Feasibility Study of Oyster and Mussels Aquaculture in South Africa

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EXECUTIVE SUMMARY

World fish stocks are currently under considerable pressure, with 29% classified as overfished and a further 61% as fully exploited, with no ability to produce greater harvests (FAO, 2014). The total global capture production of 93.7 million tonnes in 2011 was the second highest ever. However, these recent results should not raise expectations of significant catch increases. Rather, they represent a continuation of the generally stable situation.

With only 6.5% of the global protein consumption currently being produced in water, replacing fish with alternative land-based sources of protein is an unlikely solution to addressing future needs. The recognition of fish as the preferred protein will continue to drive global demand and **aquaculture represents the only sustainable option to addressing a widening supply-demand gap**.

Global aquaculture production has made significant progress over the past 3 decades, sustaining an average growth rate of 8.6% per annum and is now the fastest growing animal-based food producing sector and has a crucial role to play in reducing pressure on wild fish stocks. In 2014, global aquaculture production stood at 44% of the total world fish supply (FAO, 2016) with molluscan aquaculture production contributing 22% to this. In Africa, the contribution by aquaculture to total production in 2014 was a mere 2.3%. Africa's low aquaculture productivity is mirrored in South Africa where less than 5 000 tonnes of fish per year comes from aquaculture, while over 600 000 tonnes is from capture fisheries (Britz, 2007). Even at continental level, South Africa contributes less than 1% to Africa's aquaculture production.

Through a combination of national-level strategy setting and prioritisation, private-sector investment, and multilateral assistance and support, a strong and vibrant aquaculture sector could begin to emerge in key African countries and contribute to the strong global growth that has already been occurring in recent decades.

In South Africa, the Department of Agriculture, Forestry and Fisheries (DAFF) sees the potential for commercial aquaculture to contribute to this global growth and expand the range of aquatic food products on the market, and consequently improve food security, job creation, economic development and export opportunities.

It is on this basis that the DAFF have invested into research and development for aquaculture industry growth. Part of this initiative was the undertaking of several feasibility studies to assess the technical and commercial viability of specific species for aquaculture production in South Africa.

This high-level, non-site specific, feasibility study evaluates the technical and financial feasibility of Mediterranean mussel (*Mytilus galloprovincialis*) and Pacific oyster (*Crassostrea gigas*) aquaculture in South Africa. This study provides a background on the biology and environmental requirements of these species, different aquaculture systems used to produce them, and investigates the operational scale, timeframe, and financial requirements of a commercially viable operation.

Mediterranean mussels (and black mussels)

The Mediterranean mussel, *Mytilus galloprovincialis*, is a filter-feeding bivalve native to the Mediterranean (Barsotti & Meluzzi, 1968) and the eastern Atlantic, from Ireland and the United Kingdom

(Gosling, 1992) to northern Africa (Comesana *et al*., 1998). It has been introduced to the Pacific coast of North America (McDonald & Koehn, 1988), Hong Kong (Lee & Morton, 1985), Japan (Wilkins *et al*., 1983), Chile (Hilbish *et al*., 2000; Gerard *et al*., 2008), Australia (Hilbish *et al*., 2000), New Zealand (Gerard *et al*., 2008), and South Africa (Grant & Cherry, 1985). Introductions were initially accidental e.g. via ballast water and subsequently via aquaculture activities (CABI, 2016a). It is considered to have been introduced into South Africa in the 1970's (Grant & Cherry, 1985).

Mussel culture was first practiced in Tarragona and Barcelona, Spain, in 1901 and 1909, respectively (FAO, 2004). After initial attempts, the use of poles was abandoned and the utilisation of floating structures began (FAO, 2004). Some bottom culture of mussels was practiced along the Mediterranean coast (FAO, 2004). However, in 1946, raft culture of mussels was introduced to the Mediterranean and, in subsequent years, production increased sharply (FAO, 2004). In 2014, global aquaculture production of Mediterranean mussels was estimated at 114 802 tonnes which far exceeds that of capture production. Mussel production (Mediterranean *Mytilus galloprovincialis* and black mussel *Choromytilus meridionalus*) comprised 37.4% (1 116 tonnes) of total mariculture production in South Africa in 2013 and was the second largest contributor to total mariculture production in South Africa.

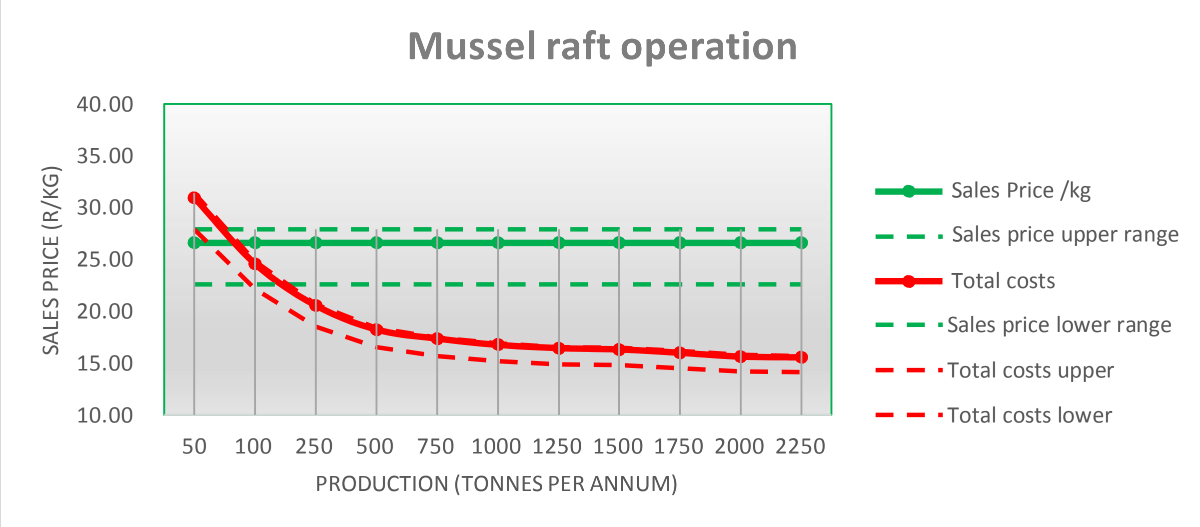
Production systems for mussels are entirely offshore-based. Traditional production technology is relatively simple and involves culture on suspended ropes which are attached to floating raft structures, longlines with floating buoys or, less commonly, on racks (FAO, 2004). A new production system has been developed in Norway by a company called SmartFarm. The SmartUnits consist of a PE pipe for buoyancy, a head rope, suspended mesh ropes for mussel attachment, and bottom weights (Smartfarm, 2016). These units are currently used in the Mediterranean, Brazil, and Chile.

On a global scale, Europe is a major producer of mussels, supplying over a third of the total production. The European market size for mussels is estimated to be slightly below 600 000 tonnes, of which 500 000 tonnes is of domestic origin and about 100 000 tonnes of international origin. The popularity of mussels differs from country to country; per capita consumption varies from less than 200 g to nearly 4 kg (FAO, 2015a). Spain, France and Italy make up 78% of total consumption (FishStatJ, 2016). When considering the South African market potential for mussels, it is evident that there is a demand, although this is limited. Careful consideration and planning would be required to avoid market saturation and increased competition between the major South African players. Focus should rather be placed on international markets, such as Asia.

Aquaculture production of mussels (Mediterranean *Mytilus galloprovincialis* and black mussel *Choromytilus meridionalus*) does present a financially viable investment case (see below). The key strengths for the mussel sector are an absence of seed stock and feed costs associated with grow-out, other than that produced in bivalve hatcheries. Furthermore, the technology required for grow-out is relatively simple and easy to operate. Currently, South African mussel operators rely entirely on natural settlement and seed collected using spat collectors which creates a considerable amount of risk for investors. A state hatchery would go a long way to reduce these risks and would thus promote the growth of small-holder mussel production.

Financial indicator	Result
Capex (ZAR '000)	22 007
IRR (%)	21
Max. cash outflow (ZAR '000)	25 098

Financial indicator	Result
NPV over 10 years (ZAR '000)	27 673
Break-even point (yr)	3
Pay-back period (yr)	6
Minimum viable scale (tpa)	100



Pacific oysters

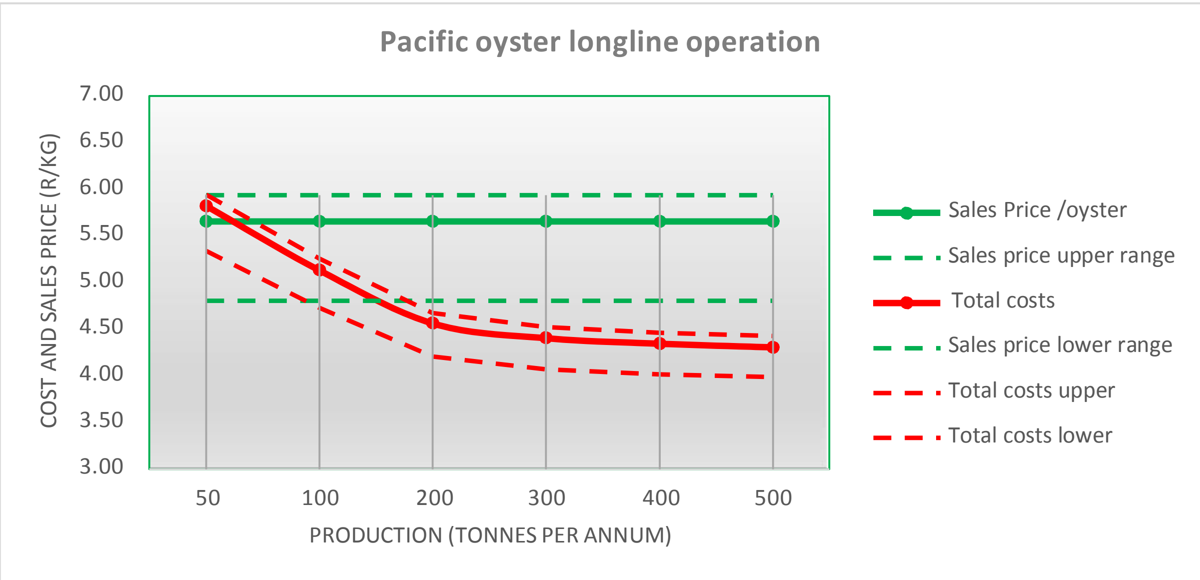
The Pacific oyster is a filter-feeding bivalve species, native to Japan (FAO, 2005). It has been introduced to at least 27 other countries in the Americas, Europe, Australasia and Africa (GISD, 2012). The species was both intentionally introduced in order to enhance depleted oyster fisheries and/or to develop aquaculture, and accidentally introduced via ballast water (FAO, 2005). It is the most commercially marketed oyster globally and in South Africa (Haupt, 2009).

Pacific oyster aquaculture was developed in Japan and has been ongoing for centuries. With widespread global introductions, culture techniques have significantly advanced. Historic methods of extensive culture, supported by wild seed capture and relaying in productive areas, have evolved over time to include a wide range of suspended (hanging culture) and off-bottom methodologies utilising both wild and hatchery cultivated seed (Garrido-Handog, 1990; FAO, 2005). More recent methods include the production of triploid seed in hatcheries and selection programmes that focus on producing fast growing, higher quality seed stock suited to particular conditions (FAO, 2005).

Global production of the Pacific oyster has exceeded that of any other oyster species and continues to expand, with major producing countries including China, Japan, Korea, the United States, France, European states, Australia, New Zealand and South Africa. Global production amounted to 633 542 tonnes in 2014 (FishStatJ, 2016). The leading producers are the Republic of Korea, Japan and France. When considering the South African market potential for oysters, it is evident that there is a demand, although this is limited. Careful consideration and planning would be required to avoid market saturation and increased competition between the major South African players. Focus should rather be placed on international markets, such as Asia. It is also proposed that projects consider diversifying their market by establishing alternative outlets to supplement sale/ exports to a single source. Fundamental to achieving this is resolving the legislative requirements related to the export of the cultured candidate species to target countries. Requirements vary per country and some can be resolved on a project level e.g. food safety certification, while others must be addressed at an industry or governmental level.

Like the Mediterranean mussel, oyster aquaculture production does present a viable investment case (see below). The key strengths for the oyster sector are a reliable and readily available source of seed and zero feed costs associated with growout. Furthermore, the technology required for grow-out is relatively simple and easy to operate. Historically, South African oyster operators have relied entirely on imported seed from Chile, Guernsey, and Namibia. A state hatchery would go a long way to reduce these risks and would thus promote the growth of small-holder oyster production.

Financial indicator	Result
Capex (ZAR '000)	20 331
IRR (%)	13%
Max. cash outflow (ZAR '000)	25 271
NPV over 10 years (ZAR '000)	15 412
Break-even point (yr)	3
Pay-back period (yr)	7
Minimum viable scale (tpa)	100



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LIST OF ACRONYMS

ADA	Animal Diseases Act
ADEP	Aquaculture Development and Enhancement Programme
ADZ	Aquaculture Development Zone
B-BBEE	Broad-based Black Economic Empowerment
CIF	Cost, insurance and freight
DAFF	Department of Agriculture, Forestry and Fisheries
DEAT	Department of Environmental Affairs and Tourism
DSBD	Department of Small Business Development
DTI	Department of Trade and Industry
EIA	Environmental Impact Assessment
EFCR	Economic feed conversion ratio
EMPr	Environmental Management Programme
EXW	Ex works
FAO	Food and Agriculture Organisation of the United Nations
FCR	Feed conversion ratio
GDP	Gross Domestic Product
GIS	Geographic Information Systems
GMO	Genetically Modified Organism
HAB	Harmful Algal Bloom
HACCP	Hazard Analysis and Critical Control Points
IPAP	Industrial Policy Action Plans
IRR	Internal Rate of Return
MLRA	Marine Living Resources Act
MPA	Marine Protected Area
NASF	National Aquaculture Strategic Framework
NEF	National Empowerment Fund
NEMA	National Environmental Management Act
NEMBA	National Environmental Management: Biodiversity Act
NEMICMA	National Environmental Management: Integrated Coastal Management Act
NEMWA	National Environmental Management: Waste Act
NPV	Net Present Value
NRCS	National Regulator for Compulsory Specifications
SAMSM&CP	South African Molluscan and Shellfish Monitoring & Control Programme
SEZ	Special Economic Zone
SMMEs	Small, Medium and Micro-sized Enterprises
UNDP	United Nations Development Programme

GLOSSARY

Ballast water	Fresh or salt water, sometimes containing sediments, held in tanks and cargo holds of ships to increase stability and manoeuvrability during transit
Bivalve	Class of marine and freshwater molluscs that have laterally compressed bodies enclosed by a shell consisting of two hinged parts.
Broodstock	Group of mature individuals used for breeding purposes
Byssal threads	Small, proteinaceous "ropes" extending from the muscular foot of a mussel and used for attachment and movement along a surface.
Cilia	Thick protuberances on the gill surface used for moving food particles.
Cultch	Fossilised shell, coral or other similar materials produced by living organisms designed to provide points of attachment for oysters.
Epifauna	Animals living on the surface of the seabed or a riverbed, or attached to submerged objects or aquatic animals or plants/
Gamete	A mature haploid male of female germ cell which is able to unite with another of the opposite sex in sexual reproduction to from a zygote.
Gonochoristic	Those species with sexes separate, the male and female reproductive organs being in different individuals.
Larvae	Early juvenile stage which, in mussels and oysters, is characterised by free-drifting planktotrophy.
Planktotrophy	Development via a larva that must feed in the plankton in order to develop to metamorphosis.
Polyspermy	The fertilisation of an egg by multiple sperm.
Protandry	The condition in which an organism begins life as a male and then changes into a female.
Post-larvae	Developmental stage characterised by the use of abdominal appendages for propulsion.
Trocophore	The planktonic larva of certain invertebrates, including some molluscs and polychaete worms, having a roughly spherical body, a band of cilia, and a spinning motion.
Sedentary	Organisms usually attached to a substrate exhibiting little movement.
Veliger	Planktonic larva of oysters
Pump-ashore	Refers to water abstracted from the ocean and pumped onto land.
Recirculating aquaculture system	Multiple-pass production systems where water is passed through the systems and re-used before being drained.
Salinity	Salinity is the measure of all the salts dissolved in water. Salinity is usually measured in parts per thousand (ppt)
Spat	Early juveniles used to seed grow-out systems. In oysters and mussels, attached larvae are commonly referred to as spat.

1. INTRODUCTION

1.1. Background

This high-level, non-site specific, feasibility study evaluates the technical and financial feasibility of Mediterranean mussel (*Mytilus galloprovincialis*) and Pacific oyster (*Crassostrea gigas*) aquaculture in South Africa. This study provides a background on the biology and environmental requirements of these species, different aquaculture systems used to produce them, and investigates the operational scale, timeframe, and financial requirements of a commercially viable operation.

While the focus is on an economic assessment, it was also necessary to consider social aspects including potential stakeholders and community impacts. A realistic feasibility study requires knowledge and understanding of the following key elements:

- Geographic location, physical environment and social aspects
- Technical aspects of the aquaculture system
- Analysis of local and international markets
- Economic assessment and financial modelling
- Development, construction and project management needs

1.2. Aims and objectives

The overall goal of this study was to assess the feasibility of mussel (Mediterranean mussel (*Mytilus galloprovincialis*)) and oyster (Pacific oyster (*Crassostrea gigas*)) aquaculture in South Africa, specifically looking at environmental, financial and market conditions in South Africa and abroad.

The following aspects are addressed within this study:

- Description of oyster and mussel biology and aquaculture including historical background, production techniques and systems in use;
- Suitable regions where oysters and mussels can be farmed based on environmental and logistical criteria;
- The socio-economic context of aquaculture in South Africa with a focus on overall impacts;
- Market conditions for oysters and mussels in South Africa and internationally;
- Conceptual production system designs for oysters and mussels;
- Financial modelling
- Risks associated with the culture of the candidate species based on the viability assessment; and
- Recommendations on the best way forward for the sustainable development of the aquaculture of these species in South Africa.

To place this study into perspective, a brief overview of the current state of play of marine aquaculture (mariculture) development in South Africa is presented in the following section.

1.3. Summary of current status of mariculture in South Africa

In general, total aquaculture production in South Africa has increased over the period 1987-2013 (Figure 1), with temporal fluctuations as certain farms became inactive or operational over this period (DAFF, 2012a). Data for South Africa from FAO FishstatJ indicate that mariculture production (4 255 tonnes) comprised 70% of total aquaculture production (6 010 tonnes) within the country. Geographically, mariculture production is highest in the Western Cape (87%) followed by the Eastern Cape (12%) (DAFF, 2014a).

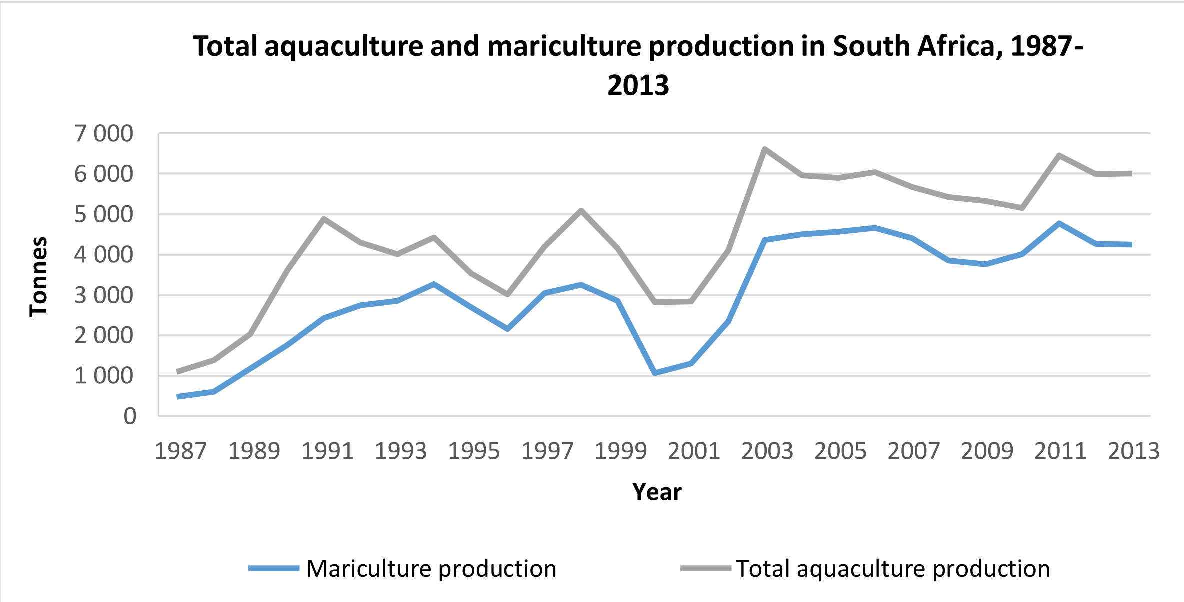

FIGURE 1: TOTAL AQUACULTURE AND MARICULTURE PRODUCTION IN SOUTH AFRICA (1987-2013) (FAO FISHSTATJ, 2016).

Species cultured in the South African mariculture industry in 2013 included abalone (*Haliotis midae*), Pacific oyster (*C. gigas*), Mediterranean mussels (*M. galloprovincialis*) and black mussels (*Choromytilus meridionalis*), dusky kob (*Argyrosomus japonicas*) and seaweed (*Ulva* spp and *Gracilaria* spp) (DAFF, 2014a).

Farmed mussels comprised 37.4% of total mariculture production in 2013 (Table 1) and were the second highest contributor to South African mariculture production. The species' cultured in South Africa were the non-native Mediterranean mussel (*Mytilus galloprovincialis*) and the native black mussel (*Choromytilus meridionalis*). In 2013, mussel farming in South Africa was conducted entirely in Saldanha Bay, Western Cape, and there were four mussel farms operational in the area. Since 2000, mussel production was highest in 2013 (1 116 tonnes), increasing by 256.37 tonnes (30%) from the 859.77 tonnes of production recorded in 2012.

Oyster farming comprised a smaller component of the South African mariculture industry and contributed 9.3% to total mariculture production in 2013. The only oyster species cultured was the Pacific oyster (*Crassostrea gigas*), which is native to Japan. In 2013, operational oyster farms were situated in the Northern Cape, Western Cape and Eastern Cape, with the majority (69.7%) of total oyster production occurring in the Western Cape (DAFF, 2014a).

TABLE 1: MARICULTURE PRODUCTION PER SPECIES GROUP PER PROVINCE IN SOUTH AFRICA (2013) (DAFF, 2014A).

Species	W. Cape	E. Cape	N. Cape	KZN	Total
Abalone	1 299.78	170	0	0	**1 469.78**
Finfish	0	122.55	0	0	**122.55**
Mussels	1 116.14	0	0	0	**1 116.14**
Oysters	193.23 (40)	84	0 (30)	0	**277.23**
Total	**2 609.15**	**376.55**	**0**	**0**	**2 985.7**
() Oysters sold or moved to other provinces for grow out to market size					

1.3.1. Aquaculture Development Zones

Nine Aquaculture Development Zones (ADZs) have been identified, with eight for marine and one for freshwater aquaculture in South Africa and the location of these is illustrated in Figure 2. An ADZ refers to any zone or area, in water and/or on land, set aside for the purposes of exclusive use by the aquaculture sector and in which specific measures are taken to encourage the sustainable development of aquaculture. The objectives of ADZs are to facilitate aquaculture development by providing incentives and services for industry development that encourage investment, reduce risks, and provide skills development and employment for surrounding communities. ADZs are subject to undergoing Environmental Impact Assessment (EIA) processes and receiving Environmental Authorisation, as well as installation of basic infrastructure prior to being declared ADZs. Once declared, a major advantage of developing a project within an ADZ is that there is no requirement for a project-specific EIA. In South Africa, the establishment of ADZs is supported by the Department of Trade and Industry (DTI) Policy on the Development of Special Economic Zones (SEZ) which, through investment incentives, promotes trade, economic growth and industrialisation.

FIGURE 2: GEOGRAPHIC LOCATION OF ADZS IN SOUTH AFRICA.

The Department of Environmental Affairs and Tourism (DEAT) completed a Strategic Environmental Assessment aimed at identifying suitable land and sea space surrounding South Africa's coastal provinces for the establishment of ADZs (Jooste, 2009). Subsequent refinement of these areas, for offshore-based marine finfish cage aquaculture, was undertaken by Hutchings *et al*. (2011). In 2011, the Qolora land-based ADZ in the Eastern Cape received a positive Environmental Authorisation from the Eastern Cape provincial Department of Economic Development, Environmental Affairs and Tourism and will be the first promulgated ADZ once relevant infrastructure has been installed (DAFF, 2012a). To date, no ADZs have been officially promulgated.

1.4. Need for economic feasibility studies

Production from capture fisheries has stagnated in recent years (FAO, 2016) while global population numbers, and overall consumption of fish, is increasing. Aquaculture will play a significant role in providing much needed animal protein to feed future generations. However, extensive research is required to plan, develop, establish and operate a commercially viable aquaculture operation. It generally requires a large investment of time and money over a period of several years. By conducting a feasibility study before starting an aquaculture venture, prospective developers and operators will gain a clearer understanding of the proposed operation from an environmental suitability and financial viability perspective (Bloom *et al*., 2013). Furthermore, financial modelling and market analysis can highlight the scope for product diversification rather than confining operations to traditional farming and product offerings (Sathiadhas *et al*., 2009).

The viability of a typical aquaculture venture depends on:

- suitable environmental conditions to support production;
- availability of seed stock;
- access to feeds and production technology;
- access to equipment and supplies such as boats, farm platforms, etc.;
- access to markets;
- access to health management services, consultants and technical services
- a supportive regulatory environment that facilitates aquaculture development; and
- public acceptance of the environmental impacts associated with aquaculture development and production.

Ultimately, the decision whether to proceed with a given project should be based on a thorough feasibility study that takes into account location, site characteristics, environmental parameters, available technologies, financial and human resources, environmental impacts, market opportunities and risk factors. It is envisaged that the Department of Agriculture, Forestry and Fisheries (DAFF) will use the results of this study in an advisory manner in order to focus efforts and funds for aquaculture of the candidate species. Furthermore, the results of the study, in terms of return on investment, cost of start-up, time to break even, will assist the government in determining the time period of leases and permits in order to support and secure investment. Lastly, the results can be used by government and financing institutions as a tool to captivate interest in the aquaculture sector and unlock financing schemes for the development thereof, based on sound economic principles.

2. REGULATORY FRAMEWORK

2.1. Legal aspects related to aquaculture in South Africa

The various legislative frameworks and policies which regulate or influence the aquaculture industry in South Africa are shown in Table 2 below:

TABLE 2: LEGISLATION, GUIDELINES, MANUALS AND FRAMEWORKS RELEVANT TO AQUACULTURE IN SOUTH AFRICA.

LEGISLATION RELEVANT TO AQUACULTURE IN SOUTH AFRICA	
1.	Marine Living Resources Act (Act No. 18 of 1998)
2.	National Environmental Management Amendment Act (NEMA) (Act No. 25 of 2014)
3.	National Environmental Management Biodiversity Act (Act No. 10 of 2004)
4.	National Environmental Management: Integrated Coastal Management Amendment Act (Act No. 36 of 2014)
5.	National Environmental Management: Waste Act (Act No. 59 of 2008)
6.	National Environmental Management: Protected Areas Amendment (Act No. 15 of 2009)
7.	Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act (Act No. 36 of 1947)
8.	The Health Act (Act No. 63 of 1977)
9.	Animal Diseases Act (Act No. 35 of 1984)
10.	Genetically Modified Organisms Act (Act No. 15 of 1997)
11.	National Health Act (Act No. 61 of 2003)
12.	The National Regulator for Compulsory Specifications Act (Act No.5 of 2008)
13.	Standards Act (Act No. 8 of 2008)
14.	The Animal Improvement Act (Act No. 62 of 1998)
15.	The Water Services Act (Act No. 108 of 1997)
16.	The Foodstuffs, Cosmetics and Disinfectants Act (Act No. 54 of 1972)
17.	The Sea Birds and Seals Protection Act (Act No. 46 of 1973)
18.	Medicines and Related Substances Act (Act No. 101 of 1965)
GUIDELINES/MANUALS/FRAMEWORKS RELEVANT TO AQUACULTURE IN SOUTH AFRICA	
19.	The Draft Policy for the Development of a Sustainable Aquaculture Sector in South Africa (DEAT, 2006a)
20.	Draft Policy and Guidelines for Finfish, Marine Aquaculture Experiments and Pilot Projects in South Africa (DEAT, 2006b)
21.	Marine Aquaculture Sector Development Plan (DEAT, 2006c)
22.	Aquaculture Research and Technology Development Programme (DAFF, 2012b)
23.	Environmental Integrity Framework for Marine Aquaculture (DAFF, 2012c)
24.	National Aquaculture Policy Framework (DAFF, 2013a)
25.	Aquatic Animal Health Strategic Framework (DAFF, 2013b)
26.	Environmental Impact Assessment Guidelines for Aquaculture in South Africa (DEA, 2013)
27.	South African Molluscan Shellfish Monitoring and Control Programme (DAFF, 2016)

A brief description of the legislation and guidelines is provided below:

- ***National Environmental Management Amendment Act (NEMA) (Act No. 25 of 2014)***

The NEMA is the cornerstone of South Africa's environmental management legislation. NEMA also outlines the principles for integrated environmental management, which has led to the development of the EIA Regulations (R543, R544, R545 and R546 of 2010, with due consideration of subsequent amendments).

At present, a number of aquaculture-related activities trigger the requirement for an environmental authorisation in terms of NEMA and EIA Regulations. According to the recently amended EIA Regulations Listing Notice 1 of 2014, only a Basic Assessment is required for aquaculture activities.

- ***National Environmental Management: Biodiversity Act (NEMBA) (Act No. 10 of 2004)***

The authorisations for the NEMBA, although complementary, are independent of the requirement for environmental authorisation in terms of NEMA. The NEMBA prescribes specific protocols for the management and culture of exotic/alien organisms and, therefore, has a direct bearing on those aquaculture activities based on non-native species. Where the introduction of an exotic/alien species for aquaculture is proposed, this Act (through the Alien and Invasive Species Regulations – GN No R. 69 of 2008) requires that a risk assessment be completed to determine the environmental implications. Where the introduction of an endangered or threatened species for aquaculture is proposed, this Act (through the Threatened or Protected Species Regulations) requires that certain authorisation procedures are followed.

- ***National Environmental Management: Integrated Coastal Management Amendment Act (NEMICMA) (Act No. 36 of 2014)***

This Act provides norms, standards, and policies to promote the conservation of the coastal environment, and to ensure that the development and use of the coastal zone is socially and economically justifiable and ecologically sustainable. The Act defines rights and duties in relation to the coastal zone as well as the responsibilities of organs of state.

The discharge of any effluent into the coastal environment from a land-based process in which it has been heated must be authorised by the DEA in terms of section 69 of the NEMICMA. Any discharge of land-based effluent to the coastal environment from an activity triggering any of the Listing Notices in the EIA Regulations under the NEMA, is subject to the applicable environmental authorisation issued under the NEMA: EIA Regulations (2014) administered by the DEA and / or a Coastal Waters Discharge Permit (CWDP) or a General Authorisation in terms of Section 69 of the NEMICMA, unless the activity conforms to a standard as prescribed in section 24 of the NEMA and in terms of the NEMICMA.

- ***National Environmental Management: Waste Act (NEMWA) (Act No. 59 of 2008)***

This Act governs minimisation, recovery, re-use, recycling, treatment, disposal, and integrated management of waste. A number of listed waste management activities have been promulgated in Government Notice 718 (2009) and require authorisation by means of either a Basic Assessment or Scoping & Environmental Impact Report (more details about these different authorisations in Section 4). Although few of these listed waste management activities are directly applicable to aquaculture, the onus is on the aquaculture proponent to fully investigate all of the waste producing activities that may arise. A waste authorisation may be required for the treatment and/ or on-site disposal of aquaculture wastes.

- ***Marine Living Resources Act (MLRA) (Act No. 18 of 1998)***

Section 18 of the Act provides for the granting of a compulsory "right" to engage in marine aquaculture. Permission to exercise such a "right" is granted by means of a permit issued in terms of Section 13 of the Act. Chapter 6 of the Act covers the requirement for applications, general permit conditions, environmental impacts, genetically modified organisms (GMOs), EIA's, food safety issues, use of chemicals and notifiable diseases.

In response to the Act and related legislation, the DAFF have developed comprehensive guidelines, food safety programmes and permit frameworks to allow, guide and regulate marine aquaculture projects in compliance related matters. One of these guidelines is the South African Molluscan Shellfish Monitoring and Control Programme (SAMSM&CP) (DAFF, 2016), described on page 8.

- ***Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act (Act No. 36 of 1947)***

This Act requires that all processed animal feeds and stock remedies (therapeutants) meet certain specifications and are registered for use in farming. In this regard, fish feeds must meet certain minimum specifications and the minimum proximal composition of the feed must be declared on the packaging.

- ***Animal Diseases Act (ADA) (Act No. 35 of 1984)***

Aquaculture is recognised as an agricultural activity and, hence, the State Veterinary Services have a mandate to protect the industry in terms of the Animal Diseases Act. This Act includes various measures for the control and management of disease.

- ***Genetically Modified Organisms Act (Act No. 15 of 1997)***

The Act aims to provide for measures to promote the responsible development, production, use and application of GMOs. This Act is applicable in the event that exotic/alien species are considered for an aquaculture operation. In this case, all relevant permits and licenses must be obtained prior to any introduction.

Other applicable acts include Health & Safety, Water and Animal protection regulations such as:

- National Health Act (Act No. 61 of 2003)
- The National Regulator for Compulsory Specifications Act (Act No.5 of 2008)
- Standards Act (Act No. 8 of 2008)
- The Animal Improvement Act (Act No. 62 of 1998)
- The Water Services Act (Act No. 108 of 1997)
- The Foodstuffs, Cosmetics and Disinfectants Act (Act No. 54 of 1972)
- The Sea Birds and Seals Protection Act (Act No. 46 of 1973)
- Medicines and Related Substances Act (Act No. 101 of 1965)

Various Government departments have compiled guidelines and manuals to assist in the development of an aquaculture in South Africa. A few of these guidelines/manuals are described below.

- ***South African Molluscan Shellfish Monitoring and Control Programme (SAMSM&CP) (DAFF, 2016)***

The SAMSM&CP manual addresses public health concerns related to production, harvesting, storage, depuration, packaging, dispatch, transporting, labelling and traceability of cultured marine shellfish and associated products intended for human consumption. It also contains the audit specifications for such facilities.

- ***Draft Policy for the Development of a Sustainable Aquaculture Sector in South Africa (DEAT, 2006a)***

The Draft Policy aims: (1) to create an enabling environment that will increase the contribution of aquaculture to economic growth within the Accelerated and Shared Growth Initiative for South Africa; (2) to transform and encourage broader participation in the aquaculture sector; (3) to develop regulatory and management mechanisms aimed at minimising adverse environmental impacts associated with aquaculture practices (e.g. sea ranching, sea-based cage farming etc.); and (4) to increase the resource base of aquaculture from the few species that are being farmed currently to a more diverse suite of species.

- ***Marine Aquaculture Sector Development Plan (DEAT, 2006c)***

The plan outlines strategies that will give practical development effect to the mariculture policy objectives. Some of the objectives are: (1) to create an enabling environment that will promote increased contribution from mariculture to economic growth; (2) to ensure that mariculture adheres to internationally accepted environmental and fisheries standards; (3) to develop regulatory and management mechanisms; and (4) to encourage research aimed at increasing the resource base of mariculture.

- ***National Aquaculture Policy Framework (DAFF, 2013a):***

The National Aquaculture Strategic Framework (NASF) was developed as a roadmap to help Government facilitate the development of the aquaculture industry. The National Aquaculture Policy Framework was thereafter compiled as an implementation guideline for the NASF. The Policy aims to ensure that an appropriate enabling regulatory environment is created to optimise opportunities and to contribute to national food security, national wealth and job creation. An Aquaculture Act is still to be drafted, however, this policy framework is the document to guide development of the industry.

- ***Environmental Integrity Framework for Marine Aquaculture (DAFF, 2012c)***

The Framework is an informative tool and platform for project level to sector level, for the planning of marine aquaculture and monitoring approach for EIAs.

- ***Environmental Impact Assessment Guideline for Aquaculture in South Africa (DEA, 2013)***

This EIA Guideline aims to assist with environmental authorisations and to provide a framework for sound environmental management in the sector. The guideline describes the pathway towards improved management of potential impacts and emphasises the importance of ensuring that development is aligned with environmental legislation. Further details are described in Section 2.3. It must be noted, however, that there have been numerous amendments to other relevant legislation and regulations (e.g. EIA Regulations), and this guideline is outdated with amendments required.

2.2. Permitting requirements

To promote the sustainable development of the aquaculture sector there are a variety of aquaculture rights under the MLRA which will need to be approved. Such a right is valid for 15 years and is required to be renewed annually. Pilot operations are currently issued with aquaculture rights. Permits are required to undertake aquaculture-related scientific investigations and practical experiments e.g. research institutions, private companies.

In future, licenses will be issued under the Aquaculture Act which will be valid for a period dependent on the activity and scale of operations e.g. pilot, commercial, research.

The licenses required will be wholly dependent on the project components (scale, location, operational model etc.). All operational-specific permits and licenses must be obtained by the individual project proponents before commencement of any activities.

Various guidelines on applications and other legal requirements for aquaculture developments are available. These include:

- Guidelines and Requirements on Applying for a Marine Aquaculture Right
- Guidelines for Aquaculture Better Management Practices in South Africa
- Guide to the authorisations requirements for aquaculture in South Africa (DAFF, 2015a)
- Legal guide for the aquaculture sector in South Africa (DAFF, 2013c)
- General Guidelines for Marine Ranching and Stock Enhancement in South Africa (DAFF, 2010)

There are various permits/licences which may apply to an oyster or mussel operation and these include[1]:

- Land use rezoning
- Permit to engage in marine aquaculture activity (e.g. grow out, nursery)
- Permit to operate a marine aquaculture fish processing establishment
- Import and export permits for marine aquaculture fish and fish products and marine ornamentals
- Permit to collect brood stock for marine aquaculture purposes
- Permit to possess broodstock and operate a hatchery
- Permit to undertake marine aquaculture scientific investigations and practical experiments
- Permit to transport marine aquaculture products
- Marine aquaculture export permit
- Marine aquaculture import permit

Applications for a Marine Aquaculture Right can be submitted to the DAFF on a continuous basis. The applicant must meet the criteria as set out in the application form and submit the relevant supporting documentation.

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[1] All such licences can be found on the DAFF website: http://www.daff.gov.za/daffweb3/Branches/Fisheries-Management/Aquaculture-and-Economic-Development/aaquaculture-sustainable-management/Authorisation

2.3. Environmental Impact Assessment requirements

The EIA Regulations (2014) for a specific aquaculture project are guided by the NEMA (Act No. 107 of 1998) and are largely dependent on the nature and scale of a project. The EIA may consist of a Basic Assessment or, alternatively, a more detailed Scoping and Environmental Impact Reporting exercise. According to the EIA Regulations Listing Notice 1 of 2014, the development and related operation of facilities, infrastructure or structures for aquaculture of molluscs that have a production output exceeding 30 tpa (wet weight) are subject to a Basic Assessment. Furthermore, the development and related operations for sea-based molluscan aquaculture with a production output exceeding 50 tpa is also subject to a Basic Assessment.

Within the EIA (both Basic Assessment and Scoping exercise) there is a mandatory public participation process which requires that interested or affected parties be provided with an opportunity to comment about a proposed project. Social Impacts are also identified during an EIA and mitigating factors to minimise negative social impacts are addressed within the EIA.

Environmental authorisation requires the compilation and submission of an Environmental Management Programme (EMPr). The purpose of the programme is to plan and document the management approach that will best avoid or minimise potential environmental impacts in the construction, operation and decommissioning phase of a project. The EMPr is a legally binding document and implementation and compliance of the EMPr are a condition for project authorisation.

Provincial-level environmental departments are typically responsible for receiving and evaluating applications for environmental authorisation. A suitably qualified Environmental Assessment Practitioner is required to perform the tasks associated with the respective EIA processes.

There are various impacts which will be assessed in an EIA process. Some of these impacts include:

- Indigenous habitat destruction
- Public safety
- Genetic impact of escapees on wild populations
- Effluent discharge (feed waste and fish faeces)
- Disease, parasites and species health
- Reduction of available phytoplankton
- Nutrient dynamics/loading around offshore sites
- Anti-fouling products
- Medication, antibiotics and pesticide
- Human health issues
- Resource conflicts
- Infrastructure construction (access roads, noise, erosion)
- Chemicals and antibiotics

2.4. Import and export regulations

Best practice guidelines for import and export of food stuffs are contained in global health and safety regulations. Many export standards are based on the Hazard Analysis and Critical Control Points (HACCP) standards, which are internationally recognised and structured operating methods that help organisations in the food and beverage industry identify their food safety risks, prevent food safety hazards and address legal compliance. The National Regulator for Compulsory Specifications (NRCS) is established in terms of the National Regulator for Compulsory Specifications Act, 2008 (Act No. 5 of 2008). The NCRS is responsible for the administration and maintenance of compulsory specifications and the implementation of regulatory and compliance systems for compulsory specifications. In particular, the NRCS is responsible for monitoring and auditing the applications of the HACCP standards which guarantees the health of food products through the whole food production process from "farm to fork".

For the export of aquaculture products, the NRCS certifies live, fresh, frozen and canned products. HACCP standards regulate the entire production process from the live production tank/cage to the processing plant to the buyer. For non-export items, the NCRS verifies products (the individual responsible is Ms. Meisie Katz (Meisie.Katz@nrcs.org.za).)

The CODEX Committee on Fish and Fishery Products (CCFFP) of the Food and Agriculture Organisation (FAO) provide internationally recognised standards for fresh, frozen or otherwise processed fish, crustaceans and molluscs. South Africa is a signatory to CODEX and incorporates these standards into South African regulatory framework and implementation programmes. The NRCS makes use of agents such as DAFF and other state veterinarians to provide guarantees in respect of specialised analyses such as the monitoring of shellfish toxins, microbiological contamination, drug residues, chemical residues, radio-nuclides and residues in fish and animal health and welfare aspects[2]. Operators planning to produce shellfish for human consumption will be required to comply with the requirements of the SAMSM&CP.

Oysters are typically consumed live and raw, and both oysters and mussels can accumulate algal biotoxins produced during harmful algal blooms (HABs) (Pitcher *et al.*, 2011). Consequently, health and hygiene standards for the culture, packaging and sale of these products are extremely important for consumer safety (Olivier *et al.*, 2013). In South Africa, the SAMSM&CP, in conjunction with municipal authorities, conducts regular and compulsory monitoring of oyster and mussel products for heavy metals, algal bloom biotoxins, and human pathogens such as coliform bacteria (Olivier *et al.*, 2013). Full details of sampling and control programmes for bivalve farming is available within this DAFF manual (DAFF, 2016). Furthermore, the South African National Standard 2879 for live and chilled raw bivalve molluscs was published in 2016 and stipulates the requirements for harvest, processing, transporting and labelling of live bivalve mollusc products.

[2] Additional permits which may need to be obtained for import and export operations and these are available online at: http://www.daff.gov.za/daffweb3/Branches/Fisheries-Management/Aquaculture-and-Economic-Development/aaquaculture-sustainable-management/Authorisation

3. SOCIO-ECONOMIC ASSESSMENT

3.1. Overview

South Africa has a medium human development ranking (value of 0.666) and is ranked 116th out of 188 countries according to the United Nations Development Programme (UNDP) Human Development Index. The UNDP Human Development Index judges a country's social and economic development according to key indicators such as life expectancy at birth, mean years of schooling, expected years of schooling and gross national income per capita (UNDP, 2015). Gross Domestic Product (GDP) is approximately USD 360.1 billion and the economy is distributed between the main sectors as follows (World Bank, 2014):

- Agriculture: 2.49%
- Industry: 29.47%
- Services: 68.05%

TABLE 3: SOUTH AFRICA'S HUMAN DEVELOPMENT INDICATORS.

Indicator		Year	Source
GDP Growth Rate	1.52%	2014	World Bank, 2014
GDP Per Capita	USD 6 482.82	2014	World Bank, 2014
Unemployment	25.10%	2014	World Bank, 2014
Youth Unemployment (ages 15-24)	52.60%	2014	World Bank, 2014
Adult Literacy	94.3%	2015	CIA World Factbook, 2016
Life Expectancy	57 years	2013	World Bank, 2014

South Africa is characterised by a high unemployment rate (Table 3), with more than 50% of the labour force characterised as unskilled and semi-skilled. Furthermore, 45.5% of South Africans are living in poverty (Stats SA, 2014). Food security remains a pressing issue. In 2011, 23% of households did not have adequate access to food and 13% experienced hunger. Many of the rural coastal communities are largely reliant on subsistence from coastal food sources, indicating the importance of job creation within isolated coastal communities. While the government is implementing important programmes to reduce poverty and improve access to social services, high inequality levels profoundly affect social cohesion (Kumo *et al*., 2015).

3.2. Socio-economic impacts of aquaculture in South Africa

Direct permanent employment in the South African aquaculture industry has had a large local impact in previously disadvantaged coastal communities where any increase in employment is valuable and necessary, as indicated by the unemployment rates in the Section 3.1. Aquaculture is an industry where environmental and socio-economic systems are intertwined. Therefore, information about the ecological and economic impacts of different practices is required for sustainable development. This implies communication between the commercial, scientific, management and policy-making communities, and integration among disciplines using mutually understandable concepts.

The financial feasibility and long-term viability of a venture is essential as positive economic impacts can only flow from a project that is financially viable. Any operation must also be compatible with current legislation, policy, and guidelines that address the development of aquaculture facilities. These requirements are a critical aspect relating to economic desirability, ensuring that the proposed venture compliments economic development and planning as reflected in existing policy and development guidelines for aquaculture. In addition, the development of an aquaculture operation should also be desirable from a societal cost-benefit perspective.

Aquaculture can result in several social benefits including employment, income and food security, which are particularly important to poor, rural coastal communities worldwide. A summary of the main socio-economic impacts of aquaculture are provided below:

- ***Benefits***
  - Increase in fish supplies
  - Improved food security
  - Export earnings
  - Creation of good quality employment
  - Conservation of social structure
  - Improved infrastructure in rural areas
  - Creation of local business opportunities for entrepreneurs
  - Skills development in surrounding communities

- ***Costs***
  - Environmental damage
  - Conflict over resource usage
  - Market competition between aquaculture and fisheries sectors
  - Creation of a resource sink
  - Disruption of social structure
  - Loss of traditional occupations

An important condition for aquaculture development is public acceptance i.e. that attitudes towards aquaculture are at least neutral (Barrington *et al*., 2010). There is significant evidence that demonstrates the detrimental effect of hostile social perceptions on aquaculture industries. For example, shrimp (prawn) farming in India resulted in sabotage and litigation (Ridler & Hishamunda, 2001). In North America, individual homeowners and communities opposed salmon farming because of perceived environmental damage or for aesthetic reasons (Ridler & Hishamunda, 2001). Other negative perceptions associated with aquaculture include the presence of heavy metals and toxins in cultured shellfish and fish, GMOs, sea lice, and genetic pollution of wild fish populations. If aquaculture is to be acceptable to the general public, the biological potential of the candidate species must be appropriate to the environment, the local communities should benefit, and consumers must be willing to purchase the end product.

Aquaculture addresses poverty and food insecurity in a variety of ways and at different scales. For small-scale farmers, it offers a means to diversify production, providing nutritious food for their own families (and sometimes those of their neighbours) while potentially generating surplus product for sale. Larger commercial enterprises create farm income and employment opportunities throughout the value chain and provide affordable, highly nutritious food in response to market demand.

Many of the negative impacts associated with aquaculture could be mitigated, and/ or positive impacts generated, by introducing measures proposed within an EIA or EMPr, which the developer and/or operator must implement. Monitoring and evaluation of socio-economic obligations will further enhance the contribution of farms to community upliftment and development. The socio-economic risks associated with oyster and mussel production are addressed in Section 9 of this report.

3.3. Employment opportunities

South Africa has a high unemployment rate with economic growth required to absorb the unemployed through job creation. Direct permanent employment in the South African aquaculture industry has had a local impact in previously disadvantaged coastal communities, where any increase in employment is valuable.

Marine and freshwater aquaculture was one of the top 5 contributors to employment in the South African fisheries sector in 2013 (Table 4). In comparison to other sub-sectors, aquaculture was characterised by high employment per ton of production (approximately 1 direct job per 3 tonnes production), with high quality jobs and high growth potential. By comparison, employment in the capture fisheries sector shrunk by 17% between 2000 and 2008. Some socio-economic indicators for the various subsectors are presented in Table 5.

The South African marine aquaculture industry employed 1 607 people on a permanent basis in 2013 (DAFF, 2014b). The majority of jobs were created by the abalone sub-sector whereas the oyster and mussel sub-sectors accounted for only 9.8% and 4.9% of job opportunities, respectively.

As marine aquaculture generates small profits per unit production, is highly labour-intensive and requires unpredictable and often exceptionally long work-hours, particularly during peak seasons, its sustainable development requires a local community with a high proportion of unskilled and semi-skilled labourers living relatively close to their place of employment. This workforce also needs to be flexible in their approach to work-hours and highly dependable (Olivier *et al*., 2013).

TABLE 4: CATCH, VALUE AND EMPLOYMENT IN THE RSA FISHERY SECTOR (2013)

	Tonnage per annum	Value (ZAR million)	Employment (direct jobs)
Hake	126 000	1 977	8 350
Small pelagics	526 000	911	5 204
Aquaculture	7 489	470	2 676 direct
WC Rock lobster	2 895	390	1 283
Squid	4 500	391	2 998

TABLE 5: SOCIO-ECONOMIC INDICATORS OF VARIOUS FISHERIES SUB-SECTORS INCLUDING AQUACULTURE (2013)

	Jobs/ 100 tonnes	Value/ tonne	Product value/ job
Hake	7	15,690	236,766
Small pelagics	1	1,732	175,058
Aquaculture	36	62,753	175,635
WC Rock lobster	43	130,653	303,975
Squid	67	86,889	130,420

When one assesses the economic and employment opportunities provided by aquaculture, it is evident that the impact is relatively small. For example, the Mnquma Municipality, which incorporates the Qolora ADZ, had a population of approximately 252 390 people and a 44% unemployment rate in 2011 (Stats SA, 2012). It has been estimated that the ADZ has an area of 7.38ha available for production with the potential to create 600 jobs through abalone production (at 600 tpa) or 245 jobs through finfish production (at 2750 tpa) (Hunter *et al*., 2014). Therefore, assuming the full production potential of the Qolora ADZ is realised and a maximum of 600 jobs are created within the production sector, this will have a 0.5% impact on unemployment within the Mnquma Municipality.

In a previous feasibility study conducted by Hecht et al. (2015) within the Qolora ADZ, it was estimated that a 10ha aquaculture project incorporating an integrated multi-trophic aquaculture (IMTA) system with 180 tpa abalone, 146 tpa dusky kob, and a 1 280 tpa seaweed production would employ 121 people.

Therefore, the employment generated in relation to the level of unemployment in the greater municipality is relatively low.

In terms of mussels and oyster production, a case study is provided on page 18 showcasing production and employment indicators from various countries. In South Africa, the expected employment opportunities are described in Section 7 based on the conceptual designs for this Feasibility Study.

It is evident that aquaculture, alone, cannot fulfil the demand for job creation in South Africa. However, it has the potential to contribute meaningfully to employment and economic growth for local communities and the country. This is particularly relevant where unemployment is not only an economic issue but also a socio-political concern.

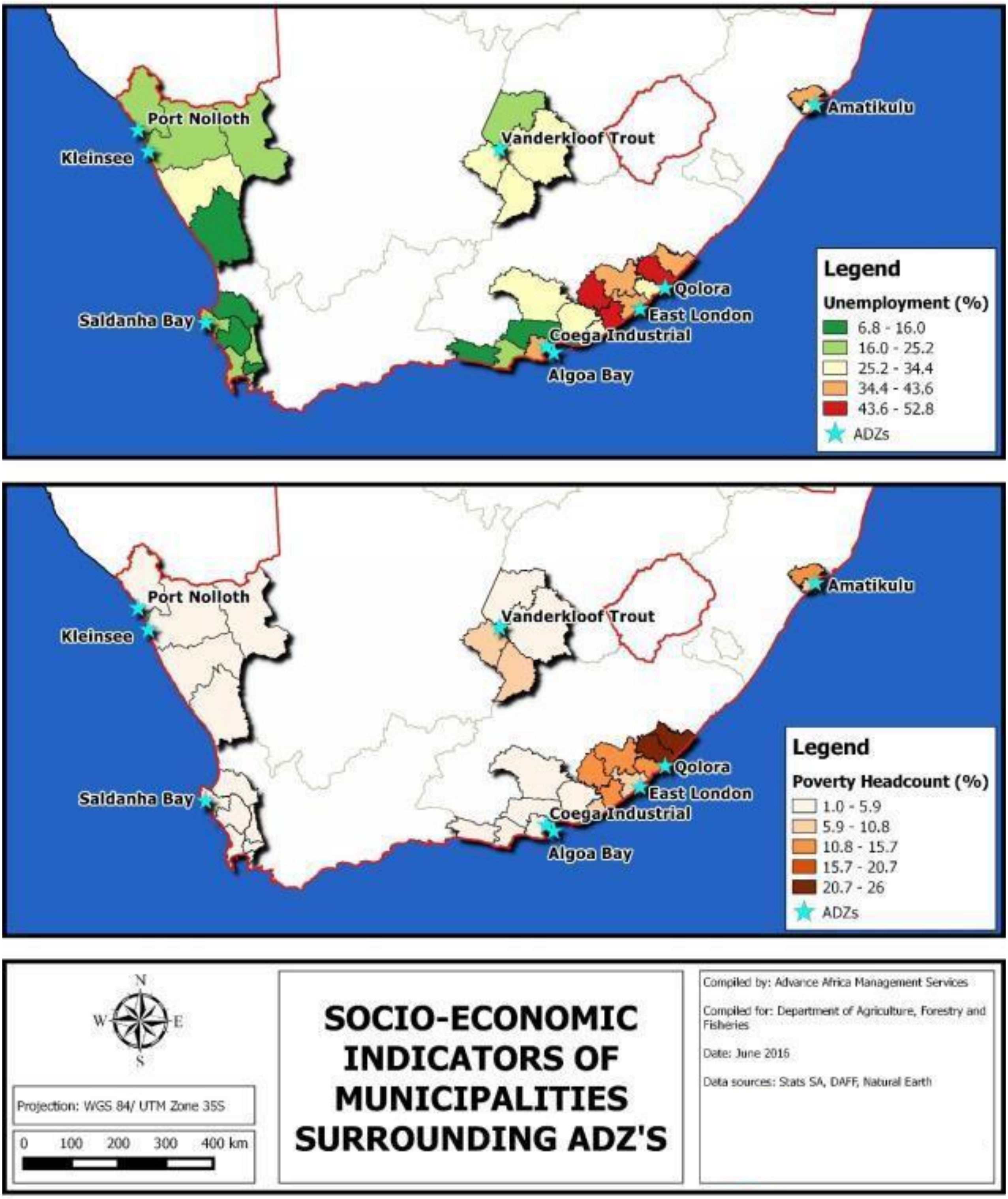


FIGURE 3: SOCIO-ECONOMIC INDICATORS (UNEMPLOYMENT AND POVERTY) OF MUNICIPALITIES SURROUNDING ADZ'S (2012).

Case Study | PRODUCTION & EMPLOYMENT

Country	Product	Production (tonnes)	Employment	Ratio: tonnes production per one person employed	Year	Reference
Bulgaria	Mussels	800	37	21.6	2012	STECF, 2014
Croatia	Mussels	1 300	173	7.5	2012	STECF, 2014
England	Shellfish*	6 915	258	26.8	2012	Ellis et al., 2015
France	Mussels	78 700	2 165	36.4	2012	STECF, 2014
France	Oysters	130 500	13 579	9.6	2012	STECF, 2014
Germany	Mussels	6 700	39	171.8	2012	STECF, 2014
Greece	Mussels	22 500	2 000	11.25	2008	Theodorou et al., 2011
Italy	Mussels	85 500	909	94.1	2012	STECF, 2014
Ireland	Mussels	15 000	443	33.9	2012	STECF, 2014
Ireland	Oysters	7 600	929	8.2	2012	STECF, 2014
Netherlands	Oysters	3 500	48	72.91	2012	STECF, 2014
N. Ireland	Shellfish*	4 920	55	89.5	2012	Ellis et al., 2015
Portugal	Mussels	400	58	6.9	2012	STECF, 2014
Portugal	Oysters	800	93	8.6	2012	STECF, 2014
Scotland	Shellfish*	6 525	358	18.2	2012	Ellis et al., 2015
Spain	Mussels	207 600	9 059	22.9	2012	STECF, 2014
Spain	Oysters	2 400	648	3.7	2012	STECF, 2014
Wales	Shellfish*	8 999	34	264.7	2012	Ellis et al., 2015
South Africa	Mussels	600	26	23.1	2008	Britz et al., 2009
South Africa	Oysters	289	111	2.6	2008	Britz et al., 2009

** Total is > 90% mussel production*

The table above demonstrates production of mussels and oysters and the resultant employment indicators for various countries. When assessing the average production per person employed, bivalves have similar values of 49 and 53 tonnes per person employed for mussels and oysters, respectively. There is a large variability in the ratio for shellfish aquaculture by country that corresponds in part to labour, processing and the use of different techniques. For example, more capital intensive techniques are used in Denmark, Germany and the Netherlands. In other countries, the business is dependent on smaller, family-owned companies with family members assisting (STECF, 2014). Other considerations that may be responsible for the variability include environmental and employment quota factors.

3.4. B-BBEE opportunities

Broad-based Black Economic Empowerment (B-BBEE) is the South African Government's policy aimed at accelerating economic transformation. The policy is directed at empowering "black" people and redressing the inequalities caused by Apartheid. The term "black" refers to Africans, Indians, and persons of mixed race. The policy also promotes the empowerment of designated groups, which include women, youth, people living with disabilities, and people in rural communities.

3.4.1. National Empowerment Fund

The National Empowerment Fund (NEF) was established by the National Empowerment Fund Act No. 105 of 1998 (NEF Act) to promote and facilitate black economic equality and transformation. Its mandate and mission is to be the catalyst of B-BBEE.

The Fund seeks to take the lead in the expansion of new industrial and manufacturing capacity, warehousing equity for the future benefit of B-BBEE in national strategic projects, increasing South Africa's export earning potential, and reducing South Africa's dependency on imports. Investors are urged to invest in the NEF to support job creation and the growth of the economy.

The NEF's role is to support B-BBEE. As the debate concerning what constitutes meaningful and sustainable B-BBEE evolves, the NEF anticipates future funding and investment requirements to help black individuals, communities and businesses achieve each element of the Codes of Good Practice. These include a focus on preferential procurement, broadening the reach of black equity ownership, transformation in management and staff and preventing the dilution of black shareholding within entities.

The NEF differentiates itself not only with a focused mandate for B-BBEE but also by assuming a predominantly equity-based risk to maximise the "Empowerment Dividend". Reward should balance the risk with the application of sound commercial decisions to support national priorities and Government policy such as the Accelerated and Shared Growth Initiative for South Africa (AsgiSA) or targeted investments through the DTI's Industrial Policy Framework. The work of the NEF therefore straddles and complements other development finance institutions by allowing the organisations to work in close collaboration.

Products and services

- ***The iMbewu fund***

This fund is designed to promote the creation of new businesses and the provision of expansion capital to early stage businesses. The iMbewu Fund aims to cultivate a culture of entrepreneurship by offering debt, quasi-equity and equity finance of up to R10 million comprising:

- Entrepreneurship finance
- Procurement finance
- Franchise finance

- ***Rural and community development fund***

The rural and community development fund facilitates community involvement in projects that promote social and economic upliftment. In accordance with the B-BBEE Act, it aims to increase the extent to which workers, cooperatives and other collective enterprises own and manage business enterprises. It also supports the B-BBEE Act objectives of empowering local and rural communities. It has four components: Project Finance, Business Acquisition, Expansion Capital and Start-up/"Greenfields" with funding thresholds between R1 million and R50 million.

- ***The uMnotho fund***

The uMnotho Fund is designed to improve access to B-BBEE capital for black-owned or black-managed businesses who are buying equity shares in black- or white-owned businesses, starting new ventures, looking to expand and/or be listed on the Johannesburg Stock Exchange. In other words, this Fund provides financing for those entrepreneurs who wish to buy into an already established business and aims to increase the number of entrepreneurs in the country. Funding ranges from R5 million to R50 million.

- ***Strategic projects fund***

It provides "Venture Capital Finance" to develop South Africa's new and strategic industrial capacity within sectors identified by Government as the key drivers to economic growth. The Fund aims to increase the participation of black people in early-stage projects. This Fund acts to stimulate economic activity. Some of the areas where NEF has invested this funding are renewable energy, mining and minerals beneficiation, agro-processing, tourism, business process outsourcing and infrastructure.

The Funds' focus is informed by Government's strategies on industrial development through the DTI's National Industrial Policy Framework and the corresponding Industrial Policy Action Plan (IPAP).The sectors identified in the Framework and IPAP are as follows:

- Agriculture
- Business process outsourcing textiles
- Mining, mineral processing and mineral beneficiation
- Automobiles
- Renewable energy and biofuels
- Plastics
- Pharmaceuticals and chemicals
- Forestry, pulp and paper
- Infrastructure
- Manufacturing
- Tourism

3.5. SMME opportunities

Government has prioritised entrepreneurship and the advancement of Small, Medium and Micro-sized Enterprises (SMMEs) as a catalyst to achieving economic growth and development. With the assistance of other government departments and institutions, the newly created Department of Small Business Development (DSBD) and the DTI takes the lead in implementing SMME-related policies to ensure that adequate financial and non-financial assistance is provided to the sector for its long-term prosperity.

3.6. Incentives and industrial financing opportunities

South African government departments offer an array of incentive schemes to stimulate and facilitate the development of sustainable, competitive enterprises (DTI, 2015). These incentive schemes seek to support the development and/or growth of commercially viable and sustainable enterprises through the provision of either funding or tax relief. Most of the incentives are housed within the DTI, with a few others in other government departments. These incentive schemes are broadly classified into three categories:

1. **Concept and Research & Development Incentives:** These are incentives available to private sector enterprises that invest in the creation, design and improvement of new products and processes. Such businesses conduct investigative activities with the intention of making a discovery that can either lead to the development of new products and processes or to the improvement of existing products;
2. **Capital Expenditure Incentives:** These are incentives for companies that want to acquire or upgrade assets in order to either establish or expand the business' productive capacity;
3. **Competitiveness Enhancement Incentives:** These are investments that facilitate increased competitiveness, sustainable economic growth and development in a specific sector.

Aquaculture has been identified as one of the priority sectors in South Africa that can contribute to food security, job creation, promote economic development and export opportunities (DAFF, 2013d). Aquaculture is a technology-driven industry that requires substantial and sustained capital investment. The majority of aquaculture businesses are faced with limited access to finance and, therefore, cannot afford to invest in research and development projects on the scale required. In countries where aquaculture has experienced rapid growth in the past, governments have provided financial assistance to make aquaculture producers more competitive, both locally and internationally. Therefore, Government assistance in the form of funding will play a vital role in the development of commercial aquaculture in South Africa. Various investment schemes are applicable in terms of aquaculture development, and B-BBEE and SMME opportunities, and these are summarised in Table 6 below:

TABLE 6: RELEVANT FUNDING OPPORTUNITIES FOR AQUACULTURE DEVELOPMENT IN SOUTH AFRICA.

Capital Expenditure Incentives: Aquaculture Development and Enhancement Programme (ADEP)	
Objective	Investment in the aquaculture sector.
Applicability	SA entities involved in fish hatcheries and fish farms (primary aquaculture), processing and preserving of aquaculture fish (secondary aquaculture), service activities to operators of hatcheries and fish farms (ancillary aquaculture).
Benefit	20% - 45% grant for investment in land, and buildings, machinery and equipment, commercial vehicles and work boats and bulk infrastructure capped at R40 million per application.
Managed by	DTI
Competitiveness Enhancement Incentives: Special Economic Zones (SEZs)	
Objective	To promote targeted investment to facilitate economic growth and job creation.
Applicability	Qualifying projects located in SEZs.
Benefit	• 15% corporate tax rate. • Accelerated write-off of buildings over a 10 year period. • Employment tax allowance per job created. • Customs controlled area for duty-free rebate and VAT exemption for importing inputs of export products.

	• One-stop-shop for investment facilitation.
Managed by	DTI
Competitiveness Enhancement Incentives: Agro-industries	
Objective	Provide support to agro-processing and aquaculture sectors.
Applicability	Focus areas are: • Horticulture primary agricultural sector • Food processing sector • Agro-industrial sector • Beverage sector • Fishing and aquaculture sectors
Minimum finance requirement	More than R1 million in debt and/or more than R5 million in equity.
Benefit	Competitive, risk-related interest rates are based on the prime bank overdraft rate.
Managed by	Industrial Development Corporation
Competitiveness Enhancement Incentives: Incubation Support Programme	
Objective	To develop and nurture sustainable SMME's that can provide jobs.
Applicability	South African registered legal entities. Specifically, registered higher education or further education institutions in partnership with private sector; and licensed and/or registered science councils in partnership with private sector.
Benefit	A grant of 50% or 60% of the qualifying costs of the incubator limited to R30 million per application.
Managed by	DTI
Competitiveness Enhancement Incentives: Jobs Fund	
Objective	To co-finance public and private sector projects that will significantly contribute to job creation.
Applicability	The Fund will, on a competitive basis, consider co-financing proposals from private sector, non-governmental organisations, government departments and municipalities that show economic development potential linked to sustainable job creation.
Benefit	Matching grant funding for the following windows: • Enterprise development initiatives: Initiatives that reduce risk, remove barriers to market access and broaden supply chains; • Infrastructure initiatives: Light infrastructure initiatives necessary to unlock job creation; and • Work-seekers initiatives: Initiatives linking work-seekers to the formal employment sector.
Managed by	National Treasury's Government Technical Advisory Centre
Rural and Community Development Fund	
Objective	To promote sustainable change in social and economic relations and supporting the goals of growth and development in the rural economy.
Applicability	Minimum black ownership of 25.1% is a requirement.
Benefit	A minimum of R1 million to R50 million
Managed by	NEF
Competitiveness Enhancement Incentives: Black Business Supplier Development Programme	
Objective	To improve the sustainability of black-owned enterprises by providing funding to increase the competitiveness of the businesses.
Applicability	Companies that are majority black-owned (51% or more), have an annual turnover of between R250 000 and R35 million and have a predominantly black management team. The entity must have a minimum trading history of one year and be registered for VAT.
Benefit	The programme provides grants up to a maximum of R1 million in total that will be limited to a payment of R800 000 for tools, machinery and equipment and limited to a payment of R200 000 for business development and training interventions.

Managed by	DSBD
Competitiveness Enhancement Incentives: The Cooperative Incentive Scheme	
Objective	To promote cooperatives by improving the viability and competitiveness of the cooperative enterprises by lowering the cost of doing business.
Applicability	Any entity incorporated and registered in South Africa in terms of the Cooperatives Act. Target is cooperatives operating in the emerging sector, and manufacturing, retail and services sector.
Benefit	Cost-sharing grant of 100% up to a maximum of R350 000 for costs relating to business development services, business profile development, feasibility studies/market research, start-up requirements etc.
Managed by	DSBD

The Marine Living Resources Fund was established in terms of the MLRA (1998). The funds mandate and core business is to manage the development and sustainable use of South Africa's marine resources and to protect the integrity and quality of the marine ecosystem (National Treasury, 2015).

The Working for Fisheries projects, in the State's expanded Public Works Programme, entail resource management initiatives that employ ecosystem approaches to fisheries and aquaculture development by encouraging communities to responsibly manage and conserve their aquatic environments. These projects are expected to result in the creation of 1 693 jobs in the fisheries sector by 2017/18, and aim to ensure environmental sustainability in rural coastal communities in line with the National Development Plan's (NDP) vision. These projects will be funded through a monitoring, compliance and surveillance programme, with an allocation of R365.2 million over the medium term (National Treasury, 2015).

Operation Phakisa is the vehicle through which government aims to implement its policies and programmes more efficiently and effectively (National Treasury, 2015). Operation Phakisa aims to implement economic and social programmes within the "Ocean Economy", of which aquaculture is one of the priority sectors. Aquaculture projects can seek implementation support through the Operation Phakisa Aquaculture Development Fund. To date, this fund has yet to be developed although is catered for in the Aquaculture Bill (Andrea Bernatzeder; personal communication).

To date, efforts to enhance the growth of SMMEs have been widespread; however, challenges still remain. There is a lack of state support and access to funding remains a challenge for SMMEs. Furthermore, there is a lack of coordination between various governmental departments which makes support of SMME operations difficult and ineffective (Olivier *et al*., 2013). Economies of scale and operational pressures often make it extremely difficult for SMMEs to generate enough profit to expand, increase efficiency, and upgrade infrastructure in order to remain competitive on national and international markets.

4. CANDIDATE SPECIES

4.1. Mussels

Two species of mussels are cultured in South Africa: the non-native Mediterranean mussel (*Mytilus galloprovincialis*), and the native black mussel (*Chromytilus meriodionalis*) (DAFF, 2014a).

4.1.1. Biological characteristics

Mediterranean mussel

The Mediterranean mussel, *Mytilus galloprovincialis* (Figure 4), is a filter-feeding bivalve native to the Mediterranean (Barsotti & Meluzzi, 1968) and the eastern Atlantic, from Ireland and the United Kingdom (Gosling, 1992) to northern Africa (Comesana *et al*., 1998). It has been introduced to the Pacific coast of North America (McDonald & Koehn, 1988), Hong Kong (Lee & Morton, 1985), Japan (Wilkins *et al*., 1983), Chile (Hilbish *et al*., 2000; Gerard *et al*., 2008), Australia (Hilbish *et al*., 2000), New Zealand (Gerard *et al*., 2008), and South Africa (Grant & Cherry, 1985) (Figure 5). Introductions were initially accidental e.g. via ballast water and subsequently via aquaculture activities (CABI, 2016a). It is considered to have been introduced into South Africa in the 1970's (Grant & Cherry, 1985).

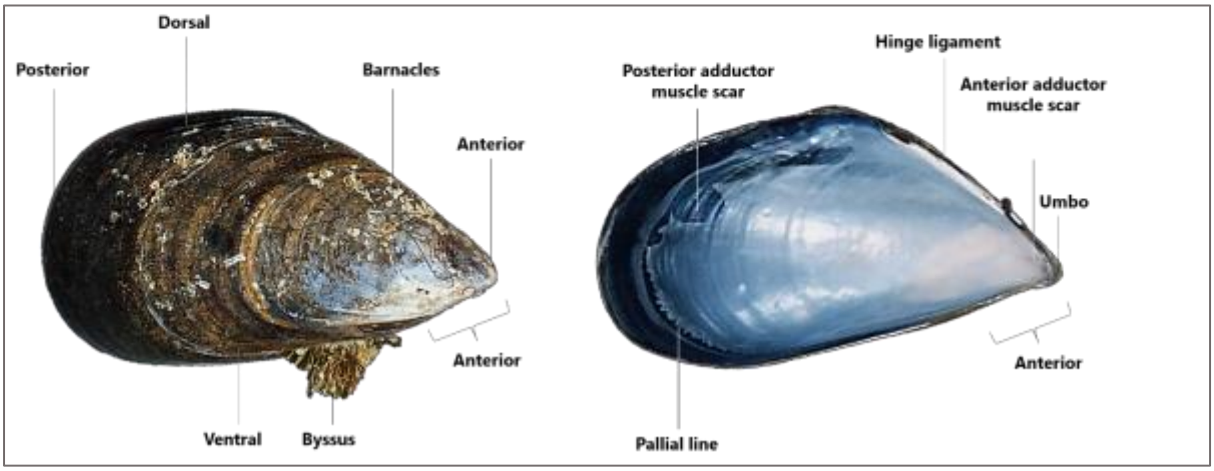


FIGURE 4: MEDITERRANEAN MUSSEL *MYTILUS GALLOPROVINCIALIS*

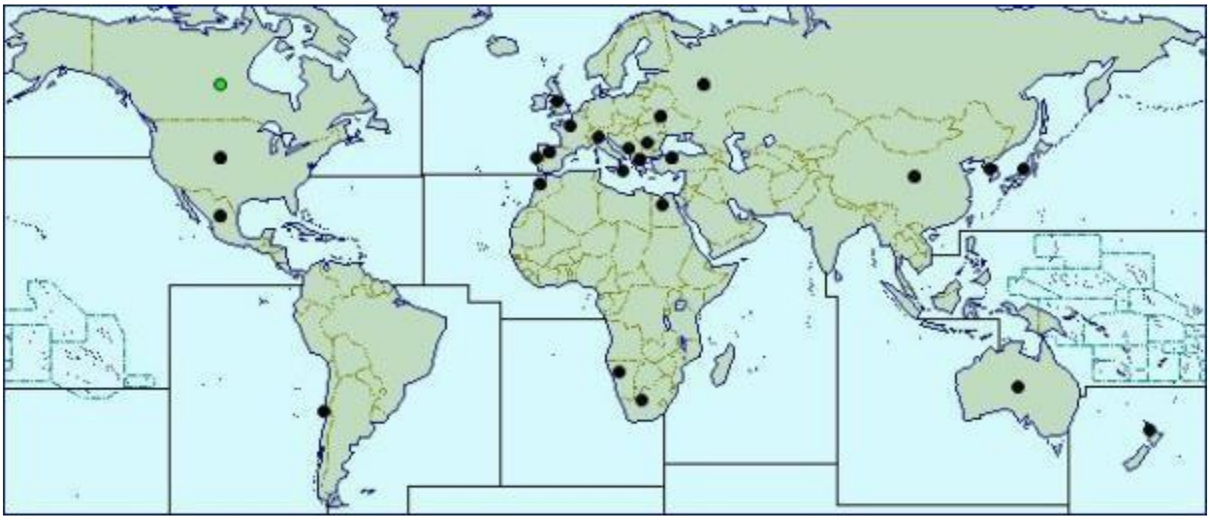


FIGURE 5: COUNTRY-BY-COUNTRY DISTRIBUTION OF THE MEDITERRANEAN MUSSEL INCLUDING NATIVE AND NON-NATIVE RANGE (SOURCE: CABI, 2016A).

In southern Africa, it is distributed along the entire west coast (Western Cape and Northern Cape coastlines) and the southern coast (Western Cape and Eastern Cape coastlines) up to East London (Viladomiu, 2004). Distribution is temperature-related with higher abundances recorded in the cooler waters of the west coast compared to the southern coastline (Viladomiu, 2004). The species occupies the intertidal zone (mid-to-high rocky shores), forming dense beds where it attaches firmly to rocks by means of strong byssal threads secreted by a mobile foot (Picker & Griffiths, 2011). Mediterranean mussels are filter-feeders that obtain food by pumping water through enlarged, sieve-like gills and transporting particles using cilia from the gills toward the mouth for ingestion. Particles include those derived from macrophytes such as kelp (*Ecklonia maxima*) as well as phytoplankton (Bustamante & Branch, 1996). It is naturally absent from the sub-tidal zone although aquaculture occurs within this zone (Branch *et al.*, 2008).

Mediterranean mussels are gonochoristic (unisexual) broadcast spawners, reaching maturity after approximately one year (Branch & Steffani 2004; Picker & Griffiths, 2011). After gametes have been externally fertilised, the embryos develop into planktotrophic trocophore larvae which may drift with water currents for several weeks before settling onto filamentous organisms such as seaweeds (known as primary settlement) (Boersma *et al.*, 2006; Green, 2014). During secondary settlement, the post-larvae secrete byssal threads in order to attach to hard substrate and undergo metamorphosis into their adult, shelled form (Green, 2014). Settlement of larvae may occur at exceptionally high densities of up to 2 million recruits per square metre (Harris *et al.*, 1998; Branch & Steffani 2004). Recruitment occurs year round and major settlement is typically observed from May to September (Green, 2014). Mediterranean mussels typically live from 1 – 2 years (Boersma *et al.*, 2006). Growth is rapid and the species may attain 70mm within a year (Picker & Griffiths, 2011). Figure 6 illustrates the life cycle of the Mediterranean mussel.

The species is listed as one of the Worlds's Worst 100 Invasive Alien Species (GISD, 2012) and, in South Africa, is associated with the almost complete displacement of the indigenous ribbed mussel *Aulacomya atra* on the west coast and, to a lesser extent, the brown mussel *Perna perna* and black mussel *Chromytilus meriodionalis* (Branch & Steffani, 2004; Validomiu, 2004). Its success as an invasive species is due to its high productivity, reproductive output, growth rate, tolerance of extended periods of dessication and tendency to grow in dense beds (van Erkom Schurink & Griffiths, 1993; Validomiu, 2004).

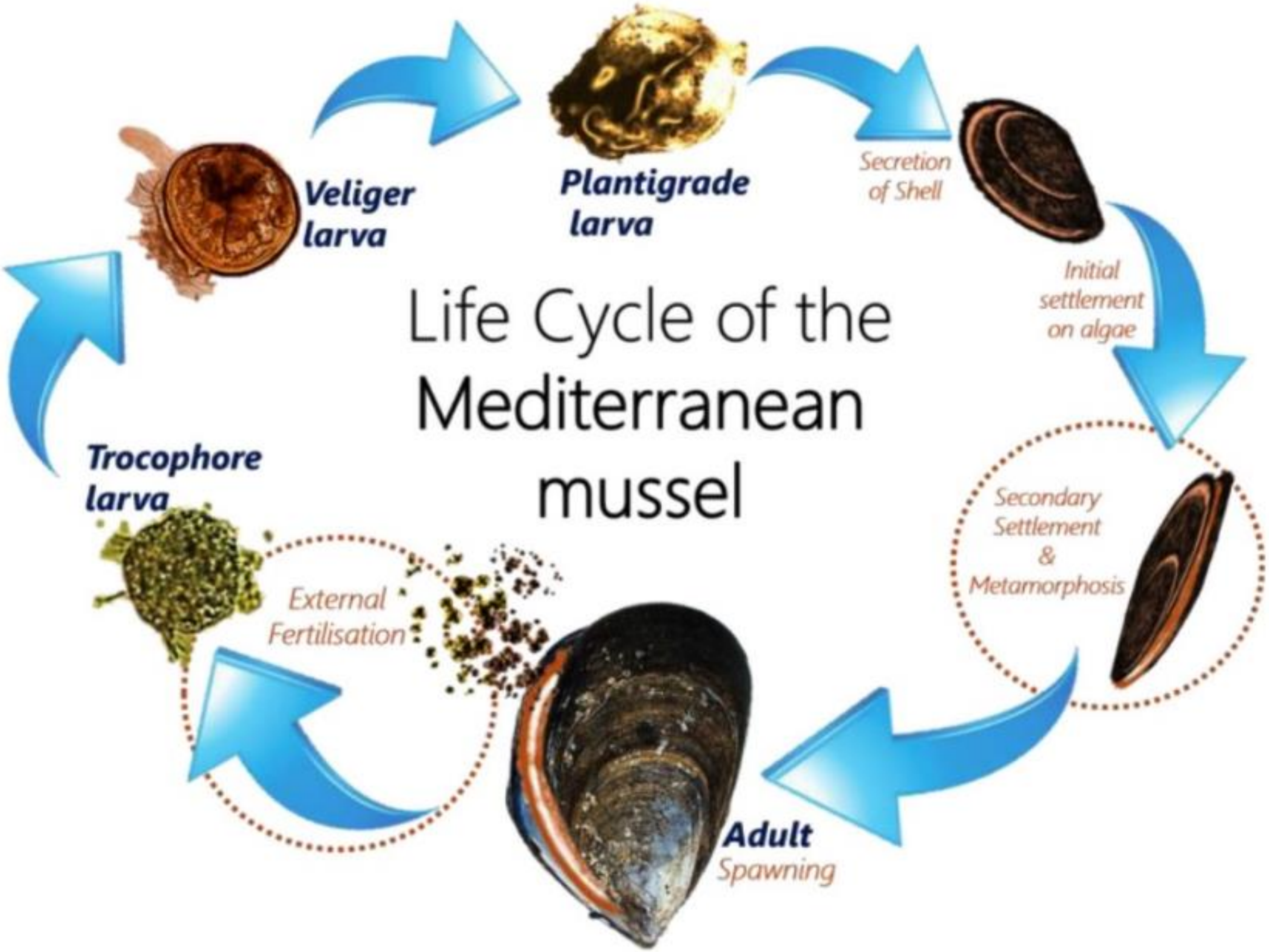


FIGURE 6: LIFE CYCLE OF THE MEDITERRANEAN MUSSEL.

Black mussel

The black mussel *Choromytilus meriodionalis* is native to the southern African coast and is distributed from central Namibia to Port Elizabeth (Griffiths, 1981; Branch *et al*., 2008). This filter-feeding bivalve is most abundant in subtidal or silted intertidal areas (Branch & Steffani, 2004) although occurs up to a depth of approximately 10m (Branch *et al*., 2008) (Figure 7). Black mussels may grow up to 150mm in length and, although frequently confused with Mediterranean mussels, are typically narrower and more black (Branch *et al*., 2008). They are gonochoristic broadcast spawners with a larval stage and settlement patterns similar to that of the Mediterranean mussel (Griffiths, 1981). Reproduction occurs primarily from July-February (Griffiths, 1980). Growth is fairly rapid although slightly slower than that of the Mediterranean mussel (Gosling, 2015)

Black mussels prefer silted areas and this generally precludes them from competitive interactions with the invasive Mediterranean mussel which is intolerant of silt (Branch & Steffani, 2004).

FIGURE 7: BLACK MUSSEL *CHOROMYTILUS MERIODIONALIS* (SOURCE: TRAUSEL & SLIEKER, 2016).

4.1.2. Fisheries

Global aquaculture production far exceeds that of capture production for Mediterranean mussels (Figure 8).

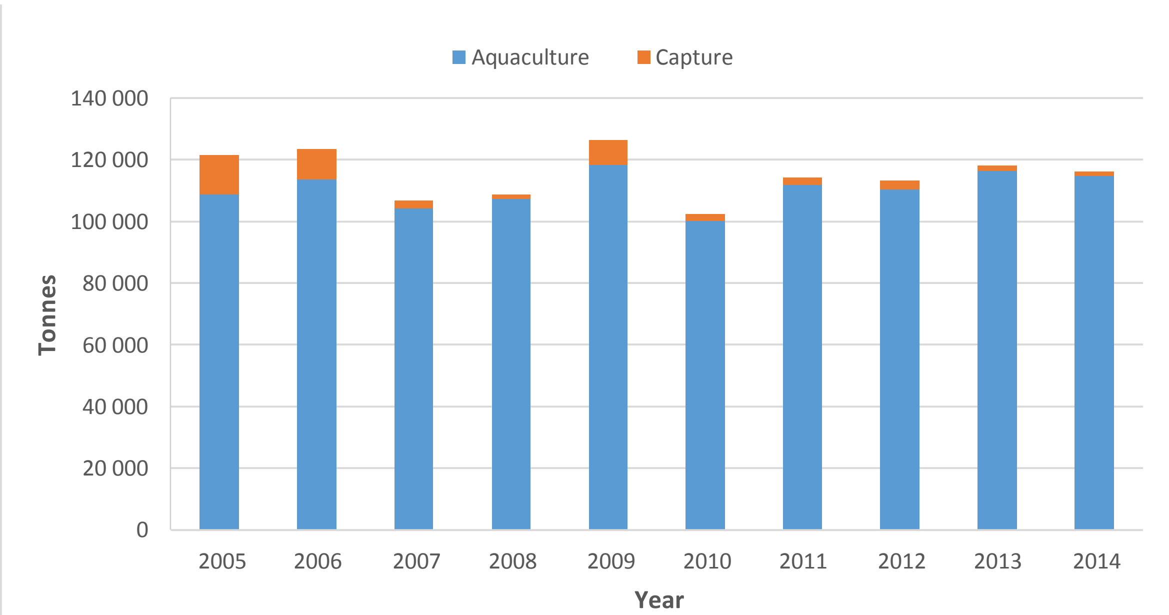


FIGURE 8: GLOBAL AQUACULTURE AND CAPTURE PRODUCTION OF MEDITERRANEAN MUSSELS (FAO FISHSTATJ, 2016).

4.1.3. Aquaculture development

Mussel culture was first practiced in Tarragona and Barcelona, Spain, in 1901 and 1909, respectively (FAO, 2004). After initial attempts, the use of poles was abandoned and the utilisation of floating structures began (FAO, 2004). Some bottom culture of mussels was practiced along the Mediterranean coast (FAO, 2004). However, in 1946, raft culture of mussels was introduced to the Mediterranean and, in subsequent years, production increased sharply (FAO, 2004).

Early rafts consisted of square, wooden frameworks supported by a central float or restored old ships that supported wooden frameworks, from which farmers hung ropes of esparto grass (*Stipa tenacissima*) (FAO, 2004). Mussel seed was attached to ropes and, upon reaching commercial size, was collected by hand or with a special pin wheel (FAO, 2004). Subsequently, square or rectangular wooden frameworks supporting small houses replaced the use of old ships and flotation consisted of wooden floats wrapped in wire mesh and coated with concrete (FAO, 2004). Currently, most rafts are constructed of a framework of eucalyptus wood (FAO, 2004).

The positive and negative attributes for aquaculture of mussels are listed in Table 7.

TABLE 7: POSITIVE AND NEGATIVE ATTRIBUTES OF MUSSEL AQUACULTURE.

Positive attributes	**Comment**
Broodstock	In South Africa, no broodstock required as settlement of seed is natural.
Growth	Growth is rapid and the species can be grown from seed to harvest size in 7 months.
Feeding	Mussels feed on naturally available sources of plankton and no feeding nor artificial feed is required.
Disease	Resistant to disease.
Technology	Proven, successful, and simple technology for aquaculture has been developed.
Capital costs	Lower capital required compared to more complex finfish production systems.
Market	Established market with opportunities for growth.
Negative attributes	**Comment**
Market concerns	Strict regulatory environment around export of bivalve products
Processing	Bioaccumulation of certain toxins and required depuration.

Mussel aquaculture in South Africa

Mussel culture in South Africa began in the 1980's. The first mussel farm was developed in Saldanha Bay in 1981 (Matthews, 2001). The then Marine Development Branch of the Department of Environment Affairs and Fisheries granted a permit to a company to farm indigenous brown mussels (*Perna perna*) and black mussels in a tidal pool in Saldanha Bay (Safriel & Bruton, 1984). At the same time, the Fisheries Development Corporation began seeding mussels in the Knysna Lagoon (Safriel & Bruton, 1984). Research needs were also identified during this period although these related more specifically to the culture of brown mussels (Safriel & Bruton, 1984). In 1986, the first mussel raft in South Africa was deployed in Algoa Bay, Port Elizabeth (CPUT, 2012) which was seeded with brown mussels. Subsequently, longline systems were deployed in Saldanha Bay followed by rafts in the 1990's (CPUT, 2012). The protocols for mussel rearing have since been established and the technology has been commercialised.

The focus has shifted somewhat from the production of indigenous mussels to non-native species, specifically the Mediterranean mussel, due to better growth rates and adaptability to culture conditions (Table 7). However, the indigenous black mussel is still cultured in South Africa (DAFF, 2014a). Mussel production is currently based entirely in Saldanha Bay in the Western Cape and, in 2014, there were four operators in the area (DAFF, 2014a).

South Africa's annual mussel production fluctuated between 600 and 1110 tonnes from 2003 – 2013 (DAFF, 2014a). Fluctuations in production may be related to certification and regulatory factors, which restricted mussel products from being marketed (DAFF, 2012a).

4.1.4. Mussel farming technology

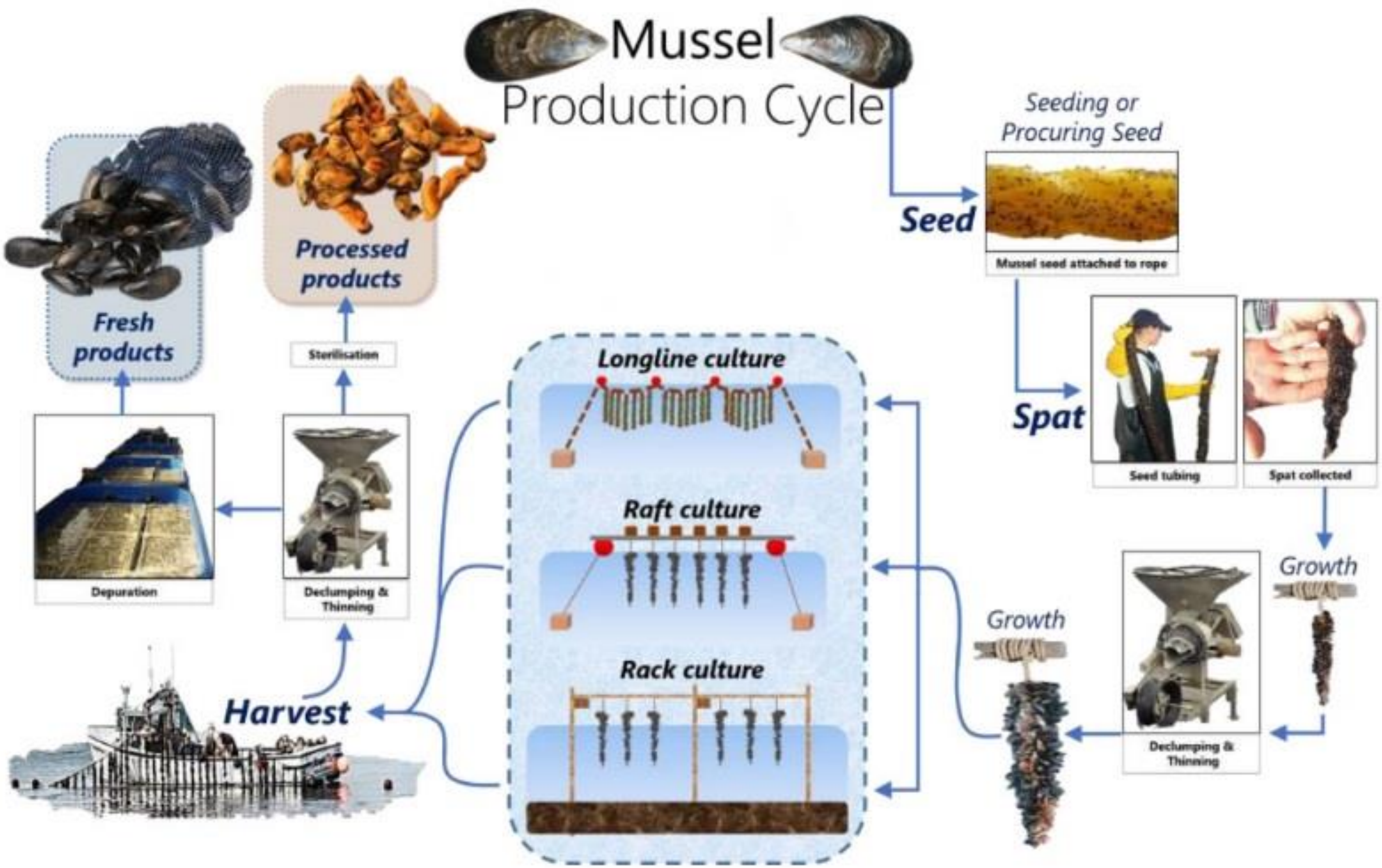
Production systems

Production systems for mussels are entirely offshore-based. Traditional production technology (see Figure 10) is relatively simple and involves culture on suspended ropes which are attached to floating raft structures, longlines with floating buoys or, less commonly, on racks (FAO, 2004). A new production system has been developed in Norway by a company called SmartFarm. The SmartUnits consist of a PE pipe for buoyancy, a head rope, suspended mesh ropes for mussel attachment, and bottom weights (Figure 9) (Smartfarm, 2016). These units are currently used in the Mediterranean, Brazil, and Chile

FIGURE 9: THE SMARTFARM MUSSEL GROWING SYSTEM DEVELOPED IN NORWAY (SOURCE: BJORN ASPOY, 2016)

All mussel production involves:

1. Seeding of mussel larvae onto suspended ropes hung from longlines, rafts, racks or suspended mesh in a SmartFarm system
2. Selective grading in early stages of production (optional)
3. Harvest after approximately 7 months
4. Depuration (optional)



Mussel
Production Cycle
Seeding or
Procuring Seed
Seed
Mussel seed attached to rope
Spat
Seed tubing
Spat collected
Growth
Declumping & Thinning
Growth
Longline culture
Raft culture
Rack culture
Harvest
Declumping & Thinning
Sterilisation
Depuration
Fresh products
Processed products

Seeding

Mussel seed is either collected from natural beds where larvae settle or from ropes, plastic mesh strips, or artificial seaweed suspended from rafts that are seeded naturally (Figure 11) (FAO, 2004). In some instances, seed collection and grow-out occur on the same suspended rope i.e. mussels are left for the entire duration of the grow-out period with some selective grading during the early stages of grow-out to reduce overpopulation and improve growth rates. This system is implemented in Saldanha Bay (Vos Pienaar, personal communication, June 2015). As the Mediterranean mussel is a Category 2 invasive species according the NEM:BA Regulations (2014), and therefore, require a permit to be cultured and is only permissible where populations of the species already occurs.

FIGURE 11: MUSSEL SEED COLLECTION USING LINES SUSPENDED OFF RAFTS (SOURCE: PENN COVE SHELLFISH, 2016).

In the case of collected mussel seed, the seed is placed into stocking mesh bags and attached to suspended ropes hung from longlines, rafts, or SmartUnits. This is done either by hand or using machines. The mesh disintegrates after a few days (Figure 12) (FAO, 2004).

FIGURE 12: MUSSEL SEED PACKED INTO STOCKING MESH AND PLANTED ONTO SUSPENDED ROPES (SOURCE: AQUACULTURE NEW ZEALAND, 2016).

Ropes, usually nylon or polyethylene, are seeded at densities ranging from approximately 1.5 – 1.75kg of seed/metre of rope. The ropes are usually between 6 – 10m long with a loop at one end to which a thinner polyester rope is knotted. This thin section of rope is then fastened to the raft or longline (Figure 13). On rafts, ropes are attached at a rate of approximately 1 – 3 ropes/m^2 and rafts may support from 200 – 700 ropes (FAO, 2004). For longlines, lines are attached every 0.5 – 1m (Seafish, 2005).

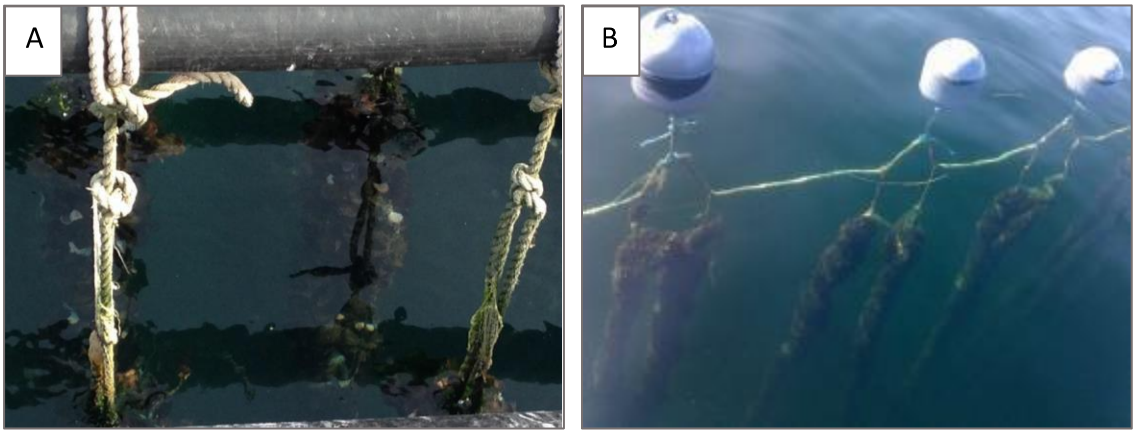


FIGURE 13: A) MUSSELS SUSPENDED OFF A FLOATING RAFT (SOURCE: ADVANCE AFRICA, 2015); AND B) A LONGLINE SEEDED WITH MUSSELS (SOURCE: RIISGARD, 2010).

Grading

During the grow-out process, the mussels are graded or *thinned* in order to ensure rapid and uniform growth which would otherwise be reduced if mussels were left to aggregate in dense clumps (FAO, 2004). Approximately halfway through the grow-out phase the ropes are lifted using a crane into workboats and the clusters of mussels are passed, either by hand or mechanically, through a screen which grades them into different size classes. The mussels are then reattached to new ropes before being lowered back into the water (FAO, 2004).

Grow-out and harvest

The grow-out period varies depending on species and environmental conditions. In Saldanha Bay, Mediterranean mussels are typically harvested after approximately 7 months (Vos Pienaar, personal communication, June 2015). In order to ensure year round production, some operations will fit their rafts or longlines with three different ropes holding seed, grow-out, and market-ready mussels (FAO, 2004). Mussels are typically harvested into crates before being transferred to the processing facility (Figure 14).

FIGURE 14: SALDANHA BAY MUSSELS HARVESTED AND PACKAGED.

Depuration

Bivalve molluscan shellfish concentrate contaminants from the water column in which they grow, potentially causing illness to humans when the product is eaten (Lee *et al*., 2008). In order to avoid this, mussels undergo a post-harvest process known as depuration during which they are held in tanks of clean seawater under conditions that maximise the natural filtering activity of the organism, resulting in expulsion of potential contaminants, specifically faecal contaminants, housed in the intestines (Lee *et al*., 2008). Depuration is not undertaken for mussels grown in water free of faecal coliforms.

4.1.5. Environmental impacts

The environmental impacts of mussel farming can be broadly classified into three main categories: impacts on the seabed, impacts on the water column and impacts on marine life (Keeley *et al*., 2009).

- ***Impacts on the seabed***

Potential impacts include enrichment of seabed sediments in the vicinity of mussel farms, accumulation of shell debris and litter beneath the site, and aggregations of echinoderms (Gallagher *et al.*, 2008) and epifauna in the immediate and near vicinity. Enrichment of seabed sediments may result in enhanced localised productivity and alterations in the composition of sediment dwelling fauna with a shift towards more abundant smaller taxa (Hartstein & Rowden, 2004; Keeley *et al*., 2009).

Impacts are most pronounced directly underneath the site. Effects can be minimised by locating the farm in well-flushed areas (Keeley *et al*., 2009).

- ***Impacts on the water column***

Physical impacts from the mussel production structure itself include a localised reduction in current speed which may affect biological processes and water residence times (Keeley *et al*., 2009). However, this is probably only important in areas where culture has intensified to an advanced stage. Despite hypothesised impacts on phytoplankton growth, and altering of phytoplankton and zooplankton species composition, there is little documented research to suggest that these impacts are significant (Keeley *et al*., 2009).

- ***Impact on marine life***

The development of mussel farming structures may impact seabirds and marine mammals, specifically through entanglement (Wursig & Gailey, 2002), habitat creation and modification, and habitat exclusion (Keeley *et al*., 2009). In New Zealand, an adult Brydes whale was fatally entangled in mussel lines (Wursig & Gailey, 2002). This is, however, the only incident of its kind reported in that country, where mussel farming is well developed, and a risk assessment exercise conducted by Keeley *et al* (2009) deemed the overall entanglement risk to be low.

Mussel farms may function as artificial "reefs" providing food, refuge and breeding habitat. Consequently, marine life, including seabirds, mammals, and fishes, will aggregate around these structures and the increased abundances of fish, in particular, may affect fishing pressure and behaviour in the near vicinity (Keeley *et al*., 2009).

4.1.6. Diseases and parasites

A comprehensive summary of diseases and parasites, symptoms and treatments/measures, adapted from the FAO (2004) and Bower (2010) is shown in Table 8.

TABLE 8: SUMMARY OF DISEASES AND PARASITES (FAO, 2004; BOWER, 2010).

Disease	Type	Agent	Symptoms	Treatment/Measures
Marteiliasis; Aber disease (Parasitic infection)	Protozoan	*Marteilia maurini; M. refringens*	Visceral tissues lose pigmentation, becoming pale yellow; mantle sometimes translucent; shell growth may cease; flesh shrunken and slimy; potentially lethal	No treatment available; avoidance of stock transfer from infected areas; site selection; preventative operational measures
Rickettsiosis	Bacteria	*Rickettsia* and *Chlamydia* type spp.	Microcolonies in the epithelial cells of the gills and digestive gland. Large colonies can cause host cell hypertrophy with displacement and compression of the host cell nucleus against the basal membrane.	No treatment available; avoidance of stock transfer from infected areas; site selection; preventative operational measures
Mussel egg disease	Microsporidia	*Steinhausia mytilovum*	Infects the cytoplasm and nucleus of mussel ova and can incite a moderate to severe diffuse-type haemocyte infiltration response (De Vico and Carella 2012).	No treatment available; avoidance of stock transfer from infected areas; site selection; preventative operational measures
Phototrophic endolith invasion	Microbial endoliths	*Plectonema terebrans*, *Hyella caespitosa*, *Mastigocoleus testarum*, *Mastig ocoleus* sp.	Numerous tiny burrows created by the endolithic cyanobacteria. Mussels with weakened shells are more vulnerable to predation and mechanical effects of wave action. Heavy infestation may result in fracture holes forming in the shell and is soon followed by mussel death.	No known method of prevention. Management measures include reducing light exposure, desiccation.
Mussel trematode disease	Trematode	*Proctoeces maculatus*	Alteration in haemolymph components, a reduction in growth rate. In heavy infections, the numerous sporocysts developing in the mantle can seriously reduce glycogen content (energy reserves) of the tissues and efficiency of the circulatory system, resulting in disturbances	No treatment available; avoidance of stock transfer from infected areas; site selection; preventative operational measures

Disease	Type	Agent	Symptoms	Treatment/Measures
			to gametogenesis and possibly castration and death	
Mussel gill flatworms	Turbellarian	*Urastoma cyprinae*	Can cause disorganization of the gill filaments, a heavy infiltration of haemocytes and subsequent necrosis of adjacent gill tissue. Possible reduction in feeding capacity in heavily infected mussels.	No treatment available; avoidance of stock transfer from infected areas; site selection; preventative operational measures
"Red worm disease"	Copepod	*Mytiloca intestinalis*	Commensal organism; mussels thought to be unaffected	No known measures
Mussel kidney coccidian	Protozoan	*Pseudoklossoa semilunar*	Infected kidney epithelial cells become hypertrophied and kidney tubules fill with coccidia. Heavy infections may cause kidney damage but associated mortalities appear restricted to artificial growing conditions.	No treatment available; avoidance of stock transfer from infected areas; site selection; preventative operational measures
Haplosporidian infection	Protist	*Haplosporidium* spp.	Causes tumefactions in the digestive gland and kidney.	No known methods of prevention or control.
Bucephalid trematode	Trematode	*Prosorhynchus squamatus*; *Rudophinus crucibulum*	Infected mussels are invariably castrated; also causes weakness and gaping which can reduce product value during shipping and marketing.	No known methods of prevention or control.
Mytilicola orientalis of mussels	Copepod	*Mytilicola orientalis*	Can alter the morphology of the epithelial lining of the gut. Attached to the gut wall with the distal segments of the second antennae which has two spine-like setae and terminates in a curved claw and can cause metaplastic changes in the gut. A fibrosis-like response may occur in the connective tissue beneath the areas of epithelial metaplasia, suggesting an attempt by the host to protect underlying tissue by	No treatment available; avoidance of stock transfer from infected areas

Disease	Type	Agent	Symptoms	Treatment/Measures
			encapsulation of the parasite (Lauckner, 1983).	
Haemocytic neoplasia of mussels	Unknown – possibly virus, environmental contamination		Progressively replace normal haemocytes and normal physiological processes. Is progressive, impairs defense mechanisms, and is lethal.	No treatment available; avoidance of stock transfer from infected areas
Gregarine parasitism of mussels	Gregarine	*Nematopsis* spp., *Porospora* spp.	Associated with a focal, benign inflammatory response, without significant health effects.	There are no known methods of prevention or control, apart from avoidance of the crustacean hosts.
Intracellular ciliates of mussels	Protozoan		Obvious host-response despite disruption of the digestive tubule epithelia and no mortalities have been associated with these infections.	Prevention and control impractical.
Sphenophyra-like ciliates of mussels	Protozoan	*Gargarius gargarius*	Large numbers can be observed with no obvious host-response.	No known methods of prevention or control.
Ancistrum mytili gill ciliate of mussels	Protozoan	*Ancistrum mytili*	Large numbers elicit no obvious host-response and attachment to the gill epithelia appears to be superficial.	Prevention and control impractical.
Trematode metacercariae of mussels	Trematode	Gymnophallidae, Echinostomatida, Renicolidae spp.	Infection can cause compression of adjacent tissues resulting in loss on normal organ architecture, reduced byssal production, impaired shell cleaning in young mussels, and induction of pearl formation.	No known methods of prevention or control.
Parasitic copepods on mussel gills	Copepod	*Modiolicola gracilis*; *Pseudomyicola spinosus*	Damage to the host tissue negligible.	No known methods of prevention or control.
Bivalve-inhabiting hydroids of mussels	Hydroid	*Eugymnanthea* spp., *Eutima* spp.	Attach to the mantle, foot, labial palps, body wall and infrequently on the gills of the mussel host. Infestations increase with mussel size and the condition index was lowest among mussels with the greatest number of hydroids. Mussels with	No known methods of prevention or control.

Disease	Type	Agent	Symptoms	Treatment/Measures
			large numbers of hydroids may have an unpleasant smell.	
Shell-boring polychaetes of mussels	Polychaete	*Polydora* spp.	Most infections are innocuous and usually of low intensity with the burrow being limited to the outside margins of the shell.	Prevalence and intensity of infection can be reduced by off-bottom bivalve culture techniques.

Note that the above table is a comprehensive list of all recorded diseases and parasites. Mussels, and in particular the Mediterranean mussel, are typically resistant to disease and good operations will reduce the prevalence of disease outbreaks.

4.2. Oysters

The only oyster farmed in South Africa is the non-native Pacific oyster, *Crassostrea gigas*. The following is a background study on this species.

4.2.1. Biological characteristics

The Pacific oyster is a filter-feeding bivalve species, native to Japan (FAO, 2005) (Figure 15). It has been introduced to at least 27 other countries in the Americas, Europe, Australasia and Africa (GISD, 2012) (Figure 16). The species was both intentionally introduced in order to enhance depleted oyster fisheries and/or to develop aquaculture, and accidentally introduced via ballast water (FAO, 2005). It is the most commercially marketed oyster globally and in South Africa (Haupt, 2009).

FIGURE 15: PACIFIC OYSTER CRASSOSTREA GIGAS (SOURCE: FAO, 2005).

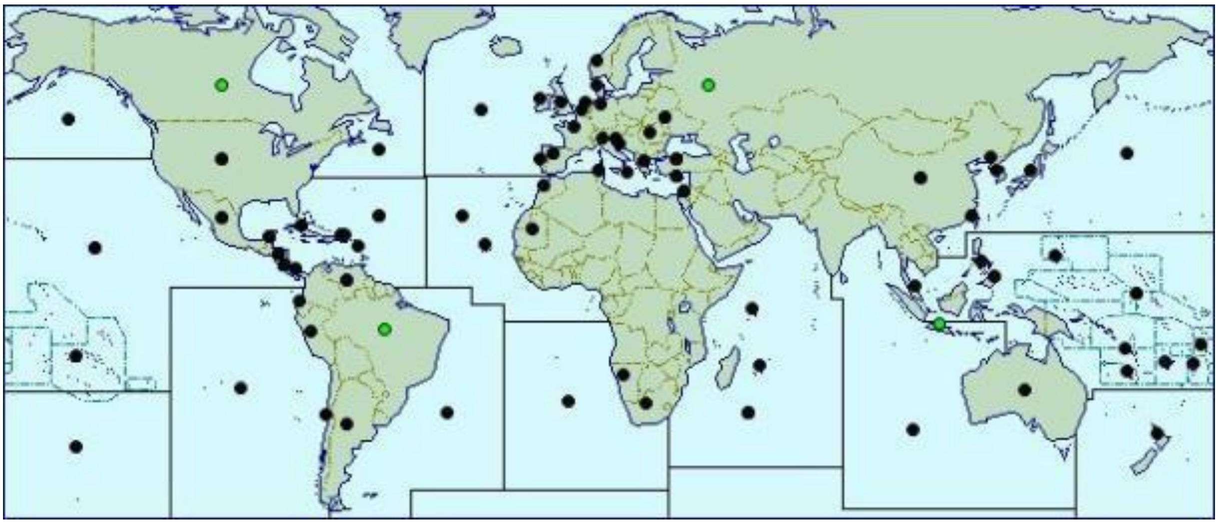


Figure 16: Country-by-country distribution of the Pacific oyster including native and non-native range (Source: CABI, 2016b).

In South Africa, the Pacific oyster was first introduced to the Knysna Estuary in the 1950's for aquaculture purposes (Robinson *et al*., 2005). Wild populations were recorded in the Breede, Duiwenhoks, Goukou, Kynsna, Kromme and Keiskamma estuaries as recently as 2005 (Robinson *et al*., 2005), with the largest population being recorded in the Breede estuary. However, subsequent sampling in 2012 of the Knysna, Goukou and Breede Rivers suggests that the species has struggled to establish wild populations and extend its range. No Pacific oysters were recorded in the Knysna Estuary with only a small population (15 individuals) recorded in the Goukou. The Breede River contained over 25 000 specimens although population numbers appeared to be on the decline (Anchor Environmental Consulting, 2012).

Pacific oysters attach to rocks or debris on firm-bottomed-, mud- and sand-bottomed substrates, usually in estuarine environments ranging from 0-40m depth. Optimal salinity ranges from 20 – 25‰, although the species can tolerate levels from 10 – 35‰, and thermal tolerance limits range widely from -1.8 – 35°C. (FAO, 2005). The Pacific oyster is a protandrous hermaphrodite and broadcast spawning occurs at temperatures greater than 20°C when females may release from 50 – 200 million eggs into the water column. After external fertilisation, the embryos develop into planktotrophic larvae which drift with oceanic currents before settling onto the chosen substrate after a period of two-three weeks. Once the larvae have settled they can be considered as oyster *spat.* Metamorphosis into the juvenile form occurs after settlement. Under ideal temperature (11 – 34°C) and salinity (20 – 25‰) conditions, the oysters can attain market size within 18 – 30 months (FAO, 2005). The species may reach a maximum length of 400mm, although specimens in South Africa generally attain 200mm (Haupt, 2009), and live for up to 30 years (Nehring, 2011).

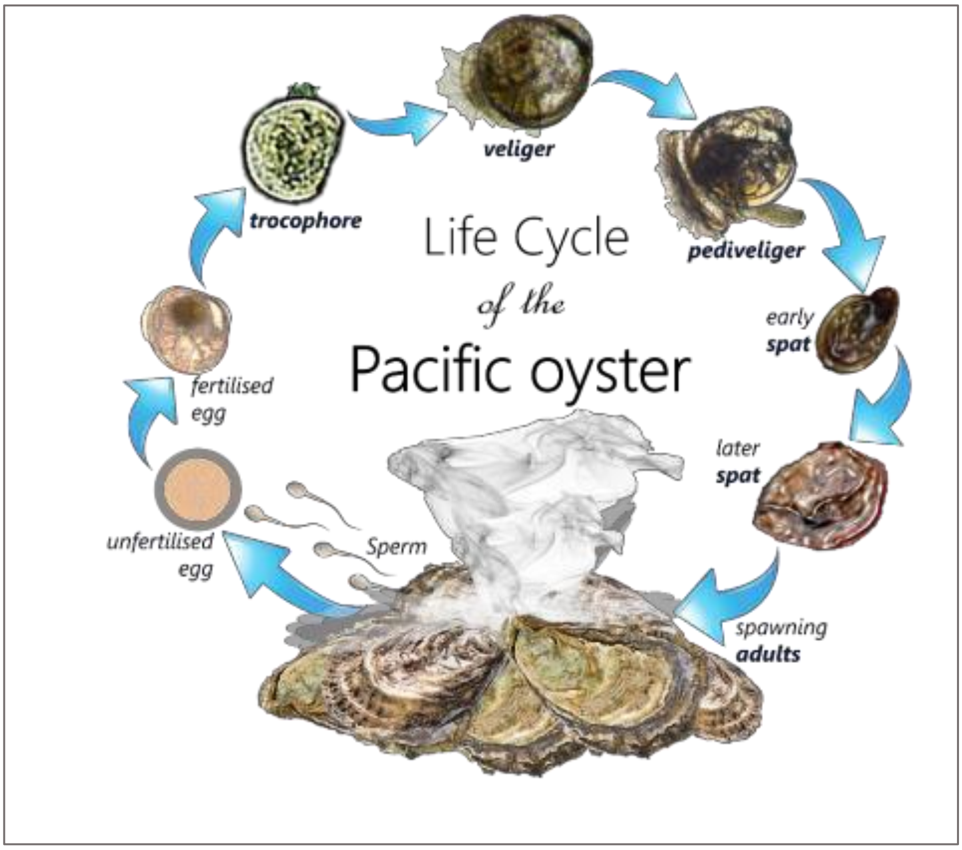


FIGURE 17: LIFE CYCLE OF THE PACIFIC OYSTER.

4.2.2. Fisheries

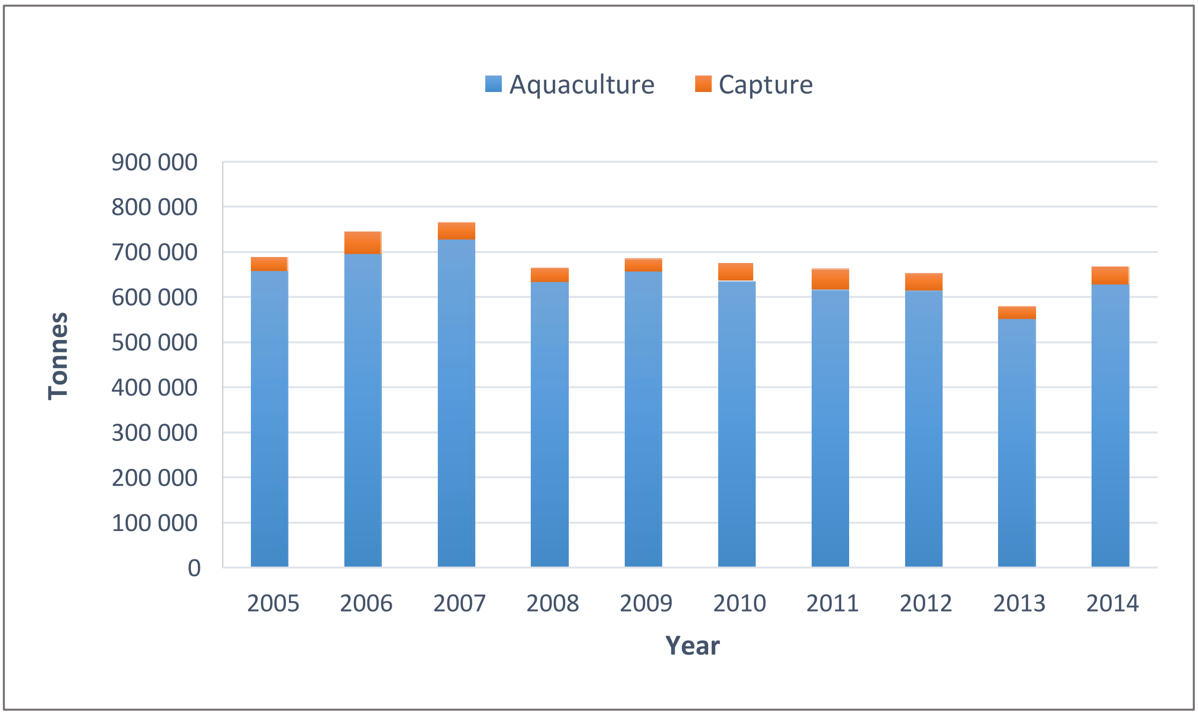


FIGURE 18: GLOBAL AQUACULTURE AND CAPTURE PRODUCTION OF PACIFIC OYSTER (SOURCE: FAO FISHSTATJ, 2016)

Aquaculture production of Pacific oyster far exceeds that of recorded wild capture production (Figure 18). Fisheries production levels have remained stable over the last decade (FAO FishStatJ, 2016). In South Africa, fisheries exploitation of the Pacific oyster is probably limited to small harvests made seasonally by holidaymakers (Robinson *et al*., 2005).

4.2.3. Aquaculture development

Pacific oyster aquaculture was developed in Japan and has been ongoing for centuries. With widespread global introductions, culture techniques have significantly advanced. Historic methods of extensive culture, supported by wild seed capture and relaying in productive areas, have evolved over time to include a wide range of suspended (hanging culture) and off-bottom methodologies utilising both wild and hatchery cultivated seed (Garrido-Handog, 1990; FAO, 2005). More recent methods include the production of triploid seed in hatcheries and selection programmes that focus on producing fast growing, higher quality seed stock suited to particular conditions (FAO, 2005).

The positive and negative attributes for Pacific oyster aquaculture are listed in Table 9.

Table 9: Positive and negative attributes of oyster aquaculture.

Positive attributes	**Comment**
Spawning	Protocols have been developed for successful breeding of the species and can be conditioned to spawn such that year round production can be achieved.
Larval rearing	Protocol and technology is established and proven.
Spat availability	Spat are available both globally and regionally.
Growth	Rapid growth rate of species in South Africa (Pieterse *et al*. 2012). Can attain market size in 6 months under optimal conditions (Enviro-Fish Africa, 2011).
Feeding	Grow-out stage oysters feed on naturally available sources of plankton. There is no requirement for artificial feed nor feeding.
Environmental tolerance	Highly tolerant of wide range of temperatures and salinities. Hardy species.
Technology	Technology for land-based hatcheries has been developed and protocols have been refined. Grow-out technology is proven and relatively simple.
Market	Well established domestic market with high demand
Negative attributes	**Comment**
Spat consistency	While available from global and regional sources, variability in supply can hinder year-round production
Environmental phenomena	HAB events present a risk and may result in significant loss of biomass
Market	Technical assistance required to improve bivalve certification for export to EU markets.

Oyster farming in South Africa

Efforts to culture oysters in South Africa began as early as the late 1600's when European settlers unsuccessfully attempted to farm the native *Striostrea margaritacea* along the Cape coast (Haupt, 2009). Despite extensive efforts to develop a protocol for successfully rearing these oysters, a lack of biological knowledge and inconsistent results led to the importation in the 1940's of the non-native *Ostrea edulis* and Portuguese oyster *Crassostrea angulate* from Europe (Haupt, 2009). This, too, proved unsuccessful and South Africa eventually imported the hardier and globally farmed Pacific oyster with a batch of spat being introduced to the Knysna estuary in the 1950's (Hecht & Brits, 1992; Robinson *et al*., 2005). Spat imports have traditionally come from Europe (France and England) and South America (Chile) (Haupt, 2009; Enviro-Fish Africa, 2011). In 2011, spat were imported from Chile, Namibia and Guernsey (DAFF, 2012a). Currently, these spat are housed in dedicated nursery facilities located in Kleinsee, Paternoster and Jeffreys Bay before being supplied to grow-out operators (Haupt, 2009).

Annual production of Pacific oyster in South Africa has fluctuated significantly since the initial introduction of the species in the 1950's. Hecht and Britz (1992) estimated annual oyster production of two million individuals throughout the 1970's and 1980s with a historical maximum of 8 million individuals in 1991 (Haupt *et al*. 2010 in Pieterse *et al*. 2012). Production has fluctuated from 250-300 tonnes throughout the period between 2000 and 2013 (DAFF, 2014a). This fluctuation can be attributed to a number of farm closures during this period due to concentrations of biotoxins and other hazardous substances that exceeded the regulatory limit (DAFF, 2014a).

In 2013, there were 11 operational oyster farms in South Africa; eight in the Western Cape (located in Saldanha Bay, Knysna and Kleinsee), two in the Eastern Cape and one in the Northern Cape.

4.2.4. Oyster farming technology

Production systems

Production systems for Pacific oyster can be broadly categorised as either land-based or offshore-based.

Land-based production involves:

1. Holding and conditioning of broodstock in tanks for spawning and egg production in hatcheries.
2. Larval rearing in static water or flow-through tank systems.
3. Nursery stage rearing in tanks or land-based ponds

Offshore-based production involves:

1. Nursery rearing of spat from 1 – 15mm.
2. Grow-out from juvenile to harvest size

Production cycle

The production cycle of Pacific oyster is shown in Figure 19:

FIGURE 19: PRODUCTION CYCLE OF PACIFIC OYSTER.

Broodstock capture, conditioning and spawning

Pacific oysters are sedentary and, therefore, broodstock can be easily captured from the wild before broodstock conditioning is undertaken. Broodstock conditioning allows for the extension of the production season by ensuring a reliable and year-round supply of gametes, instead of depending on the short, natural reproductive window when mature adults may bear gametes (Helm *et al*., 2004; FAO, 2005). The basic methods for broodstock conditioning are similar for all bivalves. Adults from the wild are brought into the hatchery, scrubbed and rinsed to remove epifaunal organisms and sediment, and then placed on a mesh tray which is fitted inside a tank. The mesh tray supports the adult oysters stocked at a density of 30 – 35kg/m^3 and held at temperatures between 16 – 24 and salinities of 15 – 34‰. (Helm *et al*., 2004). These tanks typically operate on a flow-through basis with a supply of unfiltered seawater (Figure 20). Over a period of four weeks, the gametes in these adult oysters will mature and adults will be primed for induced spawning for the following two weeks. Spawning is induced in conditioned oysters by manipulating water temperature. Water temperature is raised to 25˚C and then to 30˚C, over a half-hour period, with fluctuations between these temperatures. This induces spawning of one or both sexes. Fertilisation then takes place by mixing sperm and eggs in the ratio of 2 – 4 ml of dense sperm suspension to 4 litres of egg suspension (which equates to approximately one million eggs). Caution is taken to minimize excess sperm which may result in polyspermy, a condition that leads to abnormal embryonic development and poor survival. The fertilised eggs are passed through an 80 micron screen to remove excess debris; after which the eggs are diluted with a known volume of saltwater. The fertilized eggs should be diluted to not more than 200 eggs per millilitre and allowed to develop for 24 hours at 25 C. After enough gametes have been collected and fertilized, the adult oysters are placed in cold running seawater to end the spawning process (Breese & Malouf, 1975; Helm *et al*., 2004).

They may be retained for an additional two weeks to assure a source of conditioned oysters in the event that problems occur with the next group. In order to ensure reliable production of spat, new stock is brought in on a weekly or bi-weekly basis to ensure adults are available for spawning every week (Helm *et al*., 2004).

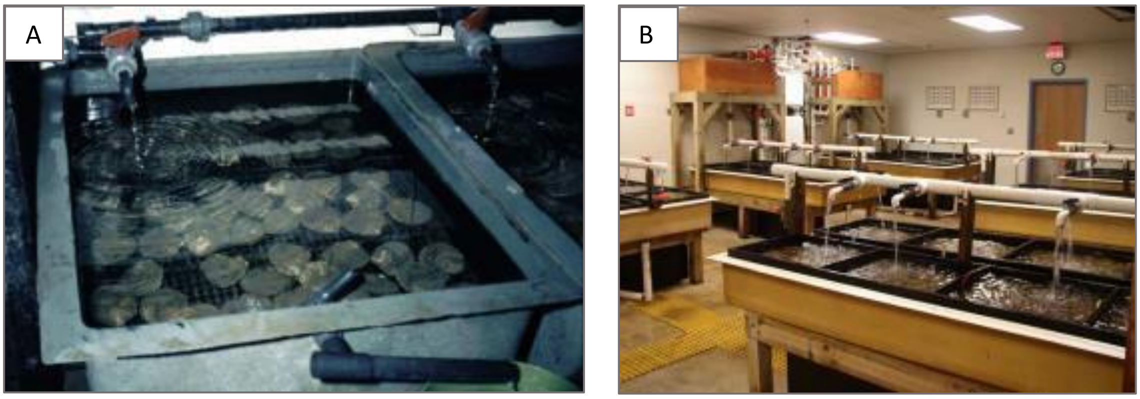


FIGURE 20: OYSTER BROODSTOCK TANK SYSTEMS (SOURCE: A - HELM *ET AL*., 2004; B - UMCES, 2016).

Broodstock are fed live cultures of marine algal species (*Tetraselmis* spp. and *Isochrysis* spp.) during conditioning. Flow rates are carefully maintained during feeding to ensure between 60 – 80% of the algae is consumed (Helm *et al*., 2004).

Larval rearing and spat production

Twenty four hours after fertilisation, the fertilised eggs develop into swimming, straight-hinged veligers measuring approximately 75 – 80µm. These veligers are fed with cultured algae at a concentration of approximately 30 000 algal cells/ml (Figure 21). For the first week, the larvae are fed once daily at this concentration. Algal cell count is increased to 50 000 cells/ml during the second week and 80 000 cells/ml for the third week. Larvae are fed these algal concentrations twice a day during the second and third weeks. At 20 days old, the larvae measure 250 – 300 microns in length. At this time, two or three clean oyster shells are placed near the bottom of the rearing tank and inspected daily for newly settled spat. The appearance of about 50 spat is an indication that the larvae are ready for transfer to settling tanks (Breese & Malouf, 1975). Fully grown larvae measure about 300 – 350 µm (Choi, 2008).

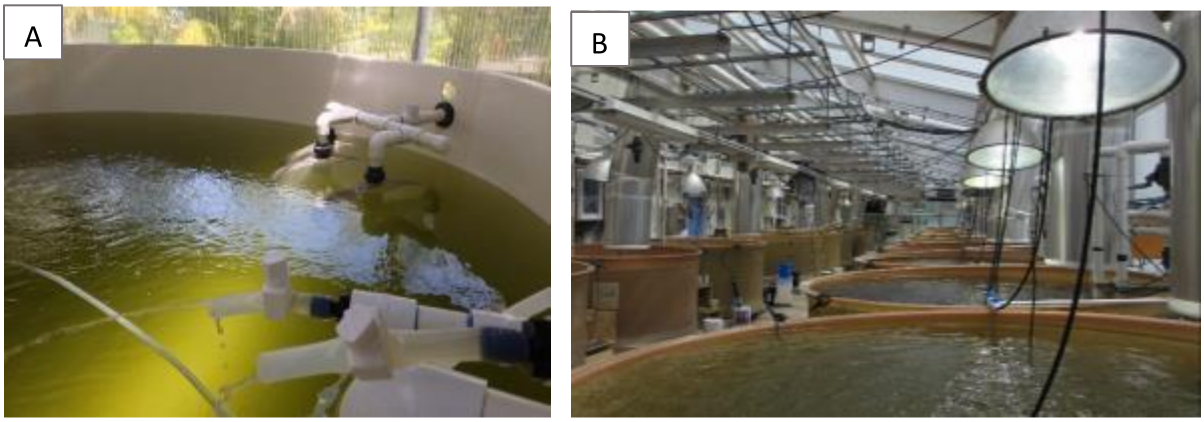


FIGURE 21: A) AN OYSTER LARVAL REARING TANK (SOURCE: MILLER AND BACKUS, 2014); AND B) ALGAL MASS CULTURE TANKS FOR SUPPLYING FEED TO OYSTER LARVAE (SOURCE: UMCES, 2016).

The larval setting period begins with the attachment of the larvae to a cultch material and extends through metamorphosis from free-swimming larvae to sedentary spat and a subsequent growth period until the spat finally leaves the hatchery as oyster seed (Helm *et al*., 2004). When the larvae are transferred to the settling tanks, the desired cultch material is added. It may consist of plastic bushel baskets filled with clean oyster shell or thin sheets of plastic for cultchless seed production. Tanks systems are used in the hatchery for the initial stages of the growth of oyster spat set on cultch (Figure 22). These may be closed systems, i.e. with a static volume of water changed two or three times per week, or open systems operated on flow-through, depending on the extent to which the water needs heating (Helm *et al*., 2004). Temperature and salinity are two important environmental factors that affect larval development. Low water temperatures and salinities slow down larval development, while higher temperatures shorten the duration of the larval period (Choi, 2008). The water temperature is increased from 25˚C – 30˚C. Algal cell concentration is established at 80 000 cells/ml and maintained by two daily feeding sessions. This feeding schedule continues until one week after setting, after which feeding is increased to between 100 000 and 150 000 cells/ml/day. The length of time the seed remains in the hatchery after setting depends on space availability, the destination of the seed and the time of the year. Prior to any move, water temperature should gradually be manipulated to avoid shock to the spat (Breese & Malouf, 1975).

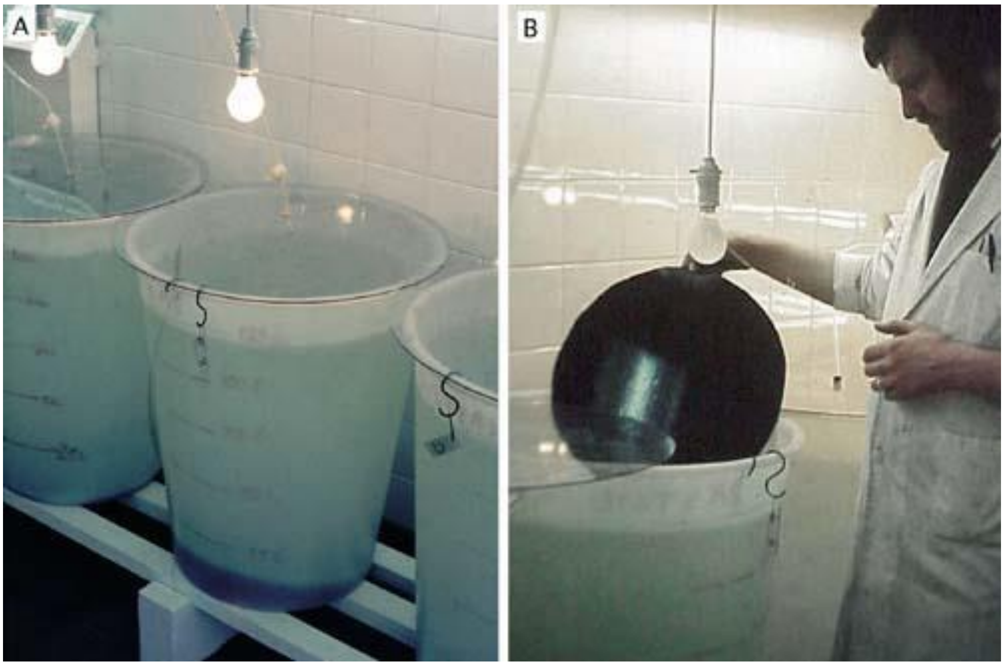


FIGURE 22: A) SPAT SETTLING TANKS ARE PROVIDED WITH A SUBSTRATE TO PROMOTE SETTLING; B) A HATCHERY TECHNICIAN CHECKS A SPAT COLLECTOR (SOURCE: HELM *ET AL*., 2004).

Nursery stage

Bivalve nurseries serve as an interface between hatcheries and the grow-out phase. They are cost efficient systems that eliminate the need for growing very small seed in fine-mesh nets. The purpose of nurseries is to rapidly grow small seed at low cost to a size suitable for transfer to grow-out trays, bags, or nets with mesh apertures of 7 – 12 mm. Larger mesh size grow-out trays are not as prone to rapid clogging and require less maintenance (Helm *et al*., 2004).

FIGURE 23: 9: 3-4MM OYSTER SEED READY FOR REARING IN A NURSERY FACILITY (SOURCE: ZWEMBESI FARMS, 2016).

Nursery systems evolved in Europe and the USA in the 1970s and early 1980s as a natural adjunct to hatcheries. They can be regarded either as the final stage in hatchery production or the first stage in grow-out. The most efficient nurseries stock seed at high density in upwelling containers (Figure 24). Others may consist of floating or submerged tray units in productive waters with or without an element of forced as against passive flow (Helm *et al*., 2004). Nursery upwelling systems circulate water upwards through the containers by air lift or pumps. Flow rate is controlled by a valve at the outlet of each upweller. An optimum flow rate through the upweller is 30 – 40mls/min/g (live weight) for oysters (Helm *et al*., 2004). Nursery spat holding containers may be mounted on rafts or barges moored in productive estuaries or saltwater lagoons (Figure 24). Others are placed in troughs adjacent to or on upwelling rafts floating in natural or artificially constructed seawater ponds. Primary production can be enhanced in ponds and lagoons by the application of natural or artificial fertilizers to encourage blooms of algae, usually of naturally occurring species. In this respect, they are more amenable to management than sea-based nursery systems because the quantity and to some extent the quality of the available food supply can be manipulated and controlled (Helm *et al*., 2004).

Nursery production may also include longline culture in small-meshed baskets suspended off longlines in sheltered bays or abandoned mining dams or salt work ponds. This is the most frequently used in South Africa.

FIGURE 24: EXAMPLES OF LAND-BASED NURSERY UPWELLING SYSTEMS (SOURCE: BLUE STAR OYSTER CO., 2016).

Grow-out and harvest

Grow-out is almost entirely sea-based and utilises a variety of bottom, off-bottom and suspended culture methods, depending on the environment (e.g. tidal range, shelter, water depth, water exchange rates in bays and estuarine inlets, the nature of substrates, etc.) (FAO, 2005).

Growth and survival of Pacific oysters depends largely on environmental conditions and variations in yield are attributed to mortality (Dégremont *et al*. 2005).

- ***Bottom culture***

Seed can be sown on suitably firm intertidal or sub-tidal ground, which may be hardened by the pre-application of shell or gravel, at densities of 200 – 400/m² when 1 to 2 g live weight, with predator-proof protection (fences or net covers). Alternatively, they can be sown without protection at ~200/m² when 10 g live weight. The objective is to sow at densities that will require no further husbandry until the oysters reach marketable size (Garrido-Handog, 1990; FAO, 2005) (Figure 25). This method is cheap and can be cost effective but is limited to firm-bottomed shallow waters and high mortalities may result in a siltation event and through predation (Garrido-Handog, 1990).

FIGURE 25: OYSTERS FARMED USING THE BOTTOM CULTURE METHOD (SOURCE: AFCD, 2015).

- ***Off-bottom culture***

Seed are contained in mesh bags or perforated plastic trays of various types attached by rope or rubber bands to wood frame or rebar steel trestles on suitable ground in the low intertidal zone (Figure 26). Such systems are sometimes located sub-tidally but this adds to handling costs. Off-bottom culture may be used for the intermediate nursery phase of growth or as a method to grow product to market size. 10 – 15 mm seed can be stocked at 1 000 – 2 000 per 0.25 or 0.5 m^2 base area trays and need regular maintenance and servicing to transfer at lower density to clean bags/trays of increasing mesh size as they grow. Growth rate slows substantially once the biomass of oysters exceeds 5 kg/m^2 tray area in reasonably productive areas (Garrido-Handog, 1990; FAO, 2005). While costs of off-bottom culture exceed those of bottom culture, growth rate is rapid and production per unit area is higher (Garrido-Handog, 1990).

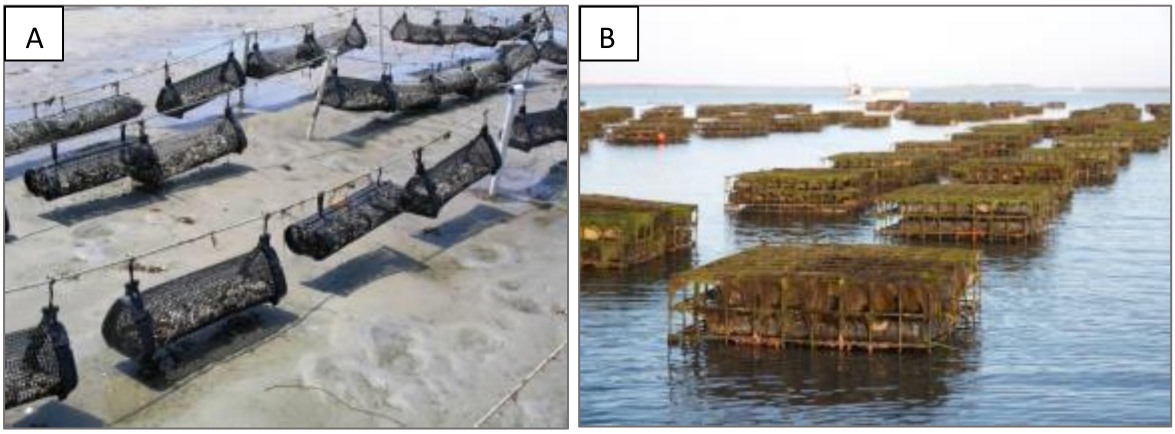


FIGURE 26: OFF-BOTTOM CULTURE METHODS FOR PACIFIC OYSTER PRODUCTION (SOURCE: A: NOAA FISHERIES, 2015; B: PANGEA SHELLFISH, 2015).

- ***Suspended culture***

Oyster production units are suspended from longlines (most commonly used) or from rafts.

The basic long-line system comprises a series of ropes, typically 100-150m long, that are anchored with mooring blocks of 3-5T at each end. The rope is usually 40-42 mm diameter polysteel that is suspended in the water column by large buoys (at each end of the rope). In order to ensure that the line remains floating in the water column, additional floats are placed every 5-6m along the line or wherever nets are suspended off the longline. Most operators use square/pillow shaped HDPE nets (in stacks of 4 or 5), lantern nets, or circular plastic stacking/interlocking basket-type nets. Nets are rigged at intervals of 1.5m along the longline using rope or clips. Mesh size of the baskets or nets varies depending on the growth stage. At the nursery stage mesh size is typically 6mm which increases to 20mm for grow-out production.

Regular maintenance and servicing is required, to transfer growing oysters at lower density to clean nets/trays of increasing mesh size as they grow (Garrido-Handog, 1990; FAO, 2005).

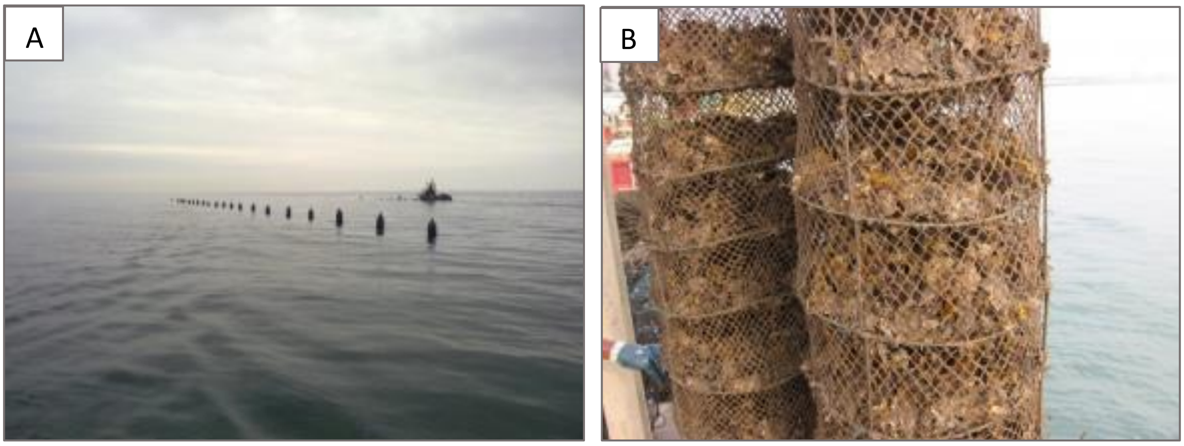


Figure 27: A) An oyster longline in Algoa Bay, Port Elizabeth, South Africa (Source: Zwembesi Farms, 2016); B) oysters stocked into lantern nets which are suspended off longlines (Source: Zwembesi Farms, 2016).

Oysters are harvested by hand in bottom culture, while boats or barges are used to harvest oysters cultured in off-bottom or suspension systems (Figure 28). These barges are often equipped with washing/cleaning machinery to prepare the oysters for processing (FAO, 2005).

Figure 28: Oysters cultured using baskets suspended off longlines are harvested at sea in Algoa Bay, Port Elizabeth (Source: Zwembesi Farms, 2016).

Depuration

Bivalve molluscan shellfish concentrate contaminants from the water column in which they grow, potentially causing illness to humans when the product is eaten (Lee *et al*., 2008). In order to avoid this, oysters undergo a post-harvest process known as depuration during which they are held in tanks of clean seawater under conditions that maximise the natural filtering activity of the organism, resulting in expulsion of potential contaminants, specifically faecal contaminants, housed in the intestines (Lee *et al*.,

2008) (Figure 29). Depuration is not undertaken for oysters grown in pristine water that is free of faecal coliforms (FAO, 2005).

FIGURE 29: OYSTERS HELD IN TANKS SUPPLIED WITH FILTERED SEAWATER FOR DEPURATION (SOURCE: DUONG, 2013).

4.2.5. Environmental impacts

The environmental impacts of bivalve farming, including oysters and mussels, can be broadly classified into three main categories: effects on the seabed, effects on the water column and effects on marine life (Keeley *et al*., 2009). The impacts are briefly discussed below:

- ***Impacts on the seabed***

Potential effects include enrichment of seabed sediments in the vicinity of bivalve farms, accumulation of shell debris and litter beneath the site, and aggregations of echinoderms (Gallagher *et al.*, 2008) and epifauna in the immediate and near vicinity. Enrichment of seabed sediments may result in enhanced localised productivity and alterations in the composition of sediment dwelling fauna with a shift towards more abundant smaller taxa (Hartstein & Rowden, 2004; Keeley *et al*., 2009).

Impacts are most pronounced directly underneath the site. Effects can be minimised by locating the farm in well-flushed areas (Keeley *et al*., 2009).

- ***Impacts on the water column***

Physical impacts from bivalve production structure itself include a localised reduction in current speed which may affect biological processes and water residence times (Keeley *et al.*, 2009). However, this is probably only important in areas where development has advanced to a very large scale. Despite hypothesised impacts on phytoplankton growth, and altering of phytoplankton and zooplankton species composition, there is little documented research to suggest that these impacts are significant (Keeley *et al*., 2009).

- ***Impact on marine life***

The development of bivalve farming structures may impact seabirds and marine mammals, specifically through entanglement (Wursig & Gailey, 2002), habitat creation and modification, and habitat exclusion (Keeley *et al*., 2009). In New Zealand, an adult Brydes whale was fatally entangled in mussel lines (Wursig & Gailey, 2002). This is, however, the only incident of its kind reported in that country where mussel farming is well developed and a risk assessment exercise conducted by Keeley *et al* (2009) deemed the overall entanglement risk to be low.

Bivalve farms may function as artificial "reefs" providing food, refuge, and breeding habitat. Consequently, marine life, including seabirds, mammals, and fishes, will aggregate around these organisms and the increased abundances of fish in particular may affect fishing pressure and behaviour (Keeley *et al*., 2009).

4.2.6. Diseases and parasites

Pathogens, predators, environmental changes, spatial and trophic competition, and toxic algal blooms are the most common causes of mass mortality in oysters (Mackin, 1961 in Dégremont *et al*. 2007). In contrast to other aquaculture oysters, and despite its widespread distribution around the world, there are relatively few disease problems of major significance for the Pacific oyster (FAO, 2005).

Summer mortality of *C. gigas*, first reported in France in the early 1980's, has been reported for many years in Japan and the United States (Koganezawa, 1975; Glude, 1975 in Dégremont *et al*. 2007). In France, mortality events among adults typically occur during spring, while among juveniles, events are more prevalent during summer (Fleury *et al*., 2001 in Dégremont *et al*. 2007).

In most cases, mass mortality events cannot be explained by a single factor and a combination of environmental (biotic and abiotic) and internal (i.e., genetic, physiological and immunological) parameters is likely to be more plausible (Dégremont *et al*. 2007).

A comprehensive summary of the major diseases and parasites, symptoms and treatments/measures, adapted from Elston and Wilkinson (1985), Boettcher *et al*. (2000), FAO (2005), ICES (2010) and ICES (2011) is shown in Table 10.

TABLE 10: SUMMARY OF PACIFIC OYSTER DISEASES AND PARASITES.

Disease	Type	Agent	Symptoms	Treatment/Measures
Denman Island Disease	Protozoan parasite	*Mikrocytos mackini*	Tissue necrosis (lesions form), mortalities	Restricted modified culture practices
MSX disease	Parasite	*Haplosporidium nelsoni*	Reductions in shell growth, meat quality and reproductive capabilities, mortalities	Maintaining oysters at reduced salinities (<15 ppt), Particle filtration (1-µm cartridge filter) and UV irradiation
Dermo disease	Parasite	*Perkinsus marinus*	Reduced feeding, growth, reproduction and mortalities	Biosecurity, selective breeding, particle filtration (1-µm filters) and UV irradiation of water coming into or exiting hatcheries
Juvenile	Bacterium	α-proteobacteria	Reduced growth	Oysters maintained in 25

Disease	Type	Agent	Symptoms	Treatment/Measures
oyster disease		*Roseobacter* group (designated CVSP)	rate, development of fragile and uneven shell margins, cupping of the left valve and mortalities	µm filtered water diluted with high salinity well water. The reduction of stocking densities within growing trays, increased flow rate in up-wells and mesh size of 6 mm or greater in grow-out containers.
Pacific Oyster Mortality Syndrome	Virus (OsHV-1 micro variant)		Mortalities	Temperature control
Nocardiosis	Bacterium	*Nocardia crassostreae* (Actinomycete bacteria)	Reduced thermotolerance, lesions and mortalities	Modified culture practices
Herpes-type virus disease of C. gigas larvae	Virus	Ostreid Herpes Virus type 1	Digestive organ of oyster changes in to white colour, reduced feeding, lesions and mortalities	Temperature maintenance below 27 ˚C and operational control
Oyster velar virus disease (OVVD)	Virus		Blister formation and mortalities	Biosecurity, destruction of infected larval groups and sterilization of associated equipment,
Gill disease of Portuguese Oyster	Virus	Icosahedral DNA virus	Extensive gill erosion corresponding with high mortalities. Initial clinical signs of yellow spots on the gills progress to brown discolouration with associated necrosis and degeneration leaving a perforation or V-shaped indentation if the lesion occurred on the edge of the gill. Yellow or green pustules may also occur on the mantle or adductor muscle.	No known methods of prevention or control.
Haemocytic infection virus (HIV) disease of oysters	Virus	Icosahedral DNA vir us	Mass mortalities	No known methods of prevention or control
Extracellular	Prokaryotic		Disappearance of	No known methods of

Disease	Type	Agent	Symptoms	Treatment/Measures
giant "Rickettsiae" of Oysters	organism		apical microvilli and cilia with concomitant lysis of gill epithelial cells. Multiple tumor-like growths on the gill lamellae.	prevention or control

5. GEOGRAPHIC LOCATION AND SUITABILITY

The evaluation criteria for selecting the ideal site for an aquaculture operation relate principally to the environmental requirements of the species to be farmed and other bio-physical and economic factors that determine the practicality and the economic feasibility of a particular site. While water temperature can be completely (at a high cost) or partially controlled in land-based aquaculture systems, the selection of a site with optimal seasonal water temperature profiles that fit the optimal thermal requirements of the candidate species is a distinct natural strategic advantage. Other factors that determine the suitability of a land-based site include water quality, proximity to water supply, the nature of the shore (rocky or sandy), proximity to heavy industry (petro-chemical, steel, shipping), proximity to large rivers and river discharge, proximity to transport infrastructure and electricity, slope, the potential impact on the terrestrial ecosystem and possible user conflict with other shore-based human activities (real estate, recreation, tourism, Marine Protected Areas). Factors that determine the suitability of offshore-based aquaculture systems relate primarily to water temperature, water quality, current, wave action and significant wave heights, the presence of HABs and, similarly to land-based systems, proximity to markets and infrastructure and conflicts with other user groups.

A rapid assessment exercise was conducted to provide an overview of the key criteria and site requirements for mussel and oyster aquaculture. As production is land- and/or offshore-based, key location and site requirements are detailed for both. The exercise did not allow for detailed site visits in different locations to determine their suitability. As a result, the areas selected and the maps provided are purely indicative.

5.1. Mediterranean mussels

5.1.1. Production system: Offshore rafts or longlines

TABLE 11: CRITERIA FOR MEDITERRANEAN MUSSEL SITE SELECTION.

Site selection parameters	Criteria
Exposure to waves	Limited. Must be located in a sheltered bay.
Water temperature	Temperature range 7-24°C; 10-20°C optimal
Water quality	Salinity range 5-40‰ – 15-25‰ optimal; preferably located outside of areas with known HABs; pollutant-free water

Food availability	Ideally located in nutrient-rich waters with significant natural algal production
Logistics	Located close to transportation network

The following broadly-defined regions were identified as suitable for offshore-based raft and longline culture of Mediterranean and black mussels:

FIGURE 30: POTENTIAL REGIONS FOR OFFSHORE-BASED MUSSEL PRODUCTION IN SOUTH AFRICA.

In southern Africa, Mediterranen mussels are distributed along the entire west coast (Western Cape and Northern Cape coastlines) and the southern coast (Western Cape and Eastern Cape coastlines) up to East London (Viladomiu, 2004). Mussel aquaculture is reliant on sheltered areas that are not exposed to high-energy wave patterns. Furthermore, production is only feasible where growth is rapid due to naturally-occurring and dense nutrient concentrations. For these reasons, the areas suitable for mussel aquaculture are limited in South Africa, despite the distribution of the Mediterranean mussel along the west and southern coastlines. Saldanha Bay is the optimal site as it provides both shelter as well as nutrient-rich waters (see Figure 30). Furthermore, it is supplied by a well-connected transport network and bulk services. North of Saldanha, opportunities are highly limited as there are few stretches of coastline which are unexposed to potentially destructive wave patterns. Along the southern coast, nutrients are more limited than in west coast waters and therefore growth is significantly slower. This is supported by the fact that, initially, the mussel aquaculture industry was based in Port Elizabeth but, due to poor growth, was relocated to Saldanha Bay. There may be marginal opportunities for mussel aquaculture in Mossel Bay. Therefore, Saldanha Bay is the hotspot for mussel aquaculture in South Africa (Figure 30).

5.2. Pacific oysters

5.2.1. Land-based production

Production system: Pond-based nursery-phase grow-out of oysters

TABLE 12: CRITERIA FOR PACIFIC OYSTER SITE SELECTION.

Site selection parameters	Criteria
Water supply	Constant supply of seawater; pump-ashore or from a beach well
Water temperature	Temperature range 5-35°C; 11-34°C optimal
Water quality	Salinity range 10-35‰ – 20-25‰ optimal; preferably located outside of areas with known harmful algal blooms (HABs); pollutant free
Elevation	Located as close as possible to sea level to reduce pumping costs
Food availability	Water of a sufficient quality to encourage phytoplankton blooms
Estuaries	Located away from river mouths/estuaries which may lower salinity levels and increase turbidity
Logistics	Located close to transportation network for transport to grow-out facilities

The following regions were identified as potentially suitable for pond-based nursery-phase grow-out of Pacific oysters:

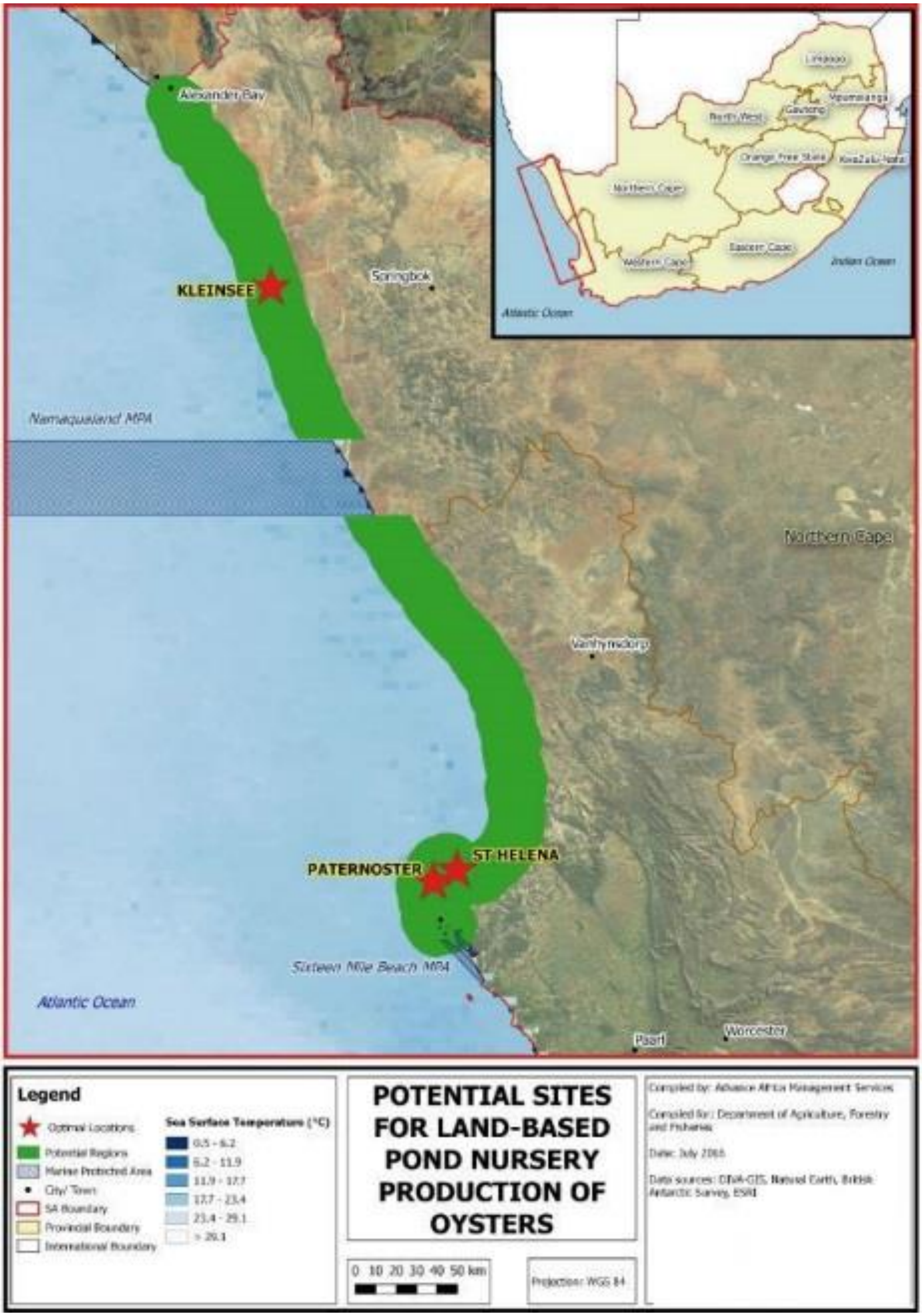


FIGURE 31: POTENTIAL REGIONS FOR POND-BASED NURSERY-PHASE GROW-OUT OYSTER PRODUCTION IN SOUTH AFRICA.

Optimal areas for pond culture are located on the West Coast of South Africa north of Saldanha Bay. These areas include Kleinsee, St Helena Bay, and Paternoster. The presence of abandoned mining dams and salt works may provide a suitable environment for an oyster nursery. However, pumping costs may be prohibitive depending on the sites elevation as water has to be pumped ashore into the dams. Beach wells may provide a viable source of water for areas which are prone to HABs.

On the east coast, areas for the development of a pond-based oyster nursery are marginal. Constructing ponds for nursery-phase oyster culture is expensive and, unlike the west coast, there are few abandoned salt works or mining dams in this region of the South Africa.

5.2.2. Estuarine-based production

Production system: Intertidal rack culture

TABLE 13: CRITERIA FOR PACIFIC OYSTERS SITE SELECTION FOR ESTUARINE-BASED NURSERY AND GROW-OUT OYSTER PRODUCTION IN SOUTH AFRICA.

Site selection parameters	Criteria
Water supply	Permanently open estuaries; preferably not prone to major flooding events and siltation
Water temperature	Temperature range 5-35°C; 11-34°C optimal
Water quality	Salinity range 10-35‰ – 20-25‰ optimal; pollutant-free
Food availability	Ideally located in nutrient-rich waters with consistent natural algal production.
Logistics	Located close to transportation network for transport to grow-out facilities

Potentially suitable estuarine areas for nursery-phase and grow-out production of Pacific oysters are shown in Figure 32.

The Knysna River estuary (Western Cape), Kowie- , Swartkops- and Keiskamma River (Eastern Cape) estuaries have had some aquaculture farming taking place in the past with varying degrees of success. However, most of South Africa's other estuaries are typically restricted due to South Africa's environmental laws and their role as nurseries to fisheries. In theory, there are a number of permanently open Eastern Cape estuaries which are potentially suitable for oysters. However, the steep slope of the plateau along the Transkei coast, plus the large catchment of some of the larger rivers, typically lends itself to flash-flooding which is highly unsuitable for oyster farming (David Krebser, personal communication, June 2016). In the Western Cape, the Langebaan Lagoon is the only estuarine environment suitable for oyster cultivation (David Krebser, personal communication, June 2016).

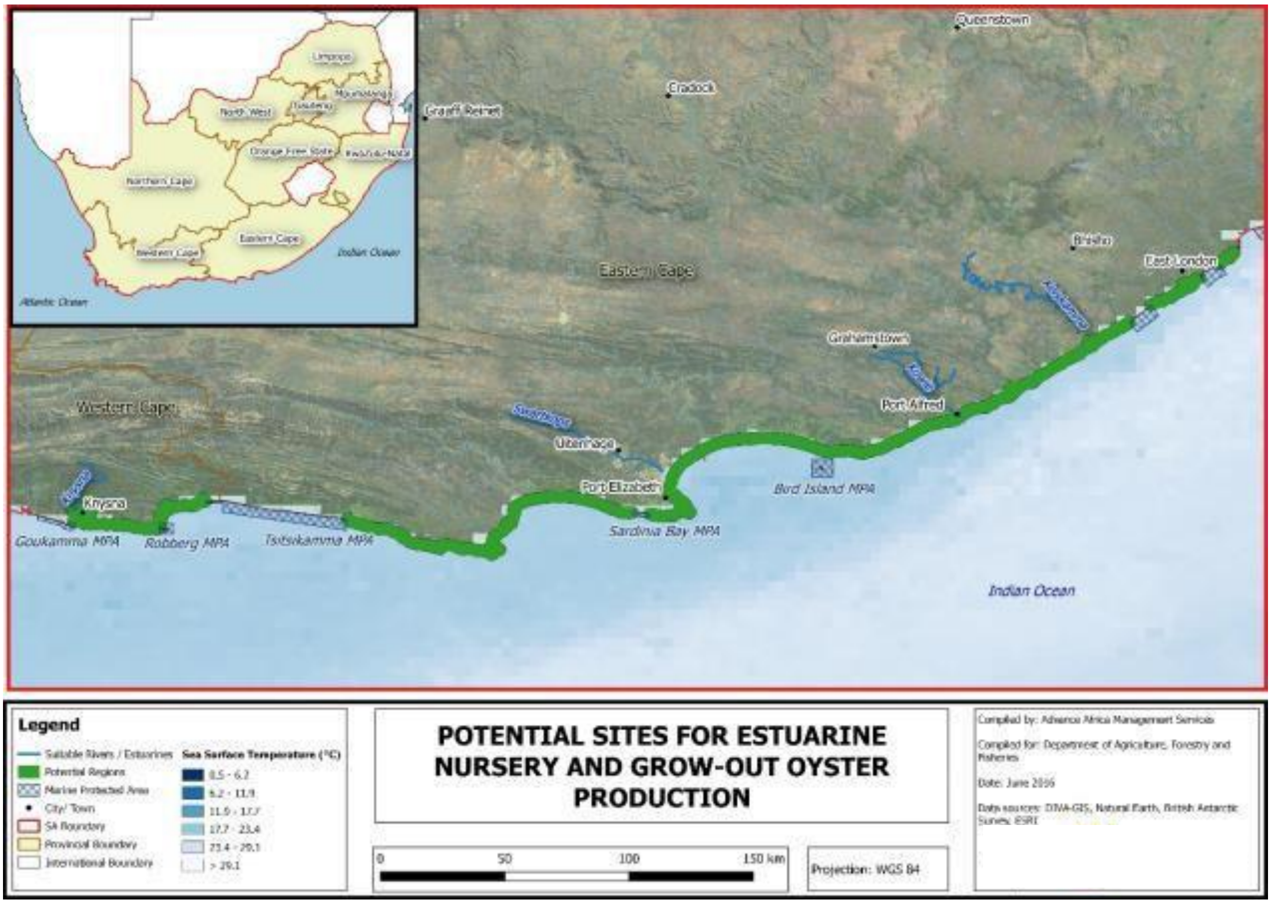


FIGURE 32: POTENTIAL REGIONS FOR ESTUARINE-BASED NURSERY AND GROW-OUT OYSTER PRODUCTION IN SOUTH AFRICA.

5.2.3. Offshore-based production

Production system: Longlines

TABLE 14: CRITERIA FOR PACIFIC OYSTER SITE SELECTION FOR OFFSHORE NURSERY-PHASE AND GROW-OUT.

Site selection parameters	Criteria
Exposure to waves	Limited. Ideally located in a sheltered bay.
Water temperature	Temperature range 5-35°C; 11-34°C optimal
Water quality	Salinity range 10-35‰ – 20-25‰ optimal; pollutant-free
Food availability	Ideally located in nutrient-rich waters with consistent natural algal production
Logistics	Located close to transportation network

The following broadly-defined regions were identified as suitable for offshore nursery-phase and grow-out production of Pacific oysters:

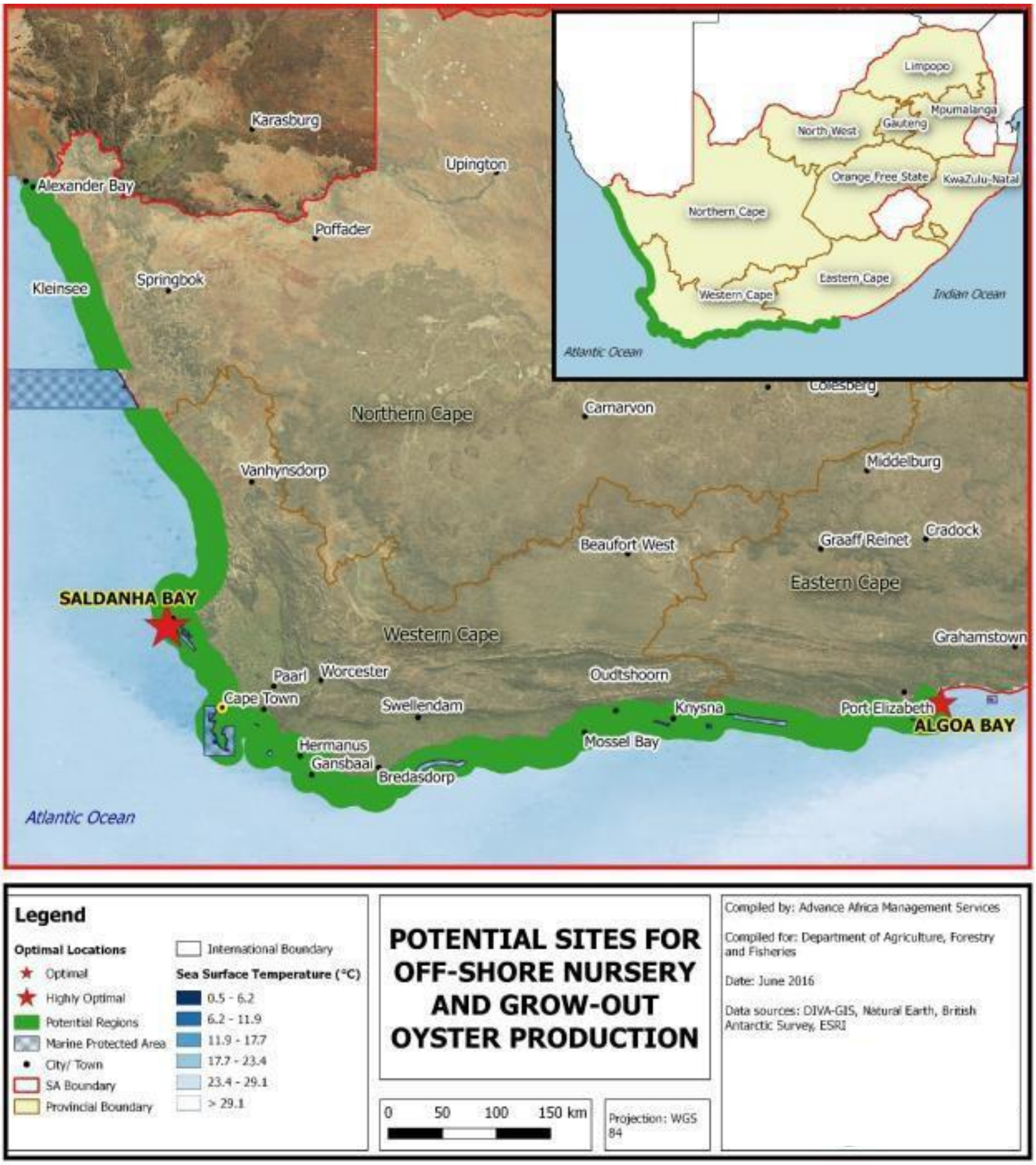


FIGURE 33: POTENTIAL REGIONS FOR OFF-SHORE NURSERY AND GROW-OUT OYSTER PRODUCTION IN SOUTH AFRICA.

Algoa Bay and Saldanha bay are currently being used as nurseries for oysters in South Africa. Algoa Bay is a highly variable site due to high summer water temperatures and highly variable phytoplankton levels. As a result, there has been success and failure with nursery-phase production of juvenile oysters (Pieterse *et al*., 2012). Unreliable phytoplankton levels can result in very poor growth rates and, coupled with high summer water temperatures, this may lead to mortalities (Pieterse *et al*., 2012). It is therefore regarded as a marginal area for nursery-phase oyster production.

Saldanha Bay can be regarded as a favourable area for nursery-phase oyster production as phytoplankton levels are higher and more consistent than Algoa Bay (Pieterse *et al*., 2012). Consequently, mortalities are far lower as there is no negative interaction between decreased phytoplankton levels and high summer water temperatures as experienced in Algoa Bay. In particular, the inner bay at Saldanha is highly favourable due to its accessibility which allows regular grading and cleaning.

Saldanha Bay is the optimal location for grow-out of oysters in South Africa. It is situated adjacent to a rich upwelling system with high phytoplankton abundance (Olivier *et al*., 2013). Growth rates and meat quality are higher in Saldanha Bay than other oyster production areas such as Algoa Bay and Kleinzee on the west coast (Pieterse *et al*., 2012). These areas are less optimal in that growth and meat quality are lower but are still suitable for oyster culture in South Africa. On a broader level, the west coast offers more favourable conditions for oyster culture than the east coast.

Logistically, Saldanha Bay is in close proximity to the large Western Cape market although Algoa Bay is closer to an airport (Port Elizabeth) and, therefore, export is somewhat simpler from this location.

6. MARKET ASSESSMENT

Forecasts of global demand for fishery products suggest that aquaculture output will need to increase to meet the projected demand. Most capture fisheries are at or near their potential production limits (FAO, 2016). Demand for food (and food fish) is primarily determined by four variables: demography, living standards, urbanisation, and price.

6.1. Bivalve production and market – A global overview

Global production of bivalves includes oysters, clams (including cockles and arkshell), scallops, and mussels. Trade in bivalve species between developing countries and major markets has not developed as well as trade in other seafood products (WHO, 2010). This is mainly due to public health concerns. Importing countries enforce strict regulations on live, fresh, and frozen bivalves which many developing countries are unable to meet. In 2005, under the EU import regulations on bivalves, only a third of the world countries were authorised to export their bivalves to EU markets (WHO, 2010). From Asia, only Japan, the Republic of Korea, Thailand and Vietnam are currently qualified to export their bivalves to the European community. Conversely, in regard to other general seafood products, almost all major seafood producers in Asia have been approved by the EU authorities.

6.1.1. Global aquaculture production

The global distribution of aquaculture production (not bivalve-specific) across regions and countries of different economic development levels remains imbalanced (FAO, 2016). In 2010, the top ten producing countries accounted for 87.6% by quantity and 81.9% by value of the world's farmed food fish. In 2010, Asia accounted for 89% of world aquaculture production, and this was dominated by China, which accounted for more than 60% of global aquaculture production in 2010 (FAO, 2016). The situation for mussels and oysters is considerably different and explored in the sections which follow.

Mussels

The majority of mussel data is available from European Union (EU) member states. On a global scale, Europe is a major producer of mussels, supplying over a third of the total production. The blue mussel (*Mytilus edulis*) and Mediterranean mussel are the two main species harvested and cultivated (FAO, 2015a). The total production of mussels in Europe peaked at nearly 750 000 tonnes in the late 1990's and has since declined to approximately 550 000 tonnes in the past few years, since 2008. Aquaculture production of mussels accounts for 90% of total global mussel production.

The European market size for mussels is estimated to be slightly below 600 000 tonnes, of which 500 000 tonnes is of domestic origin and about 100 000 tonnes of international origin (net balance import-export) (FAO, 2015a). The popularity of mussels differs from country to country; per capita consumption varies from less than 200 g to nearly 4 kg (FAO, 2015a). Spain, France and Italy make up 78% of total consumption (FishStatJ, 2016).

Of the 500 000 tonnes produced each year in the EU, Spain is the largest producer (over 200 000 tonnes per year) followed by France (80 000 tonnes per year) and Italy (65 000 tonnes per year) (Kumar, 2015). Intra-EU trade in mussels is extensive but imports into the EU are also substantial. The largest importers of mussels in the EU are France, Italy, Belgium and the Netherlands (although Netherlands mainly processes its imports and then re-exports).

Mediterranean Mussels

Total global production of the Mediterranean mussel is shown in Figure 34. In 2014, 209 363 tonnes of Mediterranean mussels were produced. Italy, France and Greece are the major producers of this species (Figure 34).

These countries produce sufficient volumes to meet consumer needs and also export to interested markets. In 2013, France and Italy exported 8 053 tonnes and 12 799 tonnes of *Mytilus* spp. respectively (FishstatJ, 2016).

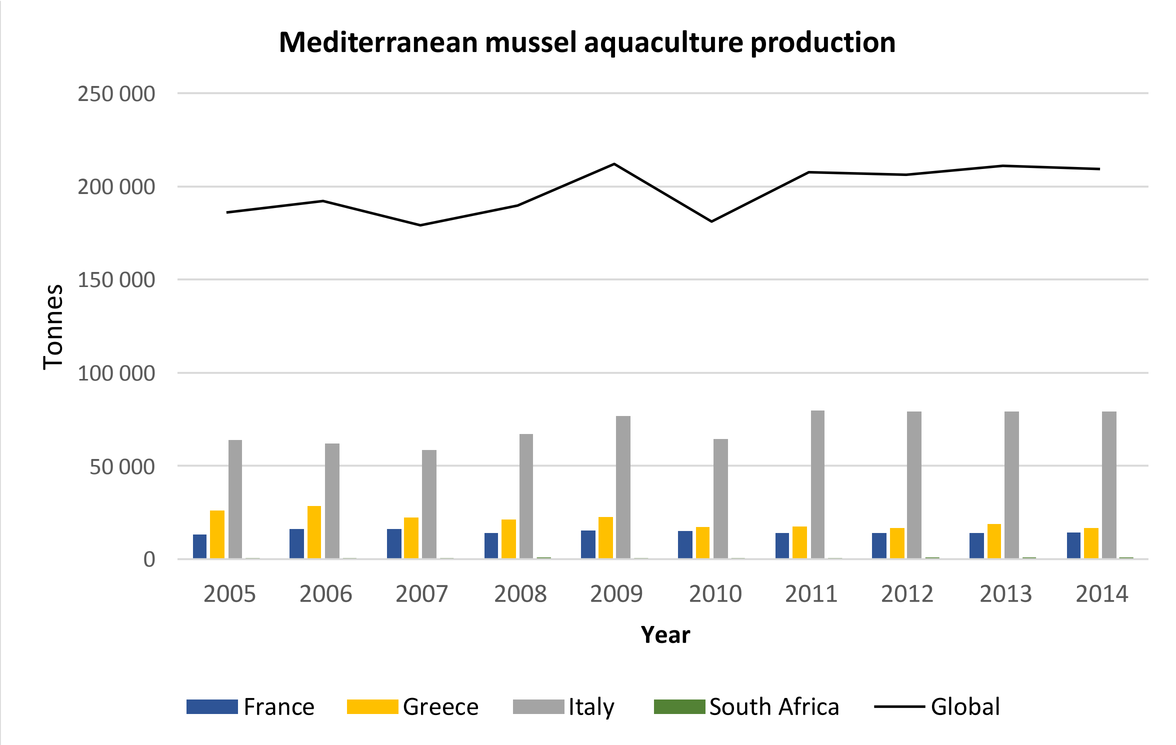


FIGURE 34: GLOBAL MEDITERRANEAN MUSSEL AQUACULTURE PRODUCTION AND THE MAJOR PRODUCING COUNTRIES (SOURCE: FISHSTATJ, 2016).

Pacific Oysters

Global production of the Pacific oyster has exceeded that of any other oyster species and continues to expand, with major producing countries including China, Japan, Korea, the United States, France, European states, Australia, New Zealand and South Africa. Global production amounted to 633 542 tonnes in 2014 (FishStatJ, 2016). The leading producers are the Republic of Korea, Japan and France.

Much of the production is consumed by local markets and is only imported when there is a surplus. The preferred product form is fresh and on the half shell, while canned, frozen and vacuum-packed forms are less common (Heinonen, 2014).

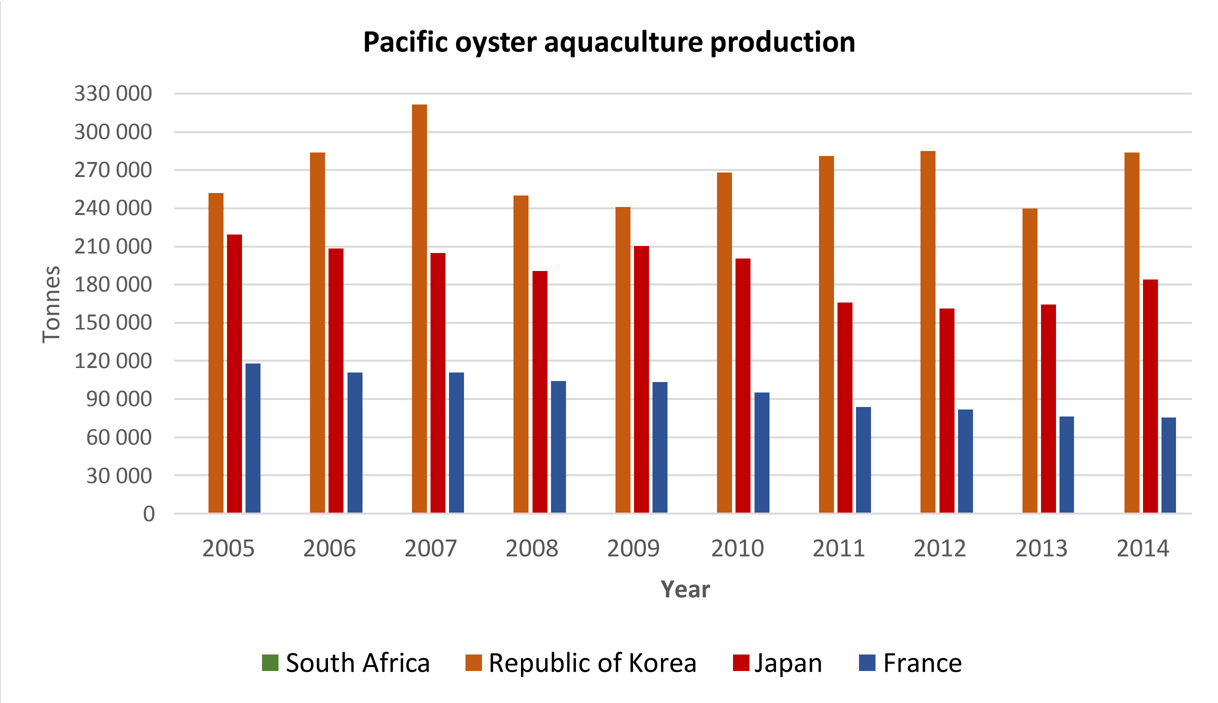


FIGURE 35: MAJOR PRODUCING COUNTRIES OF PACIFIC OYSTERS (FISHSTATJ, 2016).

6.1.2. Global capture fisheries

Mussels

Capture fisheries production of Mediterranean mussels has declined significantly since 2005 and is insignificant compared to the large volumes produced by aquaculture. Turkey used to dominate capture fisheries for Mediterranean mussels but has substantially reduced the volumes of harvested mussels since 2009 (Figure 36).

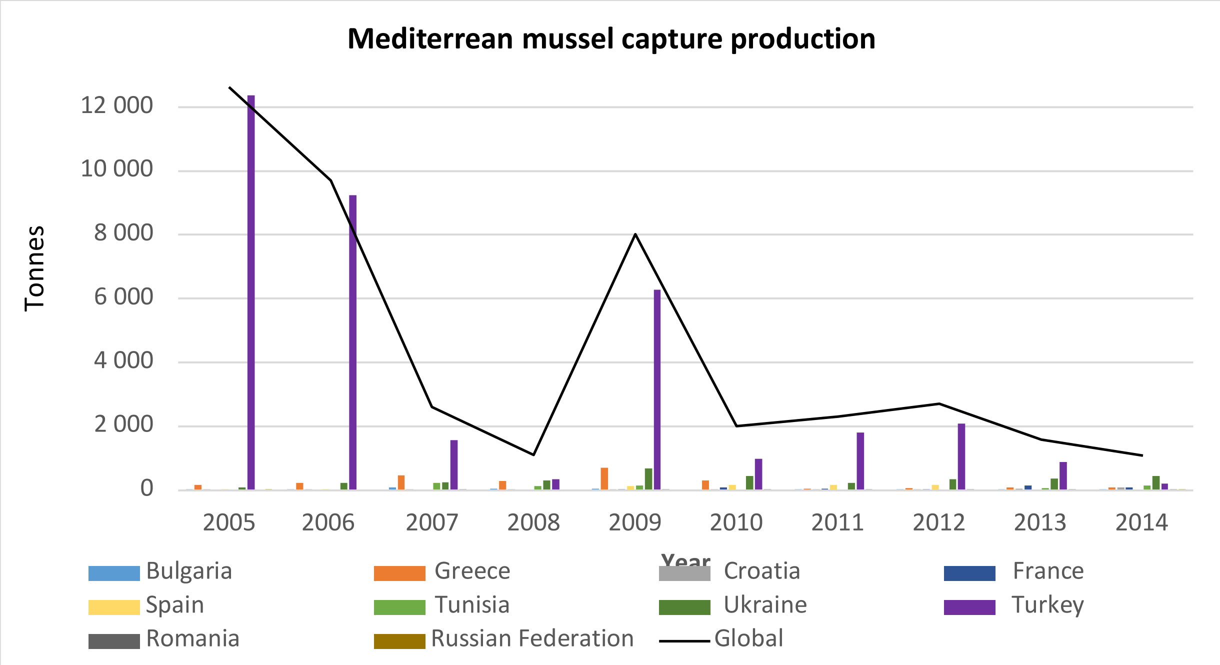


Figure 36: Global fisheries production of Mediterranean mussels and the major contributing countries (source: FishStatJ, 2016).

Pacific oysters

The Republic of Korea (South Korea) dominates capture fisheries production of Pacific oysters, followed by the United States, with far smaller contributions by the UK, Spain, Portugal, France, and New Zealand. (Figure 37).

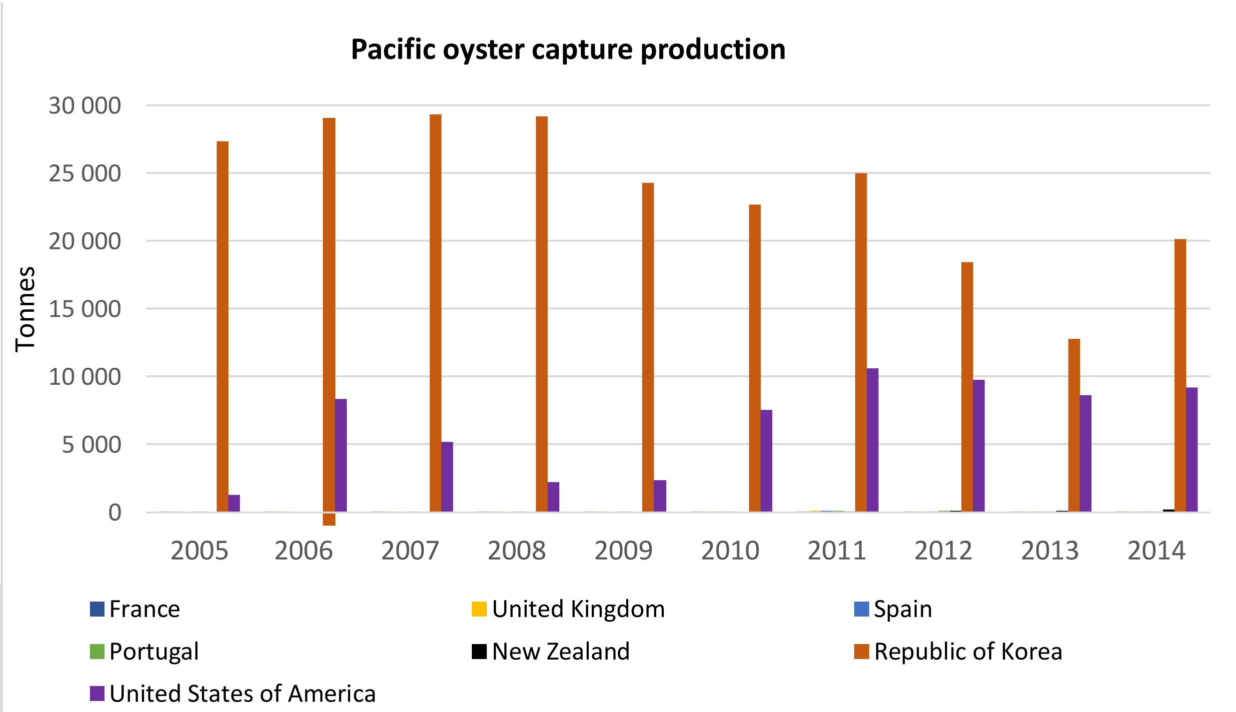


Figure 37: Major contributing countries to Pacific oyster capture fisheries (Source: FishStatJ, 2016).

6.1.3. Price and demand

International Pacific oyster and Mediterranean mussel prices vary dependent on grading, product form and demand (Table 15). Pacific oyster prices vary widely from 4.39-18 USD/kg whereas the mussel is more consistently priced at approximately 2 USD/kg. Most of the available information is based on European prices.

TABLE 15: EUROPEAN BIVALVE PRODUCT PRICES (SOURCE: FAO, 2015B).

Species	Product Form	Grading	EUR/kg	USD/kg	Market location	Origin
Pacific oyster	Live	60-80 g/pc	4.00	4.39	France prod. Price/average export price	Ireland/France
		60-100 g/pc	16.56	18.16*	Spain: *Cost, Insurance & Freight*	Netherlands
						Italy
Mediterranean mussel	Live rope	60-80pc/kg	2.00	2.19*	Spain: *Cost, Insurance & Freight* France wholesale	Spain
	Fresh	20-25 pc/kg 25-30 30-40 40-70	No prices available		Spanish market: *Ex Works*	Spain
			1.22 1.15	1.26 1.34	Italy	Spain/Italy
	Fresh-whole	Shell on	1.15 1.77 2.09 2.08 -	1.26 1.94 + 2.29 2.28 +	*Free carrier* *Carriage paid to* *Free carrier* *Carriage paid to*	Spain

+ Price increases in original currency since last report; - Price decreased in original currency since last report; Updated but unchanged price*

The increasing value of the Pacific oyster is illustrated in Figure 38. With gradually decreasing production, value has continued to increase.

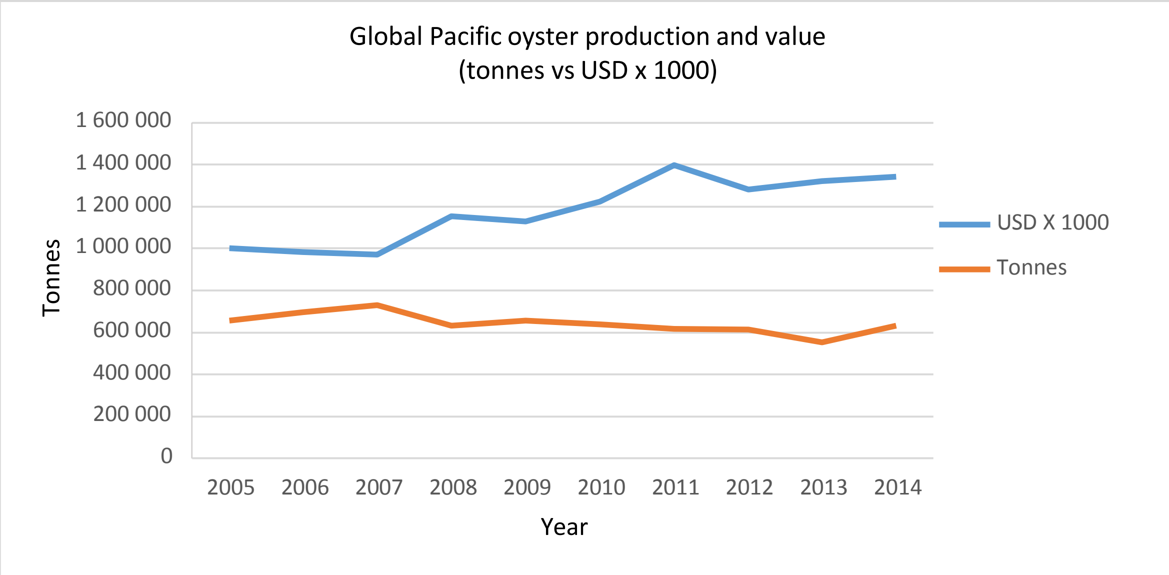


FIGURE 38: GLOBAL PACIFIC OYSTER PRODUCTION AND VALUE (SOURCE: FISHSTATJ, 2016).

6.2. South African bivalve production and market

The production of mussels and oysters has been comprehensively discussed in Sections 1.3, 4.1 and 4.2. Essentially, mussels are the second biggest contributor to total mariculture production at 37.4% and oysters contributing less at 9.3% (DAFF, 2014a). Capture fisheries are significantly less than production through aquaculture and are primarily limited to subsistence and recreational fisheries.

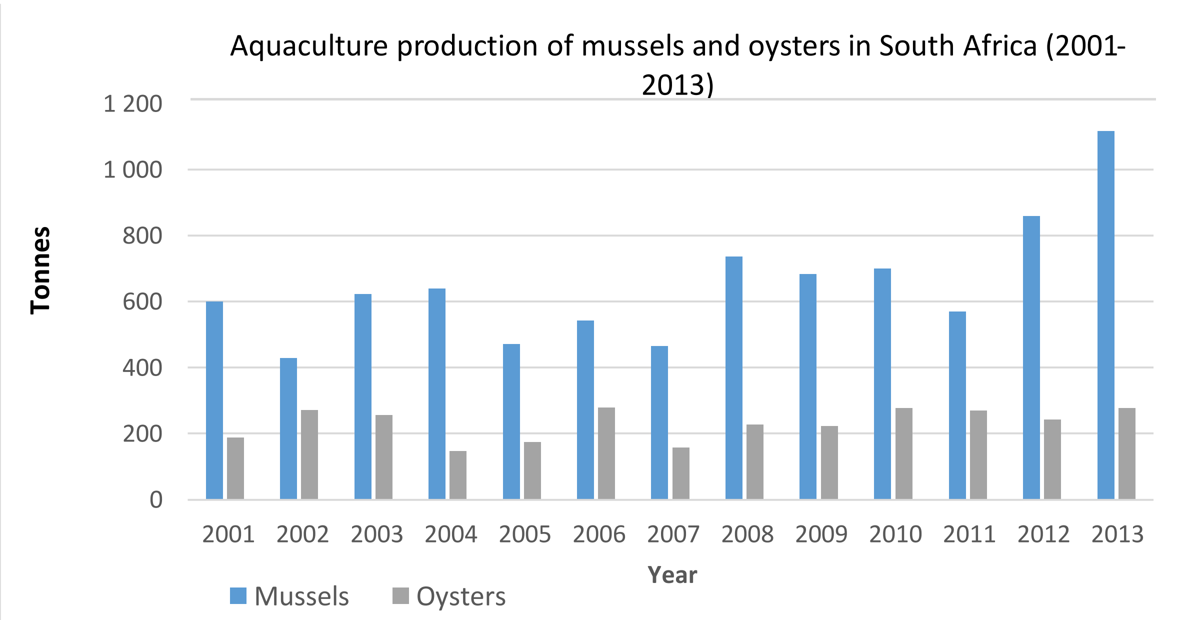


FIGURE 39: AQUACULTURE PRODUCTION OF MUSSELS AND OYSTERS IN SOUTH AFRICA (2001-2013) (SOURCE: DAFF, 2014A).

6.2.1. Price and demand

The wholesale prices for mussels and oysters in South Africa is shown in Table 16.

TABLE 16: WHOLESALE PRICES FOR MUSSEL AND OYSTERS IN SOUTH AFRICA.

Species	Product form	Price	Source
Mussels	Fresh, live	ZAR 19.95/ kg	Kaiser EDP & Enviro-fish Africa (2011)
	Frozen, half shell	ZAR 26 - 28/ kg	Kaiser EDP & Enviro-fish Africa (2011)
	Frozen, full shell	ZAR 28/ kg	Kaiser EDP & Enviro-fish Africa (2011)
	Mussel meat	ZAR 12/ kg	
Oysters	Cocktail	ZAR 5.50 /oyster	
	Champagne	ZAR 6.10 /oyster	
	Medium	ZAR 6.55 /oyster	
	Large	ZAR 7.50 /oyster	
	Extra large	ZAR 8.00 /oyster	

When considering the market potential for mussels and oysters, it is evident that there is a demand as shown by the South African import values in Figure 40. The demand is, however, limited for both species and careful consideration and planning would be required to avoid market saturation and increased competition between the major South African players. Focus should rather be placed on international markets, such as Asia. This however requires detailed international market studies. With high per capita consumption of both oysters and mussels in Europe, exports to the EU market would be highly favourable for South African producers. However, there are various challenges for the export of bivalve products to European markets as discussed in Section 6.3.

In South Africa there is a market potential for both mussels and oysters, although limited. Details of the markets were captured within the Kaiser EDP & Enviro-fish Africa (2011) report:

> "There is a steadily growing local demand for seafood, due to growing exposure of South Africans to an increasing variety of fishery products. Seafood has now become a well-established commodity in the service sector and is well established on restaurant menus. The South African public is becoming familiar with an ever growing range of seafood products prepared in accessible dishes at affordable prices. In the retail sector, fresh fish counters at the major supermarkets have been improved, and many independent retailers specialise in seafood, both fresh and frozen. The majority of consumers remain ignorant of the product characteristics of various fish species and are wary of purchasing whole fresh fish as they don't know how to prepare them. Freshness is always an issue with non-frozen fish and a further deterrent to many consumers. Consequently, there is a trend to pre-packaged fresh and value added fresh fish products. Advances in aseptic packaging now make it possible to present fresh fish in evacuated plastic with a shelf life of fourteen days. This is seen as a growth area for local demand for fish products and it is expected that producers culturing marine linefish will target this market niche to capitalise on their product characteristics" (KP EDP and Enviro-fish report, 2011).

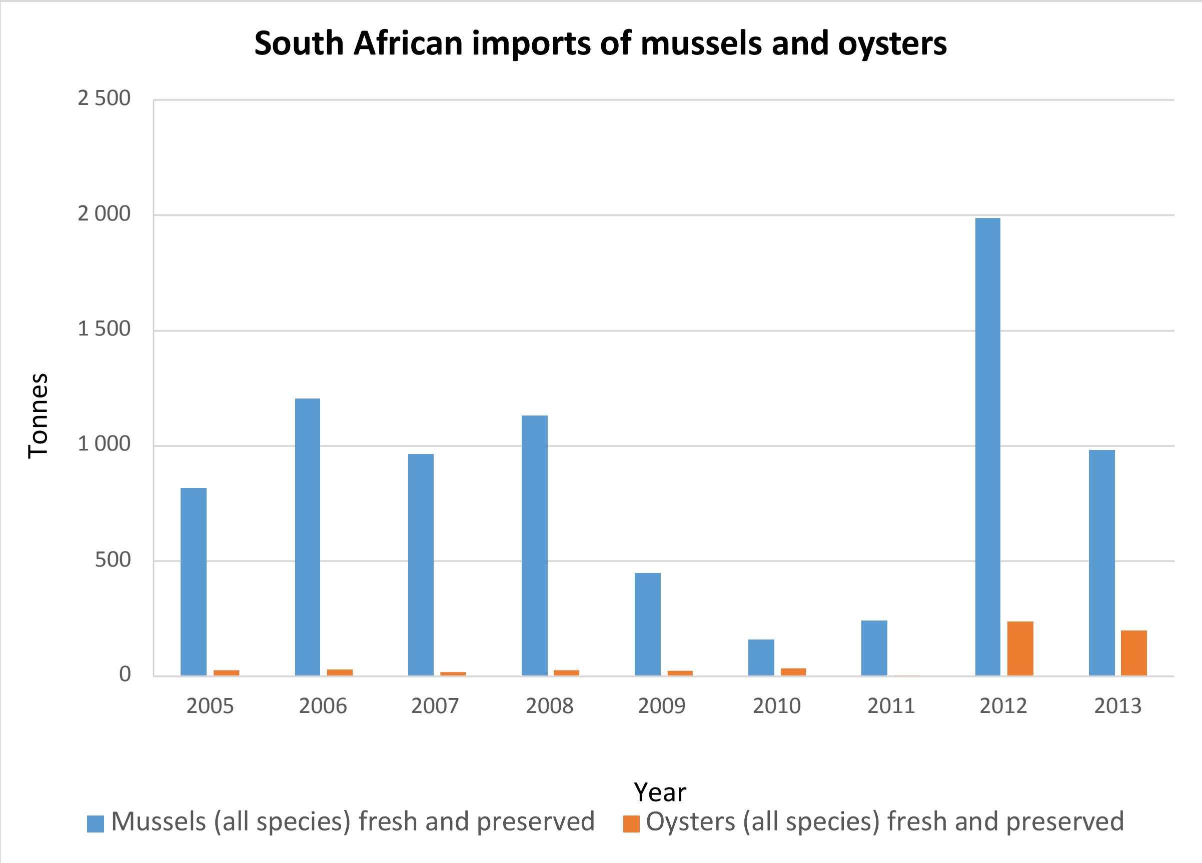


FIGURE 40: IMPORTS OF MUSSELS AND OYSTERS INTO SOUTH AFRICA.

Mussels

In general, live/fresh mussels are supplied primarily to restaurants (KP EDP and Enviro-fish report, 2011). Gauteng and KwaZulu-Natal comprise the largest markets but less live product is available due to logistical challenges associated with transportation (KP EDP and Enviro-fish report, 2011). Airfreight is expensive for a relatively low value item. Trucking live products is difficult as hairline cracks in mussels may spoil batches and fresh mussels have a short lifespan of around 3 days. Frozen (half and full shell) market demand lies within the restaurant and catering industry and higher-end supermarkets (KP EDP and Enviro-fish report, 2011). One of the major catering/food service wholesalers in the Western Cape sells approximately 14 tonnes of frozen half shell mussels per annum.

Oysters

Oysters form primarily a live market through restaurants (high-end individual restaurants in major urban centres through to middle-end restaurants; e.g. Ocean Basket chain). Restaurants are supplied mainly locally produced products (KP EDP and Enviro-fish report, 2011).

6.3. Export challenges and barriers

As mussels and oysters are filter feeders, harmful substances can accumulate in these organisms' tissues and reach dangerous levels that may result in serious illnesses (Kumar, 2015). Therefore, producer and import countries typically mandate that bivalves be harvested from approved waters only (Kumar, 2015). *Regulation (EC) No 854/2004 on the organisation of official checks on products of animal origin intended* *for human consumption* lays down specific rules for the export of bivalves to the EU. The EU requires each country to identify competent authorities to assign the responsibility of fixing the location and boundaries of bivalve production areas, and of monitoring these areas. The competent authorities must classify production areas depending on the level of contamination and ensure that all necessary purification processes are followed before any bivalves are allowed to be exported. Finally, the EU law requires each exporting country to have proper control systems in place to ensure that only bivalves that are safe for human consumption reach the market. Therefore, it is imperative that the authorities demonstrate the capability to be able to detect and stop (or recall) the export of contaminated bivalves (Kumar, 2015). The EU regulations have made export to the EU very difficult. Currently, only a handful of non- EU countries are allowed to export to the EU. These include Norway, New Zealand, Chile, Thailand and Vietnam.

The fact that Thailand and Vietnam export to the EU is good news for South Africa. Low labour costs and timing may be competitive advantages for mussel export to the EU once control system challenges have been addressed.

7. CONCEPTUAL PRODUCTION SYSTEM DESIGN AND SPECIFICATIONS

7.1. Mediterranean mussels

A conceptual system design and specification for a 500 tpa mussel farm is provided in the following section.

There is no hatchery component for this facility as it is assumed that seed settlement is natural and/ or seed will be collected from the wild using spat collectors.

7.1.1. Production plan

The production plan is shown in Figure 41.

Mussels will be seeded at a size of 20mm (0.4g) onto the ropes. Seeding will occur every month to allow for year round production and harvest. The mussels will be harvested after approximately 7 months at a minimum size of 60g and up. The size at harvest will also depend on the timing of the growout cycle as mussels grown during months with more favourable water temperatures will typically be larger at harvest.

7.1.2. System design

Seed mussels will be collected using specialised spat collectors. They will then be seeded on ropes suspended off floating raft structures. The raft structures will suspend approximately 800 ropes. Each rope is approximately 6m long and will support a mean biomass of approximately 35kg. For an operation producing 500 tpa, this equates to approximately 20 rafts and 16 000 ropes.

COMPONENT: Mussel rafts	
FUNCTION:	
The floating rafts are used to suspend ropes on which the mussels are attached.	
RAFTS	
20 x (25 x 12m) rafts each comprised of twin 800mm HDPE pipes with timber crossbeams for additional support. Ropes are suspended off 200mm HDPE pipes.	
EQUIPMENT	Twin 12m HDPE pipes 800mm Timber crossbeams HDPE pipes for rope attachment Rope Mooring blocks
CONSIDERATIONS	Each raft takes up approximately 25 x 12m of surface area.
Comments	

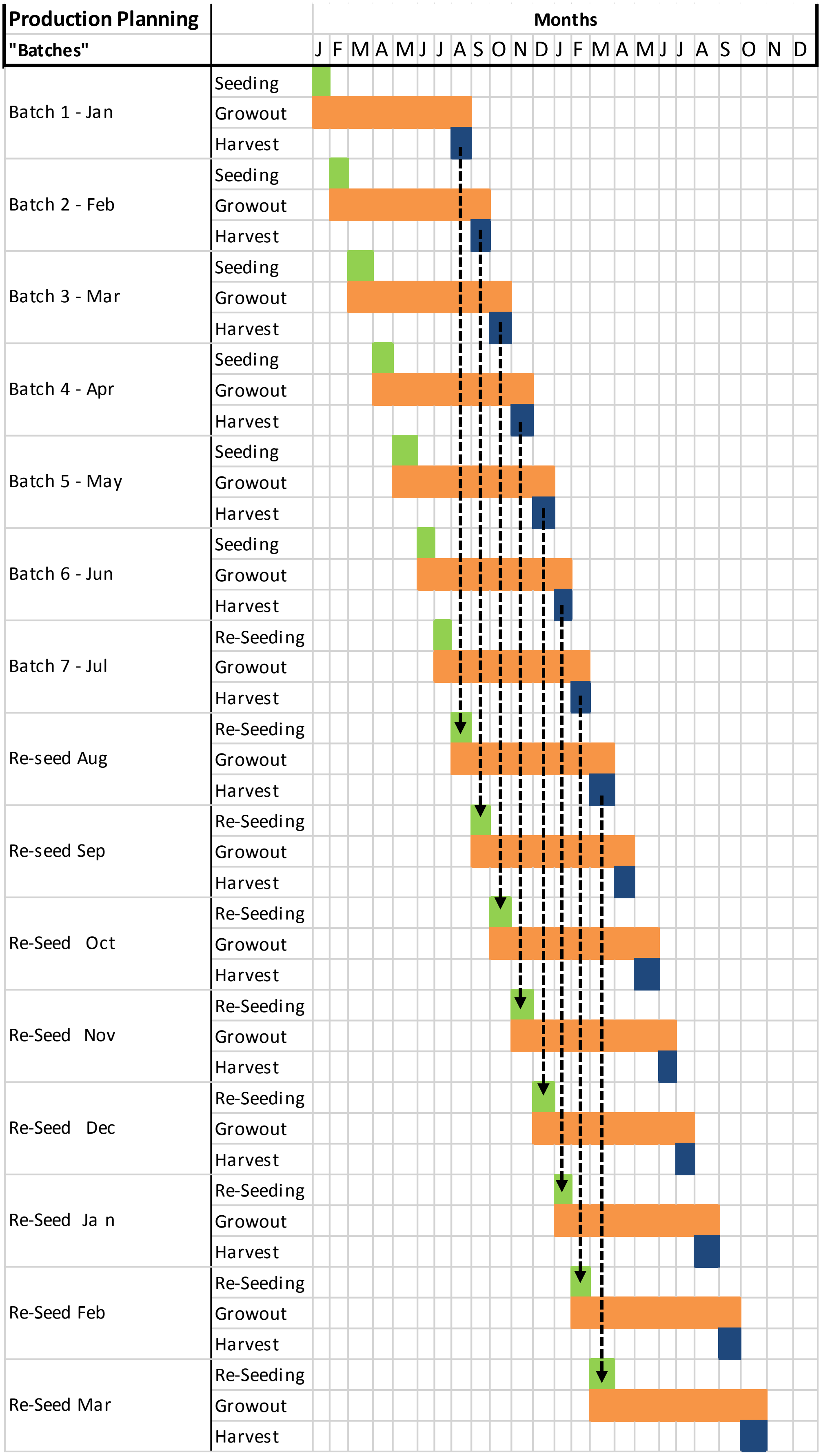


FIGURE 41: PRODUCTION PLAN FOR A 500 TPA MEDITERRANEAN MUSSEL FACILITY.

7.1.3. Human resources

When fully operational the farm would employ a total of 40 people as shown in Table 17:

TABLE 17: HUMAN RESOURCES REQUIRED FOR A MUSSEL FACILITY.

Directors Remuneration	Position	Number
Managing Director	Senior Executive	1
Financial Director	Executive	1
Processing		
Processing Manager	Management	1
Food Safety Officer	Employee Level 3	1
Team Leaders	Employee Level 4	2
General Workers	Employee Level 4	10
Grow-out		
Production Manager	Senior Management	1
Grow-out Supervisor	Employee Level 3	1
Workshop Supervisor	Employee Level 2	1
Skippers /drivers/technician	Employee Level 4	4
General Workers	Employee Level 4	10
Laboratories and Environmental		
Laboratory Technician	Employee Level 3	1
General Workers	Employee Level 4	1
Sales and Administration		
Admin Officers	Employee Level 1	1
Receptionist/other	Employee Level 4	1
Cleaners	Employee Level 4	1
	Total	**40**

7.2. Pacific oysters

7.2.1. Production plan

The production plan is based on a 200 tpa longline production system (Figure 42). This is based on imports of oyster seed and does not include a land-based hatchery. Land-based components which have been included in the model are a holding and storage area for depuration and packaging.

Oysters will be stocked at a size of approximately 10mm. Stocking will occur every month to allow for year-round production and harvest. The oysters will be harvested after approximately 7 months at a size of > 70 – 80g.

7.2.2. System design

Seed oysters will be stocked into lantern nets at a size of approximately 10mm. The lantern nets will be suspended from a longline structure comprised of a mooring block at each end to anchor the structure, buoys, and rope. The lantern nets will be suspended every 1.5m. Each rope is approximately 150m long and therefore accommodates 100 lantern nets. For an operation producing approximately 220 tpa, this equates to a total of approximately sixteen 150m longlines.

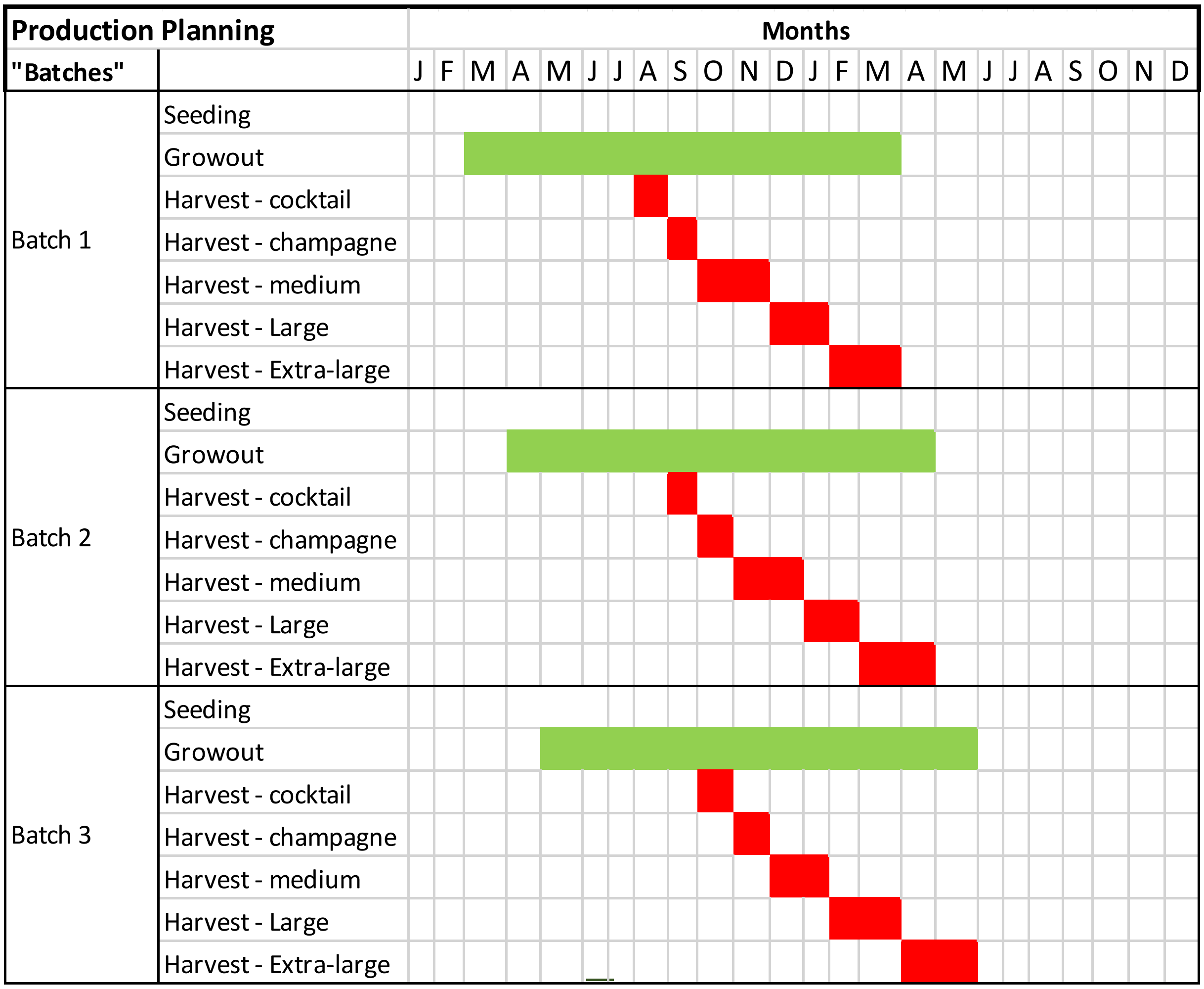


FIGURE 42: PRODUCTION PLAN FOR A 200 TPA LONGLINE PACIFIC OYSTER FACILITY.

COMPONENT: Longlines	
FUNCTION:	
The longlines are used to suspend lantern nets stocked with oysters.	
Longlines	
16 x (150m) longlines each equipped with lantern nets spaced every 1.5m along the line.	
EQUIPMENT	3T Mooring blocks Buoys Rope (40-42mmm polysteel) Lantern nets

7.2.3. Human resources

The human resource requirements for a project of this nature would be 34 people as per Table 18.

Table 18: Human resource requirements for an oyster facility.

Resource	Position	Number
Directors		
Managing Director	Senior Executive	1
Financial Director	Executive	1
Processing		
Processing Manager	Management	1
Food Safety Officer	Employee Level 3	1
Team Leaders	Employee Level 4	1
General Workers	Employee Level 4	5
Grow-out		
Production Manager	Senior Management	1
Grow-out Supervisor	Employee Level 3	1
Workshop Supervisor	Employee Level 2	1
Skippers /drivers/technician	Employee Level 4	4
Team Leaders	Employee Level 4	1
General Workers	Employee Level 4	10
Laboratories and Environmental		
Laboratory Technician	Employee Level 3	1
General Workers	Employee Level 4	1
Sales and Administration		
Admin Officers	Employee Level 2	1
Receptionist/other	Employee Level 4	1
Cleaners	Employee Level 4	2
	Total	**34**

8. FINANCIAL STUDY

8.1. Introduction

The financial models were constructed on the back of four determinants (Figure 43). These were: market intelligence; the scientific understanding of growth, mortality, FCRs, optimal stocking densities for the candidate species and the interdependence between them; the required infrastructure for the production system and the associated cost and finally the incorporation of operational costs. This framework is illustrated in the figure below.

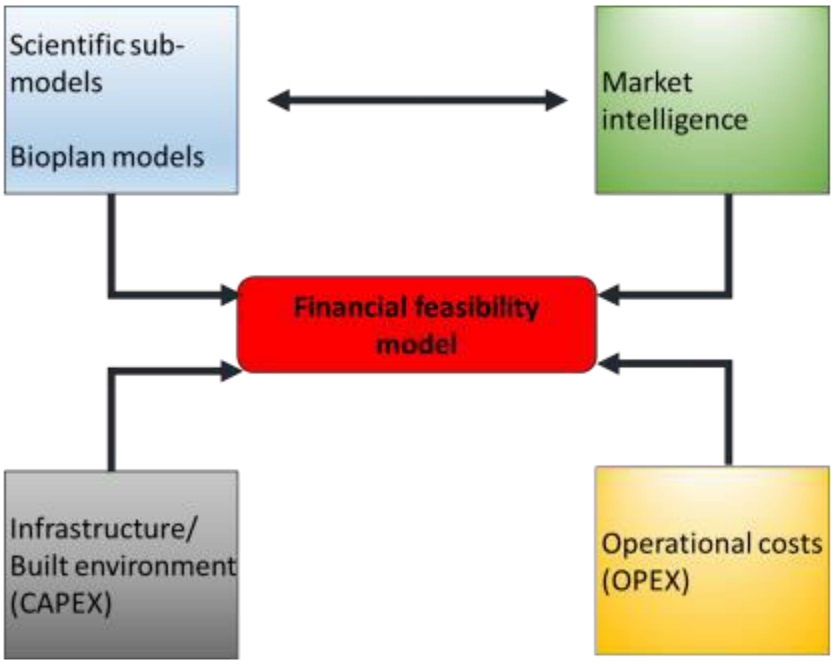


FIGURE 43: FINANCIAL MODEL DETERMINANTS.

8.1.1. Scientific sub-models

The scientific "engine room" sub-models are based on the biological performance of the candidate species under culture conditions. This information is used to derive the "bioplan model" which provides the basis for the development of the financial models.

Key data requirements for the formulation of the bioplan are:

- Growth at length/weight
- Mortality at length/weight
- Feed conversion ratio (FCR) at length/weight

Ideally, growth, mortality, and FCR data at different temperatures will allow the bioplan to more accurately track the biomass of a cohort batch over time under different environmental conditions.

Data limitations

The feasibility studies were based on the viability of farming oysters and mussels in "South Africa" and not for any specific geographic location. Environmental conditions, and specifically water temperature, will have a significant impact on the growth, mortality, and FCR of a batch of bivalves. Water temperature varies widely in South Africa, with lower temperatures associated with the Benguela current on the west coast and higher temperatures associated with the Agulhas current experienced on the east coast. With a wide range in water temperature, it was considered unrealistic to develop bioplans that covered such a large geographic area. Therefore, it was decided to use biological performance data that were available from regions where the species had been or are currently being farmed.

Growth, mortality, FCR, and stocking density data (where possible) was obtained from industry. Growth at different sizes for both oysters and mussels was modelled based on data that were available from Saldanha Bay, Western Cape.

8.1.2. Infrastructure/built environment (CAPEX)

The bioplan was used to specify and cost infrastructure and equipment requirements for the species and production system based on the biomass in the system during the production cycle. Cost estimates of the technical infrastructure required for each species were based on an intense costing exercise undertaken by Advance Africa.

The major CAPEX categories for the models are as follows:

1. Pre-development – includes typical costs associated with feasibility studies, concept designs, and fund-raising activities.
2. Land –indicative costs associated with the land requirements for different production systems – as the production system for mussels, and the growout component for oysters, are usually entirely offshore, these costs are less significant than that associated with a land-based marine finfish hatchery and growout facility.
3. Infrastructure – costs of bulk infrastructure including electricity, roads and potable water.
4. Services – costs of pumping equipment and infrastructure, the provision of oxygen and air, and wastewater treatment and drainage from the facility.
5. Buildings – costs of the built environment including hatcheries, grow-out systems, processing facilities, laboratories, canteens, offices and ablutions.
6. Aquaculture systems - Land-based – costs of aquaculture equipment including tanks, filtrations systems, lighting and life-support services.
7. Aquaculture systems- - water-based – costs associated with raft or longline infrastructure.
8. Vehicles – costs of tractors, boats and cars.
9. Transport and logistics – costs associated with the delivery of equipment and other during the construction phase.
10. Professional fees – design fees for engineers, architects, technicians and project management fees.
11. Contingency – costs at 5% of total project value.

Data Limitations

In the absence of a specific geographic location, costs of land, bulk infrastructure, buildings, and services are difficult to quantify. For example, bulk infrastructure costs may vary widely depending on whether the operation is in an IDZ or remote, rural area. The cost estimates used in the models are therefore indicative.

8.1.3. Market intelligence

Market factors are of crucial importance in determining the viability of an operation. Market factors which were considered for the financial models included:

1. Existing markets
2. Size of markets
3. Domestic and export markets
4. Market maturity and
5. Product forms
6. Sales price

Based on these factors, realistic assumptions regarding the markets that could be accessed and sales prices that could be achieved were made.

8.1.4. Operational costs

Operational costs included:

- Seed costs (oysters)
- Human resources
- Processing
- Packaging

Operational costs were obtained from various sources (e.g. ESKOM website, industry sources). Rental costs are an unknown at this stage and depend on the kind of future business relationship between the company and community. Cost of seed was obtained from potential suppliers. The cost of consumables, administration cost and general repairs and maintenance were obtained from our own database.

In summary, it is important to note that this is a high-level model. If a project is to go to the business planning phase, then the model will need to be further refined to an accuracy level of 90%. However, diligence has been applied in providing detail to the model in order to increase its accuracy for viability modelling the future.

8.2. Key assumptions to the financial model

The detailed key assumptions to the financial models are provided in the .xls file.

8.2.1. Exchange rates and inflation

The financial models are based in South African Rands (ZAR). The models assume that both income (in ZAR terms) and expenditure will be inflated at an annual fixed rate of 6% for the 10 year duration of the models in line with conservative inflation and devaluation forecasts. The exception to the above is the cost of electricity which is inflated more aggressively in line with Eskom predictions.

8.2.2. Income tax

The models are based on a commercial aquaculture project that are subject to relevant corporate tax provisions and a corporate tax rate of 28.0% has been applied accordingly. Should a potential operator implement such a project in an area marked for industrial development, such as an SEZ or ADZ, preferential tax rates may be applicable and should be adjusted accordingly.

8.2.3. Product yield assumptions

The product yield assumptions for Mediterranean mussels and Pacific oysters are reflected in Table 19 and are based on product yield.

TABLE 19: PRODUCT YIELD ASSUMPTIONS FOR MEDITERRANEAN MUSSELS AND PACIFIC OYSTERS.

Biological indicator	Mussels	Oysters
Product yield – whole	100%	100%
Product yield – half shell	85%	55%
Product yield – meat	50%	-

8.2.4. Biological assumptions

The input data, specifically growth, mortality and stocking density, are contained in the "Input Data" tab of the financial models.

8.2.5. Market and price assumptions

Mussels

Despite our best efforts to obtain industry-specific information for mussel prices and product mixes, we did not receive much assistance which may be a result of operators wishing to guard their intellectual property. Nonetheless, the market and price assumptions for mussels are as follows:

- ***Product mix***

For the purposes of the model, it was assumed that 20% of product would be sold fresh (live), and 80% would be processed and sold as frozen product (Table 20).

- ***Local and export market***

Given the barriers of entry into certain international markets (e.g. the EU) currently in place for bivalve products from South Africa, as well as a competitive international market for bivalves, it was decided to model the viability based on sales into the South African market only. (Note: the model user can input a percentage of product exported outside SA. This must be based on realistic assumptions on price and cost of sales).

- ***Price***

Pricing information was surprisingly difficult to obtain. The assumed prices for the financial model is provided in Table 20.

TABLE 20: PRODUCT AND PRICE ASSUMPTIONS OF MUSSEL SOLD INTO DIFFERENT MARKETS.

Product mix	Proportion %	SA Price (ZAR)/kg
Product sold into SA	100%	
Product for export	0%	
Fresh whole	20%	20.00
Frozen whole	40%	25.00
Frozen half shell	40%	25.00
Mussel meat	0%	10.00

Oysters

- ***Product mix***

The domestic market for Pacific oysters is based on a mix of oysters ranging from cocktail size (40-49g) to extra large (>100 g). The approximate ratio of product in different size categories was obtained from industry and is shown in Table 21.

- ***Local and export market***

Given the barriers to entry currently in place for bivalve products from South Africa, as well as a competitive international market for bivalves, it was decided to model the viability based on sales into the South African market only. (Note: the model user can input a percentage of product exported outside South Africa. This must be based on realistic assumptions on price and cost of sales).

- ***Price***

Prices for different size categories of oysters were obtained from industry and are shown in Table 21.

TABLE 21: PRODUCT AND PRICE ASSUMPTIONS OF OYSTER SOLD INTO DIFFERENT MARKETS.

Product mix	Proportion (%)	SA Price (ZAR)/ oyster
Product sold into SA	100%	
Product for export	0%	
Cocktail (40-49g) – Whole	5%	5.50
Champagne (50-59g) – Whole	20%	6.10
Medium (60-69g) – Whole	20%	6.55
Medium (70-79g) – Whole	30%	6.55
Large (80-89g) – Whole	7,5%	7.50
Large (90-99g) – Whole	8%	7.50
Extra-large (100-109g) – Whole	5%	8.00
Extra-large (110-120g) – Whole	5%	8.00

8.2.6. Cost of sales

Mussels

It was assumed that mussels would be sold in consignment sizes of 1 000kg (Table 22). In reality, this will depend on agreements with different buyers in different markets as well as the product form.

Oysters

Similarly, consignment sizes for oysters may vary widely. It was assumed that oysters would be sold in consignments of 5 000 oysters.

In the absence of a specific geographic locations of the farms, sales costs of logistics (both in SA and export) are variable and can be adjusted by the model user. The present values are considered to be within reasonable bounds, however.

TABLE 22: ASSUMED SALES COSTS FOR THE FINANCIAL MODELS.

Sales costs	Unit	Mussels	Oysters
Local consignment size	Kg & number	1 000 (kg)	5 000 (n)
SA sales costs – logistics	ZAR/ consignment	5 000.00	10 000.00
SA sales costs – commissions	%	5	5
SA packaging costs	ZAR/ kg	0.50	2.00
Waste removal	ZAR/ kg	2.50	2.50
Seed costs (Guernsey)	ZAR/ 1 000 delivered	-	182.25

8.2.7. Operational and other costs

Packaging and seed costs (oysters) were obtained from industry and are as per Table 23.

TABLE 23: ASSUMED OPERATIONAL AND OTHER COSTS FOR MUSSELS AND OYSTERS.

Operational costs	Unit	Mussels	Oysters
Waste removal	ZAR/ kg	2.50	2.50
Seed costs (Guernsey)	ZAR/ 1 000 delivered	-	182.25

Waste removal costs were determined from industry standard rates for removal of fish waste. The models assume that all fish waste from processing and mortalities will be removed by an established waste removal company. The operator may, however, consider waste treatment and storage strategies in order to reduce these costs.

8.3. Mediterranean mussels

The following financial results are based on the conceptual operations discussed in Section 7 and the key macro-economic, market and production assumptions discussed above. These are subject to change depending on the objectives of the prospective operator which will determine production volumes, market, product, CAPEX, OPEX and the feasibility or otherwise of the operation. A detailed breakdown of the financial viability, including CAPEX/OPEX/income, is provided in the financial model as an .xls file.

The modelled scenario for Mediterranean mussel is based on a raft production system with a production capacity of 500 tpa.

8.3.1. Capital expenditure

A detailed breakdown of the capital expenditure is provided in the financial models as an .xls file. The total capital costs associated with the development of a mussel aquaculture project under the model assumptions are summarised as per Table 24.

TABLE 24: TOTAL CAPITAL COSTS FOR MEDITERRANEAN MUSSELS.

Summary of capital expenses	Amount (ZAR)
Pre-Development	622 576
Land	1 000 000
Bulk infrastructure	1 678 250
Buildings	8 190 090
Services	-
Aquaculture system – rafts	4 336 255
Vehicles	2 350 000
Transport and logistics	500 000
Professional fees	2 281 564
Contingency (5%)	1 047 935
Total (excl. professional fees and contingency)	18 667 131
Total nett of consulting fees	2 281 564
Total % of consulting fees on total project cost	12.22%
TOTAL	**22 006 630**

8.3.2. Operational expenditure

A detailed breakdown of the operational expenditure is provided in the financial model as an .xls file.

Costs of production

Costs of production include human resources, and operation of equipment. The costs of production for mussels were categorised as follows:

- **Growout costs** – costs of growout of seed to harvest size, including water lease costs
- **Processing/packaging costs** - costs of processing and packaging
- **Laboratory costs** – costs of laboratory operations including equipment maintenance and calibration.
- **Overhead *and* Fixed costs** – all overhead and fixed costs including accounting, legal, insurance costs
- **Financing costs** – financing of capital investment costs
- **Processing costs** – costs of processing and packaging
- **Yield loss costs** – costs of lost product through processing
- **Sales costs** – cost of sales

The costs of production for per one kilogram of Mediterranean mussels with a terminal harvest volume of 500tpa is shown in Table 25. The results indicate that, under the current model assumptions, a mussel raft operation of 500 tpa would achieve a favourable margin (35%) based on sales price and costs of production.

TABLE 25: COSTS OF PRODUCTION FOR MEDITERRANEAN MUSSEL WITH A TERMINAL HARVEST VOLUME OF 500TPA

Cost of production (ZAR /kg)	
Grow-out costs (/kg LFE)	3.68
Laboratory costs	0.71
Overhead costs (/kg LFE)	0.87
Fixed costs (/kg LFE)	3.70
Financing costs (/kg LFE)	2.64
Total costs ex-raft (/kg LFE)	**11.60**
Whole @ 100% yield	-
Total costs ex-raft (whole)	**11.60**
Processing & packaging costs (/kg)	3.13
Total costs FOB (/kg whole)	**14.74**
Sales costs (/kg whole)	3.50
Total costs sold (/kg whole)	**18.23**
Target price @ 25% margin	24.31
Target price @ 33% margin	27.20
Through-rate price (ZAR /kg)	28.25
Margin @ budget /through-rate price	35%

8.3.3. Financial results

A summary of the projected financial results are presented in Table 26 and Figure 44. At 500 tpa, a raft production facility for Mediterranean mussels represents a reasonable scale that is financially viable under the model assumptions. Based on the budgets as concluded, the project offers a feasible investment returning a positive Net Present Value (NPV) utilising a 15% discount rate. An Internal Rate of Return (IRR) of 21% represents a relatively favourable return on a project of this nature. A terminal value has not been used in the above calculations.

The cash-flow requirements for such a project results in a maximum cash outflow of ± ZAR 25 million, peaking in Month 6 of Year 2, thus allowing for both capital development costs and working capital required to reach profitability. Break-even is attained in Year 3 and pay-back in Year 6.

TABLE 26: SUMMARY OF FINANCIAL RESULTS FOR A 500 TPA MEDITERRANEAN MUSSEL RAFT PRODUCTION FACILITY.

Financial indicator	Result
Capex (ZAR '000)	22 007
IRR (%)	21
Max. cash outflow (ZAR '000)	24 951
NPV over 10 years (ZAR '000)	28 659
Break-even point (yr)	3
Pay-back period (yr)	6

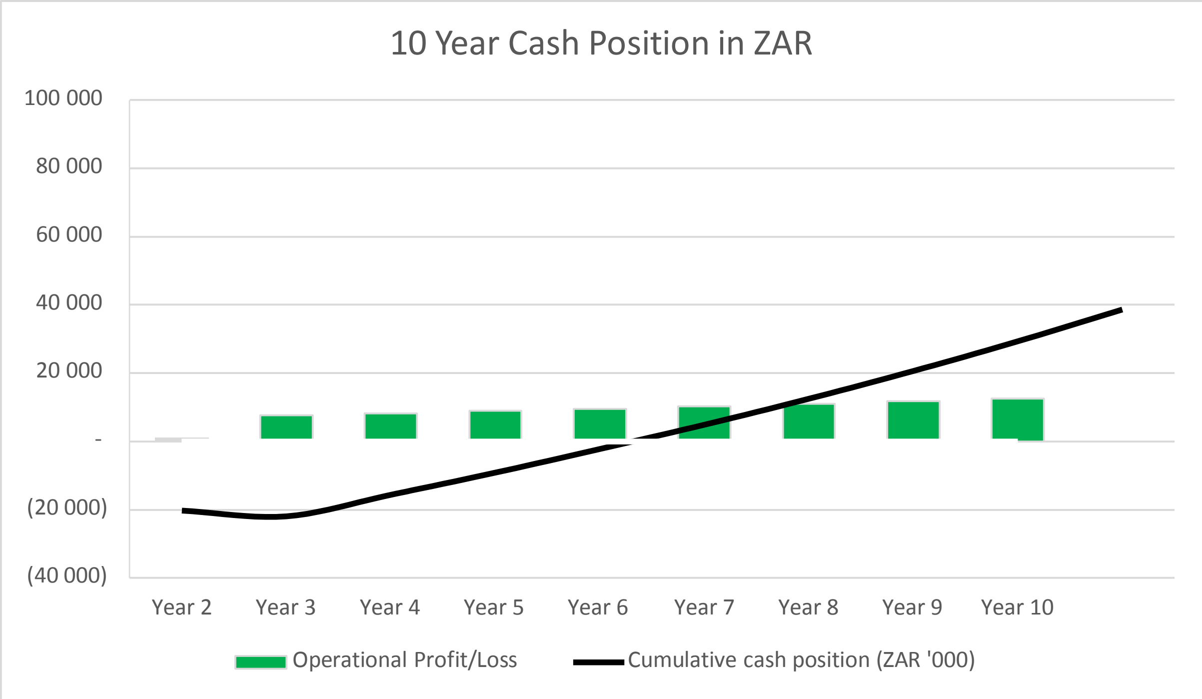


Figure 44: Cashflow requirements for a 500 tpa mussel facility.

8.3.4. Sensitivity analysis

There are a number of operational and biological performance factors that influence both sales price and production costs which were outlined in Table 35. This section aims to describe how profitability at full production (EBITDA in Year 3) for Mediterranean mussels is impacted by high- and low-case scenarios as compared to the base values used for the financial model. The sensitivity analysis predicts the outcome of a decision given a certain range of variables that contribute to production costs and sales price. This allows for the determination of how changes in one variable impact the outcome. High and low range values can be found in the Sensitivity Analysis tab of the financial model spreadsheet for each respective production system. By inputting different upper and lower range values one can visualise marginal costs vs sales price at different production scales and determine an optimum scale for production based on margin.

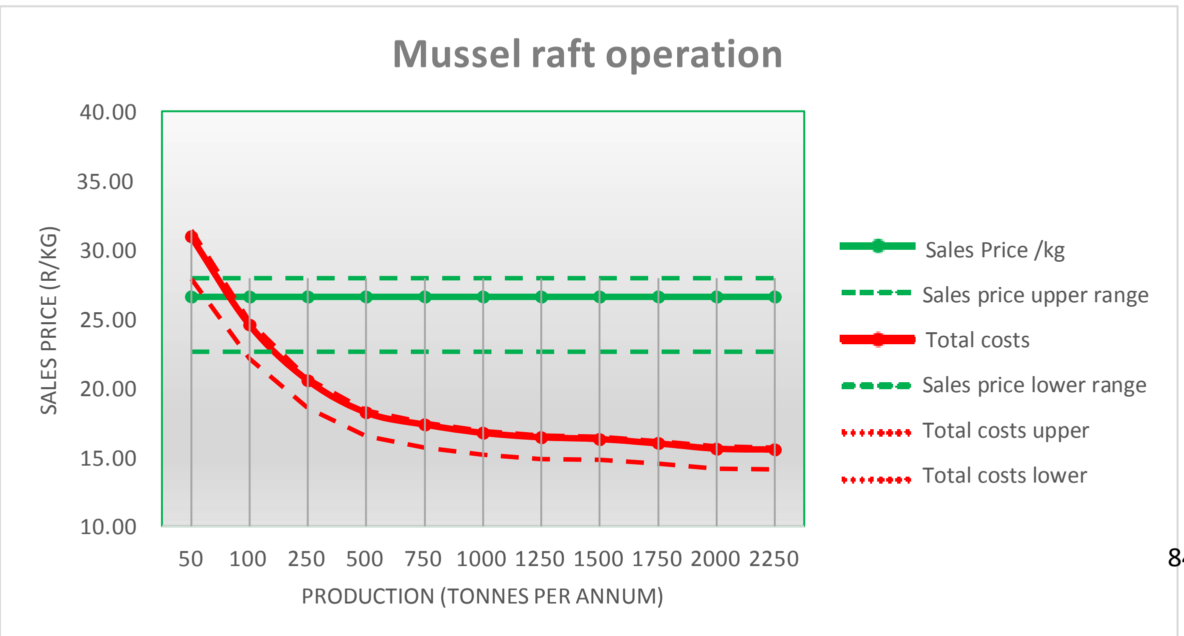


Figure 45: Marginal costs with increasing scale for raft-based Mediterranean mussel production.

As production scale increases, various capital requirements such as overhead expenses and certain capital expenditures are diluted, and thus result in lower production costs at higher scales. Based on the results in Figure 45, and the model assumptions, the mid- and upper sales price exceeds the production costs of mussel farming at scales from 100 tpa upwards. The margin between sales price and production cost is maximised from 1 500 tpa and upwards indicating that this represents the optimum theoretical scale for mussel production. However, this does not take into account the size of the South African market. A flood of 1500tpa of product would have an impact on the sales price and other factors and thus it may not be commercially viable to farm at such a large scale. In theory, production at a scale of 250 tonnes and upwards appears to be favourable from a profit margin perspective. Under the lower range scenario for sales price, the margin achieved is negative up until approximately 250 tonnes and upwards, where production costs decrease and margin increases.

- ***Scale***

Operating at scale is a prerequisite to cost competitiveness in an industry. For example, in the Norwegian and Chilean salmon industries, large companies consolidate product from multiple in-house grow-out operations that they have both independently developed and acquired. Single grow-out operations range in size but a 4 000 tpa unit is widely accepted as representing an industry norm in terms of a single economic grow-out production unit. Scale economies appreciably reduce costs through to a production capacity of approximately 4 000 tpa with moderate efficiencies expected thereafter.

- ***Sales price***

Based on the production cost analysis and under the assumed sales price of Mediterranean mussels (ZAR 26.60), a positive of approximately 20% could be achieved. Ultimately, one would aim to achieve a higher market sales price in order to increase the profitability of an enterprise. This could be achieved in a number of ways including ensuring a regular supply of quality product.

Regardless of the end market deal that is negotiated, it is important that an operator create some market diversity in the medium term as a mitigation of market risk. Establishing sales to an international off-take partner would be central to structuring a resilient marketing strategy. The complexities of establishing an international sales off-take are beyond the scope of this report but it is recommended that an investigation be launched that identifies potential markets, details the legal/ phytosanitary/ logistical/ food safety/ market requirements for importing into that market and constructs a roadmap of events leading to the first sales in an agreed period.

- ***Mortality***

It is expected that as part of normal operations, mortalities will be incurred in a cohort batch throughout the life-cycle and monthly losses are planned for. Increased mortalities often occur due to heightened stress caused by negative changes in environmental conditions, increased handling, diseases and parasites. Mortalities incurred exceeding the budgeted loss will result in increased cost on a per kg basis (less biomass is harvested versus the costs incurred).

- ***Growth***

As noted above, biomass can be negatively impacted through increased mortalities. Additionally, biomass can be negatively impacted through slower growth than planned with the same result of increased costs per kg. Growth is subject to numerous variables including temperature, oxygen, density, feed management and fish health. Impaired growth will have the impact of a reducing the average weight per individual in the batch at harvest and increasing cost on a per kg basis.

8.4. Pacific oysters

The following financials are based on the conceptual operations discussed in Section 7. These are subject to change depending on the objectives of the prospective operator which will determine production volumes, market, product, CAPEX, OPEX and the feasibility or otherwise of the operation. A detailed breakdown of the financial viability, including CAPEX/OPEX/income, is provided in the financial models as an .xls file.

The modelled scenario for Pacific oysters are based on a longline production system with a production capacity of 200 tpa.

8.4.1. Capital expenditure

A detailed breakdown of the capital expenditure is provided in the financial models as an .xls file. The total capital costs associated with the development of an oyster aquaculture project under the production assumptions are summarised as per Table 27.

TABLE 27: SUMMARY OF TOTAL CAPITAL COSTS FOR A 200 TPA PACIFIC OYSTER FACILITY.

Summary of capital expenses	Amount (ZAR)
Pre-Development	622 576
Land	1 000 000
Bulk infrastructure	1 678 250
Buildings	7 322 300
Services	-
Aquaculture system – longlines	3 814 507
Vehicles	2 350 000
Transport and logistics	500 000
Professional fees	2 074 925
Contingency (5%)	968 128
Total (excl. professional fees and contingency)	17 287 633
Total nett of consulting fees	2 074 925
Total % of consulting fees on total project cost	12.00%
TOTAL	**20 330 685**

8.4.2. Operational expenditure

A detailed breakdown of the operational expenditure is provided in the financial model as an .xls file.

Costs of production

Costs of production include human resources, and operation of equipment. The costs of production for oysters were categorised as follows (Table 28):

- **Growout costs** – costs of growout of seed to harvest size, including water lease fees and permits
- **Processing/packaging costs** - costs of processing and packaging
- **Laboratory costs** – costs of laboratory operations including equipment maintenance and calibration.
- **Overhead *and* Fixed costs** – all overhead and fixed costs including accounting, legal, insurance costs
- **Financing costs** – financing of capital investment costs
- **Processing costs** – costs of processing and packaging
- **Yield loss costs** – costs of lost product through processing
- **Sales costs** – cost of sales

The results indicate that, under the current model assumptions, a Pacific oyster longline operation of 200 tonne per annum would achieve a favourable margin (22.5%) based on sales price and costs of production.

TABLE 28: COSTS OF PRODUCTION FOR PACIFIC OYSTERS WITH A TERMINAL HARVEST VOLUME OF 200TPA

Variable cost of production (ZAR /oyster)	
Nursery/Grow-out costs	1.43
Laboratory costs	0.11
Overhead costs	0.19
Fixed costs	0.75
Financing costs at 10%	0.41
Total costs ex-longline	**2.89**
Fresh, whole @ 100% yield	-
Total costs ex-longline	**2.89**
Processing and packing costs	0.65
Total costs FOB	**3.54**
Sales costs	1.02
Total costs sold	**4.56**
Target price @ 25% margin	6.08
Target price @ 33% margin	6.81
Through-rate price (ZAR /kg)	6.04
Margin @ budget /through-rate price	24.44%

8.4.3. Financial results

Financial results are presented in Table 29 and Figure 46. At 200 tpa, a longline production facility for oysters represents a reasonable scale that is financially viable under the model assumptions. Based on the budgets as concluded, the project offers a feasible investment returning a positive NPV utilising a 15% discount rate. An IRR of 13% represents a marginal return on a project of this nature. A terminal value has not been used in the above calculations.

The cash-flow requirements for such a project results in a maximum cash outflow of ± ZAR 25 million, peaking in Month 1 of Year 3, thus allowing for both capital development costs and working capital required to reach profitability. Break-even is attained in Year 3 and pay-back in Year 7.

TABLE 29: SUMMARY OF FINANCIAL RESULTS FOR A 200 TPA PACIFIC OYSTER LONGLINE PRODUCTION FACILITY.

Financial indicator	Result
Capex (ZAR '000)	20 331
IRR (%)	13%
Max. cash outflow (ZAR '000)	25 271
NPV over 10 years (ZAR '000)	15 412
Break-even point (yr)	3
Pay-back period (yr)	7

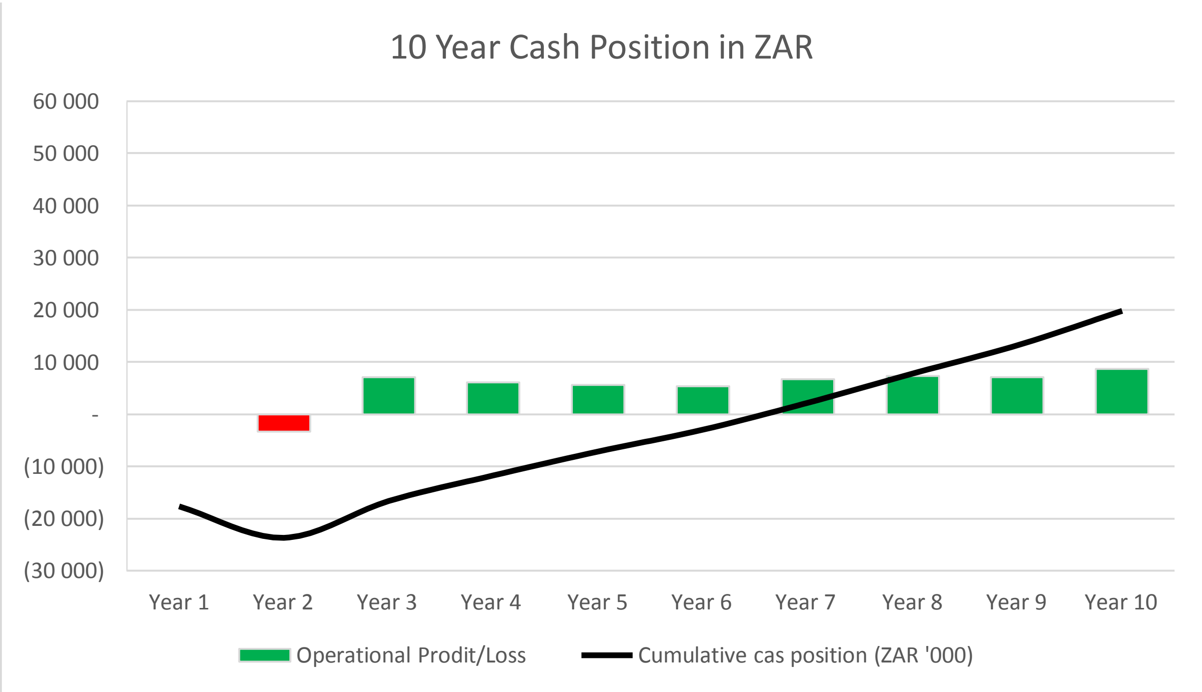


FIGURE 46: CASHFLOW REQUIREMENTS FOR A 200 TPA PACIFIC OYSTER FACILITY.

8.4.4. Sensitivity analysis

There are a number of operational and biological performance factors that influence both sales price and production costs. This section aims to describe how profitability at full production (EBITA in Year 3) for Pacific oyster is impacted by high- and low-case scenarios as compared to the base values used for the financial model. The sensitivity analysis predicts the outcome of a decision given a certain range of variables (e.g. sales price). This allows for the determination of how changes in that one variable impact the outcome. High and low values can be found in the Sensitivity Analysis tab of the financial model spreadsheet.

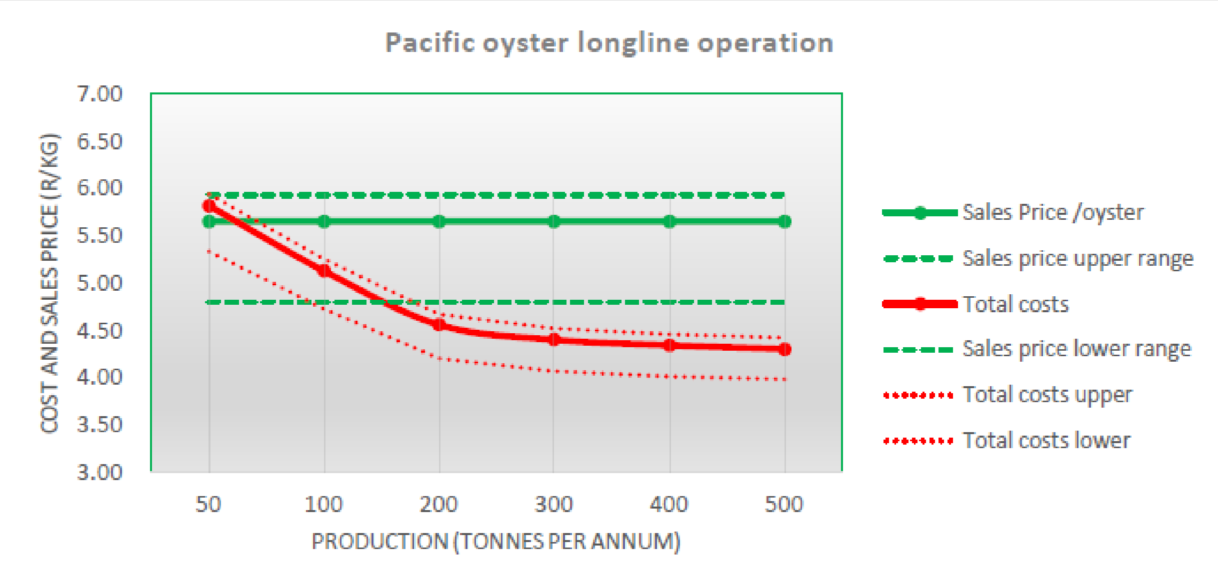


FIGURE 47: MARGINAL COSTS WITH INCREASING SCALE FOR LONGLINE-BASED PACIFIC OYSTER PRODUCTION.

As production scale increases, various capital requirements such as overhead expenses and certain capital expenditures are diluted, and thus result in lower production costs at higher scales. Based on the results in Figure 47, and the model assumptions, the mid- and upper sales price exceeds the production costs of oyster farming at scales from 100 tpa upwards. The margin between sales price and production cost is maximised from 300 tpa and upwards indicating that this represents the optimum theoretical scale for oyster production. Under the lower range scenario for sales price, the margin achieved is negative up until approximately 200 tonnes and upwards, where production costs decrease and margin increases. The results suggest that a favourable margin for oyster farming is achieved under a range of scenarios.

- ***Scale***

Operating at scale is a prerequisite to cost competitiveness in an industry. For example, in the Norwegian and Chilean salmon industries, large companies consolidate product from multiple in-house grow-out operations that they have both independently developed and acquired. Single grow-out operations range in size but a 4 000 tpa unit is widely accepted as representing an industry norm in terms of a single economic grow-out production unit. Scale economies appreciably reduce costs through to a production capacity of approximately 4 000 tpa with moderate efficiencies expected thereafter.

- ***Sales price***

The figure above illustrates the importance of optimising sales price. Regardless of the end market deal that is negotiated, it is important that an operator create some market diversity in the medium term as a mitigation of market risk. Establishing sales to an international off-take partner would be central to structuring a resilient marketing strategy. The complexities of establishing an international sales off-take are beyond the scope of this report but it is recommended that an investigation be launched that identifies potential markets, details the legal/ phytosanitary/ logistical/ food safety/ market requirements for importing into that market and constructs a roadmap of events leading to the first sales in an agreed period.

- ***Mortality***

It is expected that as part of normal operations, mortalities will be incurred in a cohort batch throughout the life-cycle and monthly losses are planned for. Increased mortalities often occur due to heightened stress caused by negative changes in environmental conditions, increased handling, diseases and parasites. Mortalities incurred exceeding the budgeted loss will result in increased cost on a per kg basis (less biomass is harvested versus the costs incurred).

- ***Growth***

As noted above, biomass can be negatively impacted through increased mortalities. Additionally, biomass can be negatively impacted through slower growth than planned with the same result of increased costs per kg. Growth is subject to numerous variables including temperature, oxygen, density, feed management and fish health. Impaired growth will have the impact of a reducing the average weight per individual in the batch at harvest and increasing cost on a per kg basis.

8.5. Investment plan

Should an investor or promoter decide to proceed with the project then the next logical step would comprise the development of a bankable feasibility study with accompanying business plan.

The components of a bankable business plan would comprise the following:

- Investment approach
- Investment structure
- Security of land tenure
- Approach to community participation and upliftment
- Infrastructure, services and buildings - concept designs and cost
- Approach to dealing with waste streams
- Operational model
- Management Structure
- HR requirement, training and development programmes
- Products
- Markets
- Prices
- Processing and storage facilities - Design and equipment
- Certification
- Logistics - priced alternatives
- Refined CAPEX - 90% accuracy
- Financial / Investment / Funding models
- Risk mitigation measures
- Fatal flaw analysis
- Implementation programme and budget
- Finalisation of business plan

9. RISK ASSESSMENT

Risk is defined as uncertain consequences, usually unfavourable outcomes, due to imperfect knowledge (Kaplan & Garrick, 1981). Risk can be lowered by reducing or removing hazards, i.e. sources of risk. Hazards are tangible threats that can contribute to risk but do not necessarily produce risk. Aquaculture is an inherently risky financial endeavour and it is important to identify the hazards that may result in a risk and attempt to quantify these in order to determine mitigations and assist in decision making as to whether an aquaculture project should proceed.

Based on the assessments done in this study and our experience in the aquaculture industry, key findings are identified below and categorised as items of risk according to the below likelihood/impact matrix.

LIKELIHOOD	F 99% Probability	Medium	Medium	High	Very High	Very High	Very High
	E >50% Probability	Low	Medium	High	High	Very High	Very High
	D >20% Probability	Low	Medium	Medium	High	Very High	Very High
	C >10% Probability	Low	Low	Medium	High	High	Very High
	B >1% Probability	Low	Low	Medium	Medium	High	Very High
	A <1% Probability	Low	Low	Low	Medium	High	High
		1	2	3	4	5	6
		IMPACT					

FIGURE 48: RISK MATRIX ACCORDING TO PROBABILITY AND IMPACT.

9.1. Commercial risks

9.1.1. Sensitivity analysis

The project is sensitive to several key financial inputs as illustrated briefly below:

RISK: Energy costs		
Energy costs are one of the largest operational costs for an aquaculture project (particularly RAS systems); and as such profitability is impacted by any upward price revisions. The production systems which have been modelled for mussels and oysters (offshore raft and longline operations) require no electricity. Energy cost risks are therefore minimal and would only apply to a processing facility. Back-up diesel generators are a means to ensuring power supply in the event that power from the grid is interrupted. Power supplied from diesel generators is however expensive (4-5 time more that grid power) and the viability would be compromised in an instance that in-house diesel supply is required for any extended period. Given the fragile balance between electricity supply and demand in South Africa and the potential for energy cost increases exceeding inflation are high.		
Consequence		
Impacts on mussel and oyster grow-out operations will be negligible as operations are largely offshore on floating rafts and longlines.		
Impact	**Likelihood**	**Risk Level**
1	**E: >50%**	**LOW**
Recommendation		
Solar/ wind energy as a cost reduction mechanism (e.g. new HIK abalone farm).		

RISK: Currency risks		
Project capital and operational costs are principally denominated in South African Rand (ZAR). Based on the above, the relative strength or weakness of 3 currencies of the USD, ZAR and EUR will impact on profitability in the event that an operation was exporting product. A strengthening of the ZAR against the USD will result in costs increasing versus income; a strengthening of the USD versus the EUR will have the effect of making the product more expensive to the EU consumer. The above is also dependant on the imports of inputs for business operations and whether or not products are exported.		
Consequence		
Transaction exposure Economic (operating) exposure		
Impact	**Likelihood**	**Risk Level**
2	**E: >50%**	**MEDIUM**
Recommendation		
Currency risk can be mitigated to a large extent through hedging and forward contracting.		

9.1.2. Management and technical skills

RISK: Management and technical skills
The aquaculture sector in South Africa is entering a state of rapid expansion and if Operation Phakisa's objectives are to be met then there will potentially be a shortage of experienced technical and management personnel in the country to successfully deliver those projects. Technical capacity is available from other countries and could be utilised if necessary. Notwithstanding the optionality of utilising foreign resources, the success of a project will be dependent on obtaining human resources that comprehend the unique socio-economic factors associated with a project and are committed to delivering against multiple objectives.
Consequence

Skills shortage leading to wages pressure, project delays, production bottlenecks and delays in expansion plans.		
Impact	**Likelihood**	**Risk Level**
3	**D: >20%**	**MEDIUM**
Recommendation		
Rapid skills transfer forms an important part of mitigating both technical and social risks into the future. Qualified resources from overseas may accelerate training and capacity building in the short-term.		

9.1.3. Health and safety

RISK: Health and safety		
Aquaculture poses a number of health and safety risks due to the operational nature of the business and the use of heavy machinery and water-related work activities among others. It is also likely that the labour force on a project will be predominantly unskilled and considerable effort will be required to quickly establish a culture of health and safety awareness.		
Consequence		
A hazard in the workplace results in employee(s) illness/injury/death.		
Impact	**Likelihood**	**Risk Level**
4	**B: >1%**	**MEDIUM**
Recommendation		
It is important that health and safety aspects and training are continually incorporated into any aquaculture project. A strong risk management plan must be developed and strict control measures implemented at all times.		

9.2. Environmental

RISK: Environmental management		
If not properly managed, marine aquaculture can impact negatively on the immediate and surrounding environment. This has led to the development of environmental management plans (EMPs) and protocols to ensure that aquaculture operations are managed responsibly. In South Africa, an EMP forms part of an EIA and is designed to ensure environmental impact is managed to minimise the potential for negative events. Failure to adhere to the EMP raises risk for the project in both the environmental and legislative fields.		
Consequence		
Poorly planned and unregulated aquaculture practises may cause negative environmental effects. Operations are suspended as the farm fails an environmental audit. Any offtake agreements with consumers are terminated as product is associated with a failed environmental audit.		
Impact	**Likelihood**	**Risk Level**
5	**C: >10%**	**HIGH**
Recommendation		
Continual and comprehensive monitoring and evaluation to ensure compliance to the EMP. As mussel and oyster aquaculture do not rely on feed, the potential impacts may be lowered and, in fact, have a positive impact if integrated culture systems are used.		

RISK: Harmful algal blooms
Harmful algal bloom events
Consequence
HAB event results in significant loss of biomass and closure of farms.

Impact	Likelihood	Risk Level
5	D: >20%	HIGH
Recommendation		
Continual monitoring of water quality and various other environmental parameters is important for early detection.		

RISK: Pollution		
Off-shore oil spills and industrial pollution		
Consequence		
Significant biomass loss and loss of income		
Impact	**Likelihood**	**Risk Level**
5	D: >20%	HIGH
Recommendation		
Continual monitoring of water quality and various other environmental parameters is important for early detection. Continuous communication with other water users is also essential.		

RISK: Alien invasive spread		
Mediterranean mussels are alien species and are listed as a Cateogry 2 species on the NEM:BA Alien and Invasive Species Regulations. A permit is required to undertake aquaculture of these species, and only in authorised areas where populations of the species already exists.		
Consequence		
Poorly managed aquaculture practices may cause negative environmental effects through introduction into areas where the species does not occur.		
Impact	**Likelihood**	**Risk Level**
4	C: >10%	HIGH
Recommendation		
Continual and comprehensive monitoring and evaluation to ensure compliance to the EMP. Prevention of escapes and introduction into natural systems.		

9.3. Social

RISK: Local community impacts		
Social risks in aquaculture include challenges due to real or perceived business impacts on a broad range of issues related to human welfare – for example, working conditions, environmental quality, health, or economic opportunity. The consequences may include brand and reputation damage, increased regulatory pressure, legal action, consumer boycotts, and operational stoppages – jeopardising short- and long-term shareholder value (Bekefi *et al*., 2006). The remote location of many projects and immediate proximity to local communities place them at considerable risk to social upheavals. Projects are regularly the subject of discussion with the local community and it would be essential to temper expectations raised and ensure that a project is geared to meet these.		
Consequence		
Failure to deliver against social objectives will place the project at considerable risk and as such budgets allow for socio-economic investment throughout the development period that are designed to impact all community members and extending beyond those directly benefiting through employment.		
Impact	**Likelihood**	**Risk Level**
3	D: >20%	MEDIUM
Recommendation		

Careful planning and stakeholder consultation is required to ensure that all stakeholders are taken into consideration and that projects deliver socio-economic benefits.

9.4. Market

RISK: Market capacity		
It is assumed that the market is able to absorb the increased harvest, without an adjustment of sales price.		
Consequence		
The positive impact of the expanded production facility would be negated if the additional supply resulted in a decreased price.		
Impact	**Likelihood**	**Risk Level**
3	**D: >20%**	**MEDIUM**
Recommendation		
A supporting document should be requested from the buyer/ distributor stating that an increased supply will not impact the current sales price.		

RISK: Market price		
Aquaculture projects are sensitive to significant negative movements in sales price and has limited optionality in terms of its ability to counter these changes by cutting costs.		
Consequence		
Reduction in selling price		
Impact	**Likelihood**	**Risk Level**
4	**D: >20%**	**HIGH**
Recommendation		
Development of strategies to counter price reductions through market and product diversification and through building customer relationships that delink contract prices from mainstream price trends.		

RISK: Access to markets		
Exposure to a single market destination is a significant risk and investing the time and money needed to enter second and third markets is considered an important part of the investment.		
Consequence		
Single market shrinks resulting in reduced demand and income		
Impact	**Likelihood**	**Risk Level**
4	**E: >50%**	**HIGH**
Recommendation		
It is proposed that projects consider diversifying their market by establishing alternative outlets to supplement sale/ exports to a single source. Fundamental to achieving the above is resolving the legislative requirements related to the export of the cultured candidate species to target countries. Requirements vary per country and some can be resolved on a project level e.g. food safety certification, while others must be addressed at an industry or governmental level.		

9.5. Biological

RISK: Biological performance
The biological performance of stock is a key determinant to profitability and as such negative deviations from plan will potentially compromise the feasibility of a project through a combination of higher costs,

lower sales volumes or lower sales price. Management experience, performance of the aquaculture system, genetic material, quality of starting stock, disease management, feed quality and environmental conditions are all variables that play an important role in achieving target biological performance and must be addressed through the location, infrastructure and human capital of the project.		
Consequence		
Yield does not meet production targets		
Impact	**Likelihood**	**Risk Level**
4	**D: >20%**	**HIGH**
Recommendation		
Ensure that the operation has access to quality inputs such that production is efficient and highly streamlined.		

10. SWOT ANALYSIS

10.1. Strengths

10.1.1. Technology

- The technology for mussel and oyster aquaculture is established.
- Technology for the grow-out of mussels and oysters is relatively simple and easy to operate.

10.1.2. Markets

- There is significant local demand for both mussels and oysters in South Africa.
- Export markets are established subject to shellfish food safety certification.

10.1.3. Seed production

- Mussel seed is sourced naturally at very little cost to the operator.
- Pacific oyster seed can be imported from a number of sources including Chile, Guernsey and Namibia.

10.1.4. Feed

- Other than live feed in bivalve hatcheries, there is no feed cost associated with the grow-out of mussels and oysters as they rely on naturally available phytoplankton.

10.1.5. Human resources

- There is an adequate human resource base in South Africa to employ highly qualified staff.
- Labour in South Africa is comparatively less expensive than in other developed countries which may proffer a competitive advantage on South African operators.

10.1.6. Industrial associations

- Bivalve farmers are strongly represented to DAFF through the Shellfish Producers Association of South Africa.

10.1.7. Institutional

- South Africa recognised the importance of mariculture and DAFF are actively supporting the development of the sector. Various government initiatives and funding schemes which create an enabling environment.

10.2. Weaknesses

10.2.1. Technology

- The technology for hatchery production of oysters and mussels in South Africa is lacking and requires further research and development.
- Hatchery production of oyster seed requires significant skills and expertise and the technology and production processes can be highly-guarded.

10.2.2. Markets

- Export market regulations are stringent and producers must comply with a significant body of standards in order for their product to be eligible for export.

10.3. Opportunities

10.3.1. Marketing

- There is considerable market potential, both local and international, for South African mussels and oysters.

10.4. Threats

10.4.1. Security

- The capital investment for aquaculture developments is substantial and security against vandalism and theft is a risk.
- Theft of stock is a risk that must be mitigated against through various security means.

10.4.2. Human resources

- Aquaculture requires highly-qualified manpower.
- Staff must be highly incentivised and motivated.
- Reliable services and supplies must be used.

10.4.3. Production

- Unforeseen problems, e.g. parasite infections, disease or off-shore oil spills may have an adverse effect on production if management protocols are not strictly adhered to.
- Limited available sites available in South Africa for production, and this is exacerbated by expensive and limited available land-sites available.
- Continuous innovation is required to reduce production and overhead costs.

10.4.4. Marketing

- Stringent EU export requirements for bivalves.
- Competitive EU market for bivalves.
- Continuous innovation is required to develop new markets and products.

10.4.5. Force majeur

- Floods
- Oil spills
- Storms

11. CONCLUSIONS AND RECOMMENDATIONS

The results of the feasibility studies indicate the following:

11.1. Mediterranean mussels

Despite limited growth data for Mediterranean mussels at different temperatures, the following base conclusions have been drawn regarding the future development of aquaculture for this species

11.1.1. Production systems and geographic suitability

Hatcheries

Currently, South African mussel operators rely entirely on natural settlement and seed collected using spat collectors. Prospective operators are encouraged to develop along the same lines as capital costs are much lower than those which would result from the development of a hatchery as part of an operation. In the long term, the development of a mussel hatchery will be advantageous in that it would avoid any inconsistencies in natural seed availability and genetics. The decision to develop a hatchery would therefore depend on the long term goals of the operator and their initial financial position.

If constructed, mussel hatcheries should be located close to the grow-out systems in order to reduce transport and other costs associated with delivery of juveniles from the hatchery to the grow-out systems.

Grow-out

Production of mussels in South Africa is based on raft systems which are relatively easy to operate and cost-effective. It is therefore recommended that entrants into mussel farming in South Africa consider this technology first. There is potential for other production systems, particularly SmartUnits developed in Norway. However, capital costs for these systems are likely to be higher than raft systems although production achieved may be higher.

Regardless, the farming of mussels requires relatively sheltered seas with high-nutrient concentrations and, therefore, farming is encouraged in Saldanha Bay. There are also limited possibilities along the west coast of South Africa in sheltered bays.

11.1.2. Market

South Africa provides a significant local market opportunity for mussels as demand is high and production costs are low. Dependence on a single market is discouraged, where possible, and it is therefore recommended that any prospective mussel aquaculture operator conduct a detailed international market assessment in order to secure an export arrangement or offtake agreement into the future which would limit the reliance, and therefore reduce the risk, on a single market.

11.1.3. Financial model

Results from the financial modelling indicate that a 500 tpa mussel operation is commercially viable under the given model assumptions. Risks include fluctuations in exchange rate, the undeveloped export market, and variability in natural seed supply.

The prospective operator should use the model to determine the scale at which he/she prefers to operate and the financial result of this scale of development.

Any further development from this feasibility study should include a detailed, site-specific feasibility study and bankable business plan.

11.2. Pacific oysters

The following base conclusions have been drawn regarding the future development of aquaculture for this species

11.2.1. Production systems and geographic suitability

Hatcheries

The oyster industry in South Africa still relies on imports of seed from Chile, Guernsey, and Namibia. The development of an oyster hatchery would reduce seed costs and, potentially, reduce the risk associated with highly variable seed supply from overseas countries. However, the prospective oyster operator needs to carefully consider the benefits of having their own supply of seed versus relying on imports. The results of the financial model indicate that imports are a significant overhead cost. However, the capital costs associated with developing an oyster hatchery are high and, furthermore, there are few suitable sites along the South African coast for oyster hatcheries. An additional concern is the fact that oyster hatcheries require extensive experience and technical knowledge to install and operate and this would require a skills transfer and capacity building period by technicians from established oyster producing countries.

The development of an oyster hatchery will therefore depend on the long term objectives and current financial position of the prospective oyster farmer.

Grow-out

Grow-out of Pacific oysters in longline systems results in rapid growth and reasonable survival rates. Furthermore, capital costs are relatively low and the longlines are uncomplicated to operate. It is therefore recommended that prospective oyster farmers utilise longline systems for grow-out of oysters in South Africa. Rack systems in estuaries typically produce fewer and smaller oysters. Oysters are not submerged throughout the growth cycle and therefore growth rates are slower than those achieved with longline systems. Other benefits of longline systems include reduced mortality resulting from benthic predators as oysters are suspended in the water column.

The best areas that entrants should focus their efforts on are Saldanha Bay and, to a lesser extent, Algoa Bay and other bays along the West Coast.

11.2.2. Market

South Africa presents a significant domestic market opportunity for oysters and demand is high. The export of Pacific oysters will require a very comprehensive market study in order to determine where the product could be sold.

11.2.3. Financial model

Results from the financial modelling indicate that a 200 tpa oyster operation is commercially viable under the given model assumptions. Risks include fluctuations in exchange rate, the undeveloped export market, and variability in natural seed supply.

Any further development from this feasibility study should include a detailed, site-specific feasibility study and bankable business plan.

11.3. Government interventions for mussel and oyster aquaculture production

This feasibility study has holistically studies the broad-based feasibility of aquaculture production of Mediterranean mussels and Pacific oysters in South Africa. The study has highlighted the key risks and opportunities towards the sustainable and successful establishment of the aquaculture species. Essentially, the aquaculture industry in South Africa is still in its infancy and there is still much work to be done in order to mature the industry such that it can be competitive at a global scale. This section broadens on the interventions that government can implement to assist with the establishment of candidate species.

It is important for one to remember that "History shows that business, not government, develops a nation economically. Governments create the frameworks that encourage – or hinder – that development; but it is the private sector that generates entrepreneurship, creates employment, and builds wealth" (page 12, World Business Council for Sustainable Development, 2004). Governments' major roles are to regulate, to promote and to support private sector investments. Governments should invest in research and development activities, capital infrastructure, and public services and utilities. Furthermore, governments should develop or strengthen the technical capacities of private farms and firms, avoiding subsidies that distort the markets and weaken the competitiveness of the aquaculture sector in the long term.

11.3.1. State-owned hatchery and processing facilities

The ability to secure land and water space at the selected location of an operation on suitable terms remains a challenge in South Africa. Furthermore, the capital requirements to invest in land-based infrastructure is high and poses as a barrier to entry for many potential investors. A government-owned hatchery and processing facility at a central location near operators would be able to assist commercial farmers to enter the sector.

11.3.2. Legal considerations

Security of tenure is a very important component in securitising investments. Despite efforts to streamline permits and rights for bivalve production, there is still a way to go. Currently, operators need to obtain a number of legal documents relating to permits to engage in mariculture, broodstock collection and imports/exports. Furthermore, there is often a mismatch between permits issues by DAFF and those granted for water and land-lease sites. A permit to engage in mariculture is typically valid for 15 years, although harbour water area leasing conditions and contracts are expensive and administered on a short-term profit-making basis that is unfavourable to medium- and long-term development of the sector. Clearly, this makes capital investment in land-based infrastructure risky, and compounds the insecurity generated by concerns over land and water area tenure and expense. Furthermore, this inhibits the ability of project proponents to easily secure loans from formal institutions.

State owned hatcheries and processing facilities (as described above) would prove to be very supportive to the industry and would also assist small-holder commercial farmers to enter the sector.

The issue of access to markets has been raised as a threat to the bivalve industry. It is proposed that projects consider diversifying their market by establishing alternative outlets to supplement sale/ exports to a single source. Fundamental to achieving the above is resolving the legislative requirements related to the export of the cultured candidate species to target countries. Requirements vary per country and some can be resolved on a project level e.g. food safety certification, while others must be addressed at an industry or governmental level.

11.3.3. Aligned institutional support for aquaculture development

There is a large need for increased collaboration between governmental institutions in terms of support for the aquaculture industry in South Africa. Whilst aquaculture has been given large focus as a mechanism for economic growth and development in South Africa, there still exists a mismatch between departments that result in high operational costs and are a hindrance to the sector. The South African Revenue Service (SARS) is the responsible institution for overseeing the imports of goods into South Africa. However, the tariff costs associated with importing various inputs into the country result in high costs to producers and indicate a lack of correlation in support for the industry. As an example, fish feed from France was re-categorised by SARS to soluble fish feed in early 2016, against professional assessment, such that a 20% import duty could be applied. This indicates that government departments are not aligned with one another, and therefore should be focused on as a priority point to assist with the establishment of the aquaculture sector.

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APPENDIX 1: COMMENTS BY INDUSTRY

Oyster Production system

The feasibility study refers to lantern net system, a stack based system can stock more oysters per unit and is therefore more efficient in terms of production per ha and therefore potentially cost.

Mussels Production system:

Continuous longline culture is another production option for mussel culture.

DAFF response: *Noted, the feasibility report is based on generic model and each farm should do their own specific financial assessment based on specific production systems and environment. The excel models can be used in this regard.*