fish farming in both Big Bay (south) and Outer Bay suggest that a conservative estimate of production (fish) would be 40 t per hectare per year.

Fish farming technically does not require a planktonic carrying capacity as is the case for bivalve culture. In contrast it has a nutrient input associated with fish feed and waste products from faeces and unutilised feed. Moorings and net-cages would also have a bioaccumulation of bivalves and tunicates and lead to additional nutrient build-up from waste products settling in sediments below cages

The ecological impact would then need to substitute the areas available for bivalves with fish cages (possibly as indicated in Figure 2). However the overall ECC would nevertheless remain unchanged for the total area and fish farming is likely only to increase nutrient loads in the total ADZ with localised ecological impacts typical of such farms in other areas of the world.

10 ADZ Management

The TNPA currently has jurisdiction over all development in the Port of Saldanha Bay, and the proposed establishment of the ADZ will have to conform to the longer term development of Saldanha Bay as an international commercial port. In the development of the ADZ, the TNPA will provide the necessary guidelines to ensure that production systems will be secure and not endanger shipping in the bay. This will include specification of moorings and the material and construction of surface and sub-surface systems. The TNPA will also be responsible for providing navigation lights and buoys to demarcate areas used for aquaculture.

The expansion of the aquaculture industry will continue to be subject to the permit conditions provided by DAFF, and this will include the implementation of the South African Live Molluscan Shellfish Monitoring and Control Programme to ensure that water and products harvested and marketed conform to international standards. Currently all the companies operating in Saldanha Bay are party to the “Bivalve Shellfish Farmers Association of South Africa”. The association negotiates with DAFF and self-regulates in terms of water and bio-toxin tests to ensure safe marketing of products from Saldanha Bay.

The “Saldanha Bay Water Quality Trust” is independent from the aquaculture industry and will also provide management control and advice on all water quality issues affecting the bay. Further expansion of aquaculture will necessitate coordination from all relevant bodies[5] to ensure that the establishment of new farms adhere to "best practice principles". Specific issues that will have to be monitored would include *inter alia*:

- specifications of materials and mooring systems that conform to TNPA requirements to prevent danger to shipping in the bay;
- farm layouts to have minimum impact on neighbouring farms, which may require regulation on:
    - spacing and positioning of lines to allow safe navigation between farms;
    - control over stocking densities to prevent exceeding localised carrying capacity that would negatively affect adjacent farms; and
    - management of discharges water used for cleaning excess fouling organisms to prevent sedimentation and conditions that could affect water quality from decomposing material on seabed.

The expansion of the aquaculture industry could also result in constraints with utilising existing harbour facilities. DAFF may be required to exercise some control over these facilities including:

- limiting time spent alongside by any one vessel for offloading product and loading equipment;
- limiting processing on or alongside the jetties;
- control over storage of crates, ropes and nets on jetties; and
- control over access and parking of vehicles that support the industry.

11 Conclusions

Saldanha Bay's exceptional natural environment gives it the potential to be a global supplier of first class mussel and oyster products, but the full potential remains unfulfilled.

This study identified a pre-mitigation area of 1 871 ha suitable for aquaculture in the ADZ, increasing the overall area allocated to aquaculture in Saldanha Bay from the current leased area of 430 ha (of which approximately 150 ha are currently farmed). Based on research data of (Probyn, 2016) rough estimates have been made of the potential Ecological Carrying Capacity for the proposed ADZ (expanded area). The lower and upper limits of ECC for ungraded bivalve aquaculture production based on the areas available for an ADZ (as designated in Figure 2) would be 8 345 t/yr (low) and 27 597 t/yr (high). This is equivalent to between 4 603 t/yr and 15 203 t/yr of graded (marketable) production).

Water exchange allows new production to be available throughout the Bay, but characteristics within the Bay suggest that Small Bay may be better suited to oyster culture, while Big Bay suits

[5] This implies possible organisations that might be formed to manage the ADZ as well as current aquaculture bodies and government organisations, such as TNPA, DAFF, Saldanha Bay Municipality, Bivalve Shellfish Farmers Association of South Africa and Saldanha Bay Water Quality Forum Trust.

mussels. Outer Bay could also be suitable for mussel culture, but the higher wave stress in these areas should be taken into account as well as the high risk of bio-toxins being transferred into the area from adjacent coastal areas. Nevertheless, Saldanha Bay's relatively sheltered position and its optimal water temperature, circulation and plankton biomass concentration could support a bivalve sector far larger than what currently exists.

The current aquaculture systems, comprising longlines and flexible rafts, will most probably continue to be used in the ADZ. However, system utilised in the more exposed area in Outer Bay will require more robust mooring and material components. Fish cages and barrel culture are also considered likely viable options in future.

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*)
- New indigenous shellfish species:
  - Abalone (*Haliotis midae*)
  - South African scallop (*Pecten sulcicostatus*)
- New indigenous finfish species:
  - White Stumpnose (*Rhabdosargus globiceps*)
  - Kabeljou (*Argyrosomus inodorus*)
  - Yellowtail (*Seriola lalandi*)
- Alien finfish species:
  - *Atlantic salmon (Salmo salar)*
  - *Rainbow trout (Oncorhynchus mykiss)*
- *Seaweed :*
  - *Gracilaria gracilis*

Potential also exists for farming Indigenous species such as South African abalone (*H. midae*) and the South African scallop (*Pecten sulcicostatus*). Several species of indigenous fish species have potential for cage culture, but their economically viable make it unlikely that will be exploited in the short term. However ongoing research and trial are possible, if export or higher priced markets are established. The proposed pre-mitigation areas and recommended species and culture methods are shown schematically in Figure 17 and summarised in Table 9 (this should also be read in conjunction with Figures 2 -6).

With regard to onshore processing, the expansion of the aquaculture industry is likely to result in constraints with utilising existing harbour facilities. In particular, the seasonal nature of commercial fishing boats will lead to congestion necessitating DAFF to exercise some control over these facilities. Further, if the full capacity of the proposed ADZ were to be realised, the expansion of not only the current areas (which are not fully utilised), but also the potential new areas, then current onshore processing capacity will be inadequate to meet the needs of the aquaculture industry. It is likely however that this would not present a constraint to development, but that expansion in a structured manner would be facilitated as needed within the current land use around the Bay.

Table 9: Summary of recommended ADZ characteristics by Area, Species and Gear

Area	Recommended species	Recommended Aquaculture Systems
Outer Bay - North	Mediterranean mussel (*Mytilus galloprovincialis*) Black mussel (*Choromytilus meridionalis*)	Sub-surface Longlines
	White Stumpnose (*Rhabdosargus globiceps*) Silver Kabeljou (*Argyrosomus inodorus*) Yellowtail (*Seriola lalandi)*	Floating cages
Outer Bay - South	Mediterranean mussel (*Mytilus galloprovincialis*) Black mussel (*Choromytilus meridionalis*)	Sub-surface Longlines
	White Stumpnose (*Rhabdosargus globiceps*) Silver Kabeljou (*Argyrosomus inodorus*) Yellowtail (*Seriola lalandi)* Atlantic salmon (*Salmo salar*) Rainbow trout (*Oncorhynchus mykiss*)	Floating cages
Big Bay - North	Pacific oysters (*Crassostrea gigas*) South African scallop (*Pecten sulcicostatus*) Mediterranean mussel (*Mytilus galloprovincialis*) Black mussel (*Choromytilus meridionalis*) Abalone (*Haliotis midae*) Gracilaria (*Gracilaria gracillis)*	Longlines / rafts
	White Stumpnose (*Rhabdosargus globiceps*) Silver Kabeljou (*Argyrosomus inodorus*) Yellowtail (*Seriola lalandi)* Rainbow trout (*Oncorhynchus mykiss*)	Floating cages (depths >13m
Big Bay - South	Pacific oysters (*Crassostrea gigas*) South African scallop (*Pecten sulcicostatus*) Mediterranean mussel (*Mytilus galloprovincialis*) Black mussel (*Choromytilus meridionalis*) Abalone (*Haliotis midae*) Gracilaria (*Gracilaria gracillis*)	Longlines / rafts
	White Stumpnose (*Rhabdosargus globiceps*) Silver Kabeljou (*Argyrosomus inodorus*) Yellowtail (*Seriola lalandi)* Rainbow trout (*Oncorhynchus mykiss*)	Floating cages (depths >13m
Small bay	Mediterranean mussel (*Mytilus galloprovincialis*) Black mussel (*Choromytilus meridionalis*) Pacific oysters (*Crassostrea gigas*) Abalone (*Haliotis midae*) South African scallop (*Pecten sulcicostatus*) Gracilaria (*Gracilaria gracillis*)	Longlines / rafts

Point	Lat S		Long E	
A	33°	2.806′	17°	55.261′
B	33°	1.934′	17°	57.442′
C	33°	3.393′	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°	0.21′	17°	57.71′
J	33°	0.213′	17°	58.03′
K	33°	0.375′	17°	58.028′
L	33°	0.38′	17°	58.575′
M	33°	0.515′	17°	58.573′
N	33°	0.517′	17°	58.702′
O	33°	0.652′	17°	58.7′
P	33°	0.648′	17°	58.379′
Q	33°	0.783′	17°	58.377′
R	33°	0.782′	17°	58.217′
S	33°	0.89′	17°	58.215′
T	33°	0.889′	17°	57.622′
U	33°	0.67′	17°	57.623′
V	33°	0.671′	17°	57.704′
W	33°	1.045′	18°	1.156′
X	33°	2.763′	18°	2.171′
Y	33°	3.031′	18°	0.371′
Z	33°	1.948′	18°	0.89′
AA	33°	1.91′	18°	0.77′
AB	33°	3.47′	18°	0
AC	33°	3.072′	18°	2.278′
AC1	33°	3.212′	18°	1.345′
AD	33°	3.82′	18°	2.193′
AD1	33°	4.036′	18°	1.195′
AE	33°	4.27′	18°	0.089′
AE1	33°	4.17′	18°	0.563′
AF	33°	4.2′	18°	0
AF1	33°	3.95′	18°	0
AG	33°	4.393′	17°	56.961′
AH	33°	4.074′	17°	58.118′
AI	33°	5.117′	17°	58.401′
AJ	33°	5.566′	17°	58.024′
AK	33°	5.662′	17°	57.316′
AL	33°	5.306′	17°	57.316′
AM	33°	5.307′	17°	57.861′
AN	33°	4.706′	17°	57.861′
AO	33°	4.706′	17°	56.961′

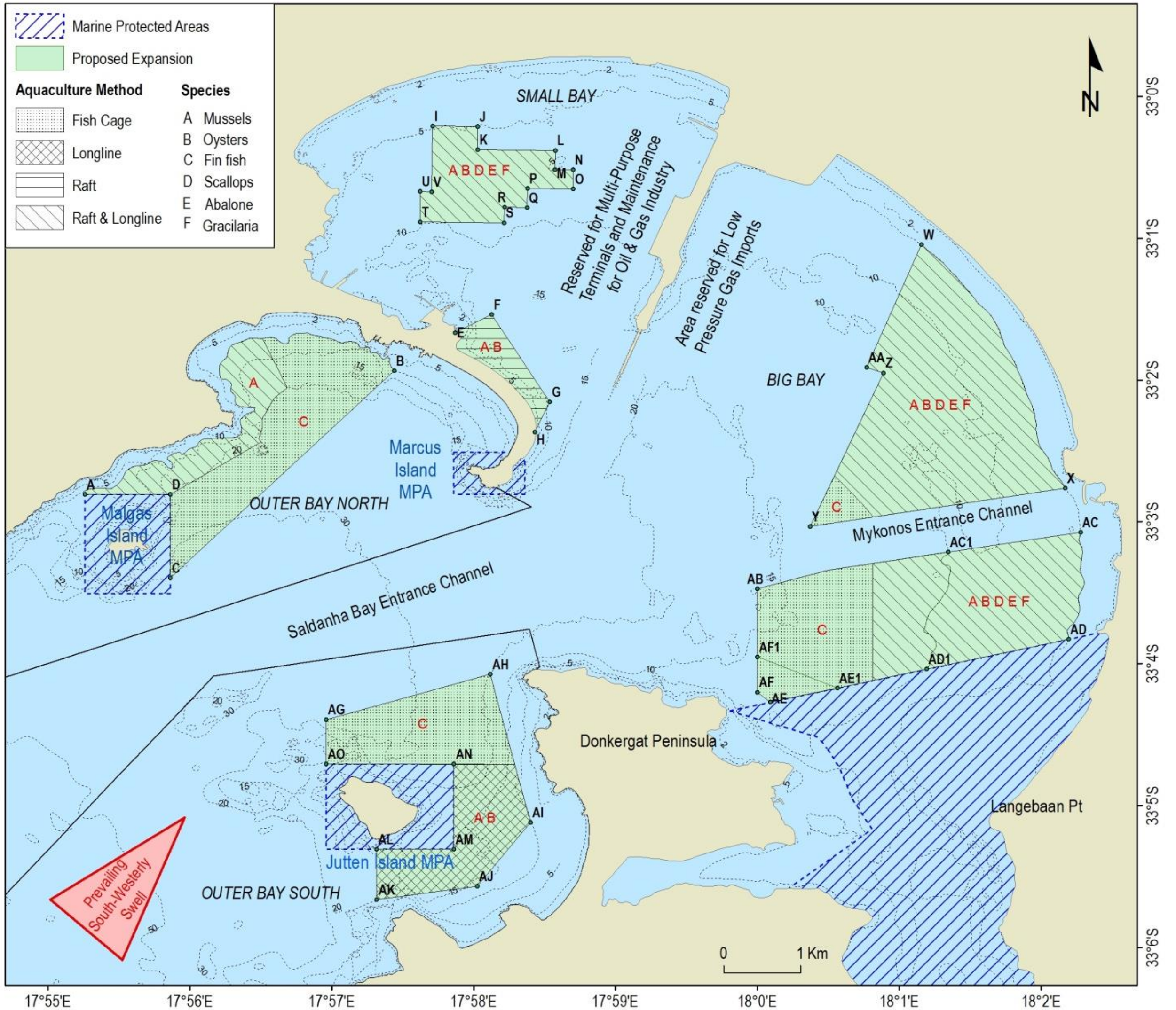


Figure 17 : Schematic representation of the proposed ADZ precincts of the Saldanha Bay ADZ and recommended culture methods and species (pre-mitigation).

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13 Appendix 1: Work scope for the Basic Definition Phase for the determination of the Saldanha Bay Aquaculture Development Zone

The Basic Definition Phase of the Environmental Impact Assessment for the Saldanha Aquaculture Zone aimed to address the following. Note that this process is adaptable and specific aspects varied and were determined as the investigations progressed.

1. Determine the environmental process applicable to the proposed ADZ.
2. Investigate the scope of the proposed activity (ADZ) and identify all listed activities that may be triggered by the proposed development, and evaluate existing information.
3. Identify the appropriate culture mechanisms and species to be cultured according to specific zones within the bay (e.g. inner, outer, north bay) based on the prevailing environmental conditions.
4. Identify additional areas for aquaculture production beyond the zones allocated to aquaculture by the Transnet National Ports Authority.
5. Identify related aquaculture land based support activities, e.g. processing and holding facilities, hatcheries and laboratories.
6. Identify alternative technologies (including greener technologies) that are feasible and reasonable.
7. Develop a detailed layout/map of the existing, proposed and expansion of sea-based and associated land- based activities of the ADZ (incorporate infrastructure, development footprints etc.). The GPS co-ordinates on the map need to be verified on the ground and discussed with those of the Port Captains and other role players.
8. Assess alternative models based on the potential production output of the proposed ADZ.
9. Develop alternative models for management /custodianship of the proposed ADZ.
10. Undertake parallel public participation processes for the EIA as well as for any of the licences/permits as required by law. Public participation should include discussion with the industry association in the bay about future plans and management measures/standards.
11. Identify existing research undertaken and identify relevant detailed specialist studies where required (the EAP is to thoroughly assess the need for all applicable and necessary specialist studies).

14 Appendix 2 : Summary of prevailing and maximum monthly oceanographic conditions recorded in Saldanha Bay for the preceding ten years.

Inner Bay	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ten year max	Ten year min
Water temperature (˚C)														
1m	20	15 to 20	16 to 18	16	*16*	*16*	15 to 16	13 to 14	14 to 15	16 to 19	16 to 19	18 to 21	*21*	*13*
10m	11	11 to 16	11 to 16	*16*	*16*	*16*	14 to 15	10 to 12	10 to 13	10 to 16	11 to 18	10 to 18	*20*	*10*
Wind														
Prevailing wind speed (m/s)	8	8	4	4	4	4	4	4	6	6	6	8	N/A	N/A
Direction of prevailing wind	SSW	SSW	S	S	S	N	N	N	S	S	S	SSW	N/A	N/A
Maximum wind speed (m/s)	30	20	20	20	20	20	20	20	20	20	20	30	30	N/A
Direction of maximum speed winds	SSW/NW	SE/NW	N/ NE	NE	NE	NE	NE	NE	NW	NW	NW	SW/NW	S	N/A
Swell														
Height max (m)	0.5	1	*1*	*1*	1	*1*	*1*	*1*	1	*1*	*1*	0.5	*1*	N/A
Direction (travelling from)	S	S	*S*	*S*	S	*S*	*S*	*S*	S	*S*	*S*	S	*S*	N/A
Current speed														
Subsurface prevailing current speed during flood/ebb (m/s)	0.07 -0.14	0.07 -0.14	0.07 -0.14	0.05-0.20	*0.07 -0.14*	*0.07 -0.14*	*0.07 -0.14*	*0.07 -0.14*	0.07 -0.14	0.07 -0.14	0.07 -0.14	0.07 -0.14	N/A	N/A
Subsurface max current speed (m/s)	*no data*	*0.21*	*0.21*	*0.21*	*0.21*	*0.21*	*0.21*	*0.21*	*0.21*	*0.21*	*0.21*	*0.21*	*0.21*	N/A
General direction of circulation at surface	Clockwise	Clockwise	*Clockwise*	*Clockwise*	*Clockwise*	*Clockwise*	*Clockwise*	Clockwise	Clockwise	Clockwise	Clockwise	Clockwise	N/A	N/A
Bottom prevailing current speed during flood/ebb	0.04-0.10	0.04-0.10	0.04-0.10	*0.04-0.10*	*0.04-0.10*	*0.04-0.10*	*0.04-0.10*	*0.04-0.10*	0.04-0.10	0.04-0.10	0.04-0.10	0.04-0.10	N/A	N/A
Bottom max current speed	*no data*	*0.14*	*0.14*	*0.14*	*0.14*	*0.14*	*0.14*	*0.14*	*0.14*	*0.14*	*0.14*	*0.14*	*0.14*	N/A
General direction of circulation at bottom	Upwelling from bottom towards shore		no data	no data	no data	no data	no data	Upwelling from bottom towards shore					N/A	N/A

Outer Bay	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ten year max	Ten year min
Water temperature (˚C)														
1m	18 to 20	13 to 18	12 to 17	13	13 to 14	14	13	*14*	15	14	17 to 19	12 to 21	20	13
10m	11 to 14	10 to 15	10 to 17	14	11 to 12	14	13	*13*	13 to 15	13	11 to 13	10 to 17	19	11
Wind														
Prevailing wind speed (m/s)	8	8	4	4	4	4	4	4	6	6	6	8	N/A	N/A

Direction of prevailing wind	SSW	SSW	S	S	S	N	N	N	S	S	S	SSW	N/A	N/A
Maximum wind speed (m/s)	30	20	20	20	20	20	20	20	20	20	20	30	30	N/A
Direction of maximum speed winds	SSW/NW	SE/NW	N/ NE	NE	NE	NE	NE	NE	NW	NW	NW	SW/NW	S	N/A
Swell														
Height max (m)	4	3.3	4.9	4.9	5.3	6.5	6.2	7.5	5	5.6	5.6	4.6	7.5	N/A
Direction (travelling from)	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	N/A
Current speed														
Subsurface prevailing current speed during flood/ebb (m/s)	0.07	0.07	*0.07*	*0.07*	*0.07*	*0.07*	*0.07*	*0.07*	0.07	0.07	0.07	0.07	N/A	N/A
Subsurface max current speed (m/s)	0.15	0.15	0.15	0.15	0.15	0.22	0.22	0.22	0.15	0.15	0.15	0.22	*0.22*	N/A
General direction of circulation at surface	Clockwise	Clockwise	*Clockwise*	*Clockwise*	*Clockwise*	*Clockwise*	*Clockwise*	*Clockwise*	Clockwise	Clockwise	Clockwise	Clockwise	N/A	N/A
Bottom prevailing current speed during flood/ebb	0.07 -0.14	0.07 -0.14	*0.07 -0.14*	*0.07 -0.14*	*0.07 -0.14*	*0.07 -0.14*	*0.07 -0.14*	*0.07 -0.14*	0.07 -0.14	0.07 -0.14	0.07 -0.14	0.07 -0.14	N/A	N/A
Bottom max current speed	0.12	0.12	0.12	0.12	0.12	0.15	0.15	0.15	0.12	0.12	0.12	0.12	*0.15*	N/A
General direction of circulation at bottom	Upwelling from bottom towards shore												N/A	N/A

North Bay	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ten year max	Ten year min
Water temperature (˚C)														
1m	*15*	14 to 15	14 to 16	14	*14*	*14*	*14*	*14*	*14*	*15*	*15*	*15-20*	*20*	*13*
10m	*11 to 13*	11 to 12	12 to 13	*14*	*14*	*14*	*14*	*14*	*12 to 14*	*11 to 14*	*11 to 14*	*10 to 16*	*19*	*10*
Wind														
Prevailing wind speed (m/s)	10	10	7	7	7	7	7	7	7	7	7	10	N/A	N/A
Direction of prevailing wind	S	S	SSE	SSE	SSE	NNW	NNW	NNW	S	S	S	S	N/A	N/A
Maximum wind speed (m/s)	20	20	20	20	20	15	15	15	20	20	20	20	20	N/A
Direction of maximum speed winds	S	S	S	S	S	SE/NW	SE/NW	SE/NW	SE	SE	SE	S	S	N/A
Swell														
Height max (m)	7	7	7	7	7	7	7	7	7	7	7	7	7	N/A
Direction (travelling from)	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	N/A
Current speed														
Subsurface prevailing current speed during flood/ebb (m/s)	0.07 -0.14	0.07 -0.14	*0.07 -0.14*	*0.07 -0.14*	*0.07 -0.14*	*0.07 -0.14*	*0.07 -0.14*	*0.07 -0.14*	0.07 -0.14	0.07 -0.14	0.07 -0.14	0.07 -0.14	N/A	N/A
Subsurface max current speed (m/s)	*0.17*	*0.17*	*0.17*	*0.17*	*0.17*	*0.17*	*0.17*	*0.17*	*0.17*	*0.17*	*0.17*	*0.17*	*0.17*	N/A
General direction of circulation at surface	Exchange in and out of the Bay according to tidal ebb and flood												N/A	N/A
Bottom prevailing current speed during flood/ebb	0.07 -0.14	0.07 -0.14	*0.07 -0.14*	*0.07 -0.14*	*0.07 -0.14*	*0.07 -0.14*	*0.07 -0.14*	*0.07 -0.14*	0.07 -0.14	0.07 -0.14	0.07 -0.14	0.07 -0.14	N/A	N/A
Bottom max current speed	*0.14*	*0.14*	*0.14*	*0.14*	*0.14*	*0.14*	*0.14*	*0.14*	*0.14*	*0.14*	*0.14*	*0.14*	*0.14*	N/A
General direction of circulation at bottom	Exchange in and out of the Bay according to tidal ebb and flood												N/A	N/A

Notes

1 Estimated values italicised
2 Water temperature estimates based on temperature ratios between known data on Inner Bay and Outer Bay
3 Water temperature maximum and minimum estimated from range of data from separate studies ranging from 1998 to 2015
4 Current speed estimates based on Weeks (1991:532)

15 Appendix 3

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[6];
3. The maximum production of fish farming, calculated at 40 tpa across the allocated area, is expected at 10 320 tpa (see Table 1).

[6] 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.

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

Precinct	Total ADZ area (ha)	Fish area (ha)	Max. fish production (t 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 t 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.

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.

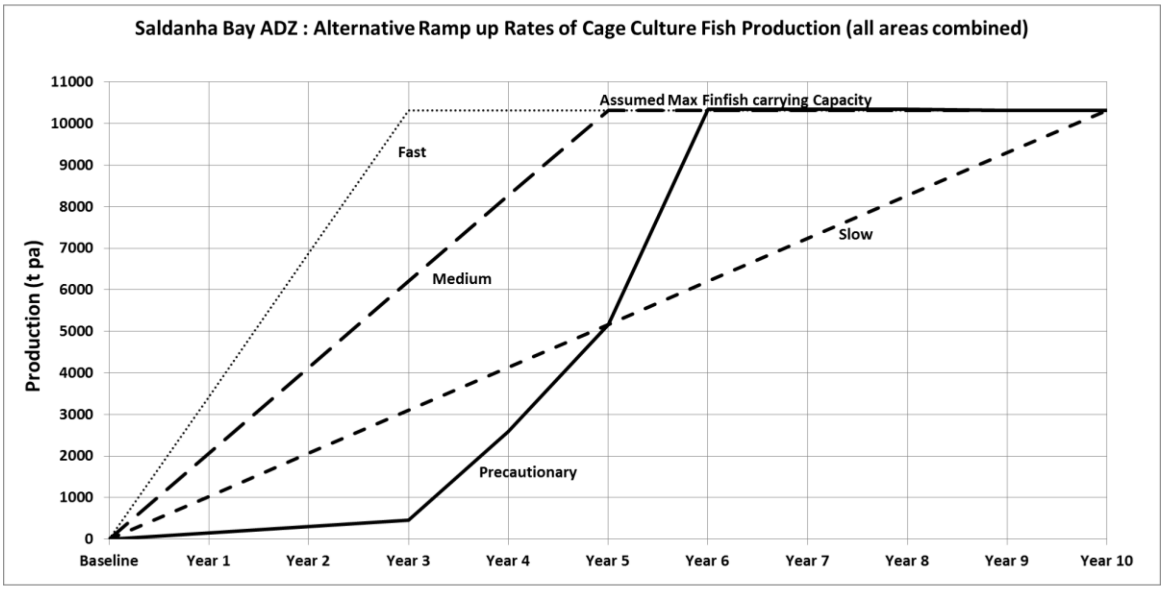

Figure 1. Precautionary Ramp-up rates of fish production by area

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.

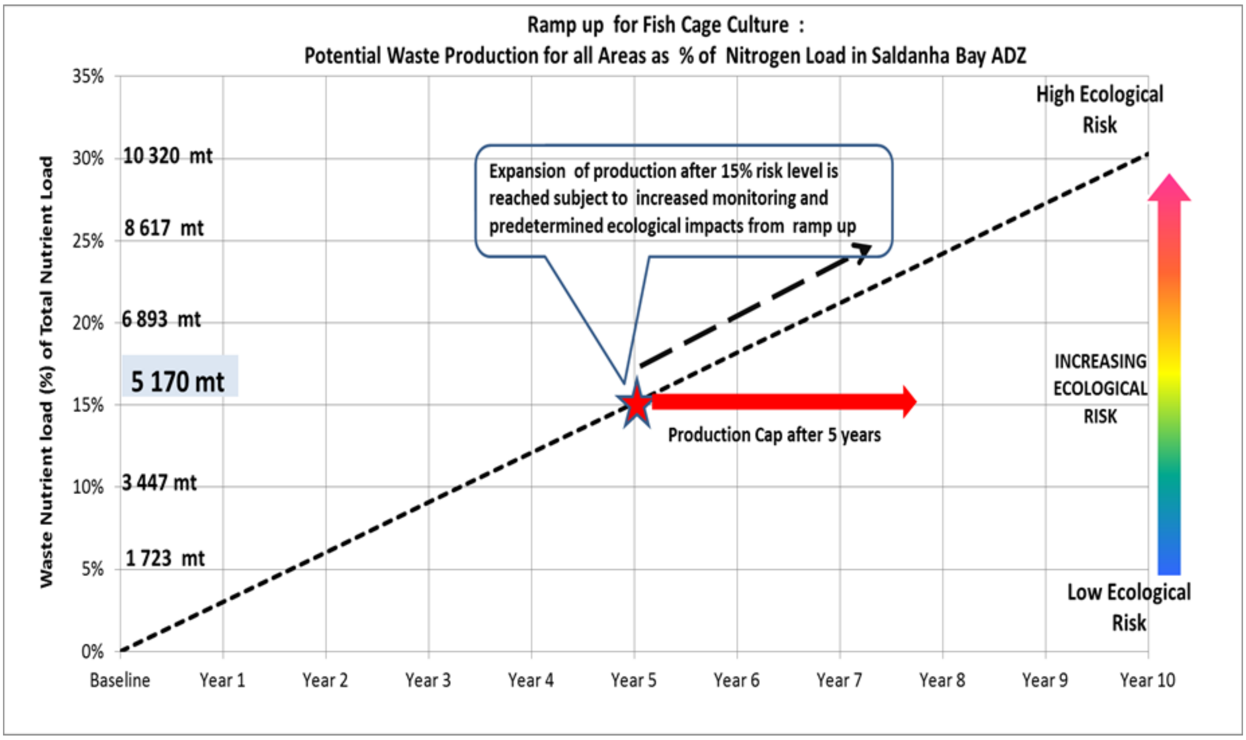

Figure 2. Waste Production (N) as a proportion of Nitrogen Load (all areas) using the slow ramp up strategy.

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 t 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 t 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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