Fish-farming in South Africa: A study of the market environment and the suitable species

by

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DECLARATION

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Abstract

Emerging global trends towards sustainable development have placed emphasis on the need to create sustainable food value chains. Many food value chains are becoming weakened through their reliance on eco-systems that are deteriorating. Furthermore, while food systems are under threat, global food consumption is on the rise. The conundrum seems inescapable.

Humanity's food supply methods have moved on from hunter-gatherer characteristics apart from the exception of the fishing industry. The current generation may be the last to witness the wide-spread practice of fishing. Aquaculture, and in particular fish-farming, has begun to show much potential as a method of producing sustainable sources of protein. Whether this can be utilized in the South African context is a challenge that needs to be verified.

This research, presented as two articles, explores the potential for the development of the fish-farming sector in South Africa, and recommends suitable species. Although there is some literature on how fish-farming may have a place in South Africa's sustainability quest, it is scarce. This research aims to enhance the literature base on fish-farming in South Africa, as well as provide further evidence on what the true potential is for fish-farming in South Africa. This was done through a series of primary and secondary data collection methods that allow for a thorough analysis of fish-farming in South Africa and the species involved.

The analysis revealed that the fish-farming sector and the cultivatable species in South Africa are met with an array of opportunities and challenges. Overcoming these challenges will open the doors to exploit the opportunities available.

Keywords: Fish-farming, Sustainable development, Food-security, South Africa, Fisheries, Aquaculture, Suitable species

Opsomming

Opkomende globale tendense weerspieël dat dit noodsaaklik is dat klem gelê moet word op volhoubare ontwikkeling en dat dit van uitterste belang is om volhoubare voedsel waardekettings te skep. Verskeie voedsel waardekettings raak verswak deur hul afhanklikheid van eko-stelsels wat vernietig word. Verder, terwyl voedsel stelsels bedreig word, is globale verbruik van voedsel besig om te verhoog. Dié raaisel lyk onvermydelik.

Mensdom se huidige voedselvoorraad metodes het aansienlik ontwikkel van dié van die jagter-versamelaars, met die uitsondering van die visbedryf. Die huidige generasie mag die laaste wees, wat die wyd verspreide praktyk van visvang beoefen, om daarvan te getuig. Akwakultuur, in besonder vis-boerdery, het begin om potensiaal te wys as 'n volhoubare bron in die vervaardiging van proteïen. Of dit in die Suid-Afrikaanse konteks gebruik kan word, is 'n uitdaging wat geverifieer moet word.

Hierdie navorsing, wat aangebied word as twee tydskrifartikels, ondersoek die potensiaal vir die ontwikkeling van vis-boerdery in Suid-Afrika, en beveel ook gepaste spesies aan.

Alhoewel daar sommige artikels is oor hoe vis-boerdery kan in pas in Suid-Afrika se soeke na volhoubaarheid, is dit skaars te vinde. Die navorsing beoog om die literatuur basis van vis-boerdery in Suid-Afrika op te skerp, en ter selfde tyd verdere bewys te gee oor die ware potensiaal van vis-boerdery in Suid-Afrika. Dit was gedoen deur 'n reeks van primêre en sekondêre data-insameling metodes wat voorsiening maak vir 'n deeglike ontleding van vis-boerdery in Suid -Afrika en die spesies betrokke.

Die ontleding het getoon dat die vis-boerdery bedryf en die aankweek spesies in Suid-Afrika verskeie geleenthede en uitdagings in die gesig staar. Oorwinning van hierdie uitdagings sal dit moontlik maak om die beskikbare geleenthede te ontgin.

Keywords: Vis-boerdery , Volhoubare ontwikkeling, voedselsekuriteit, Suid-Afrika , Visserye, Akwakultuur, Gepaste spesies

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Contents

List of acronyms and Abbreviations

AHP	Analytical Hierarchy Process
DAFF	Department of Agriculture, Forestry and Fisheries
DEAT	Department of Environmental Affairs and Tourism
DTI	Department of Trade and Industry
FAO	Food and Agricultural Organisation of the United Nations
MCDA	Multi-Criteria Decision Analysis
NAPF	National Aquaculture Policy Framework
NASF	National Aquaculture Strategic Framework
NDA	National Development Agency
PESTLE	Political, Economic, Sociological, Technological, Environmental, Legal
SAPA	South African Press Association
SASSI	The southern African sustainable seafood initiative
SWOT	Strengths, Weaknesses, Opportunities, Threats
WWF	World Wide Fund

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Chapter 1 : Introduction

The core focus of this thesis is to explain the potential of fish-farming in South Africa to develop sustainably, and to provide some insight into what species should be used to encourage this.

The theme of the thesis is therefore fish-farming in South Africa. Fish-farming is a form of aquaculture that entails the raising of finfish generally for the purpose of creating a food source(Lucas 2012). Fish-farms are mostly for commercial use and are becoming more and more common in modern times.

This thesis has been structured into two articles, which, although separate in their approach and questions, will aim to congruently provide knowledge on fish-farming in South Africa and its future. The first of the articles focuses on fish-farming in South Africa and its potential to develop sustainably, whereas the second article focuses on establishing what species will be most suitable for the growth of fish-farming in South Africa.

A conclusion will then discuss the results of both articles and explain how the results complement each other.

1.1. Background

Global fish populations have experienced staggering declines largely caused by excessive, wasteful and in some cases unregulated fishing practices (Blue Ribbon Panel 2013). It has in fact been noted by Mohammed and Wahab (2013) that over half of the known fisheries around the world are over exploited. This has caused some distress in the fields of conservation and sustainability and has consequently led to many entrepreneurs, conservationists and academics to look towards alternative sources of fish. Recent years have seen growth in the global interest of fish-farming practices and it has been recognized as a potential sustainable food source for the twenty-first century by a variety of academics (Perdikaris & Paschos 2011).

Fish-farming in South Africa is however an infant sector although growing. According to the previous Minister of Environmental affairs and Tourism (DEAT), Marthinus van Schalkwyk: "There are huge opportunities in marine aquaculture, which will not only reduce the pressure on wild stocks, but provide new economic opportunities" (SAPA 2007). Consequently, in 2008, Minister van Schalkwyk announced that the government would be investing R100 million into six different fish-farms as a means to promoting the development of aquaculture across the country (SAPA 2007). Although it has been recognized that there is significant opportunity for fish-farming in South Africa, questions around the market environment have rarely been asked in academic fields.

1.2. Rational for the study

The rationale driving this research is multifaceted in its nature. The research is aimed at providing knowledge on a potential way of dealing with food security and taking pressure off global fisheries. There are two main reasons as to why this research is important. Firstly, the research in this thesis sets the scene for further research as it aims to identify key areas that should be focussed on to assist in developing the fish-farming sector in South Africa. Secondly, the research provides knowledge on fish-farming in the South African context. Fish-farming is a technology-driven sector that relies heavily on research to develop new ways of farming species and discovering different species for cultivation (DAFF 2014a).

This research will benefit two main groups of people. These include; firstly those looking to take up a fish-farming venture as it will provide them with information on the market environment of the fish-farming sector, as well as, which species would be suitable for cultivation in South Africa, secondly, it will assist organisations aiming to encourage growth of the fish-farming sector in South Africa as it will aid them in understanding some of the challenges that faces fish-farming in South Africa. Through this, the literature will hopefully contribute towards the development of fish-farming in South Africa as a means of stimulating sustainable development.

Another rationale less significant than the other, but still relevant, is to do with the nature of the current literature on fish-farming. The majority of the literature is discipline specific, but this paper will try and add to literature on fish-farming that rather incorporates a multi-disciplinary approach. This may have great value if it can stimulate links between different types of literature on fish-farming.

1.3. Problem statement

The need for alternative and more sustainable sources of protein is increasing. Fish-farming is presenting itself to the world as an opportunity to supply its populations with a sustainable and nutritious source of protein, however achieving this will not come easily. Without a thorough understanding of the challenges and opportunities, and which fish should be used, fish-farming is unlikely to be successful in South Africa and it may become a missed opportunity. It is subsequently important that research is done into the above mentioned areas to ascertain the potential of fish-farming in South Africa as a means of providing a wide-scale sustainable source of protein and how the country can facilitate the fish-farming sector's sustainable growth.

1.4. Research objectives and questions

Throughout the thesis there are two main questions that will be answered. They are the following:

1. *What is the nature of the market environment of the fish-farming sector in the South African context?*

2. *Which species of fish are the most suitable for the sustainable growth of fish-farming in South Africa?*

In answering these research questions, the research study aims to understand what the true potential is in South Africa for fish-farming to develop by understanding the challenges and opportunities facing the sector and what fish species should be used develop the fish-farming market in a sustainable manner. These questions are essential to each other as understanding what the nature of fish-farming market is in South Africa will play a major role in deciding which fish species would be the best for fish-farming. On the other hand it is also important that the appropriate species of fish are used for fish-farming in South Africa, if the fish-farming sector is to truly develop in a sustainable manner. The research questions throughout this paper are as a result working together to formulate final conclusions.

1.5. Overarching research approach/ design/ strategy

Throughout the research process a pragmatic approach was used in which both qualitative and quantitative data is used in tangent. The qualitative and quantitative data supplemented each other to develop answers to the research questions. This was appropriate as these articles are largely exploratory and multidisciplinary in nature and thus it was important to consider all forms of data and information to understand the full picture.

The data collection methods for both articles were the same and included online data collection methods, literature review and interviews with key individuals that possessed expert knowledge on the topic. The analysis processes were however different for chapter 2 and 3 and consisted of a Political, Economic, Social, Technological, Legal and Environmental (PESTLE) analysis, and a subsection of Multi-Criteria Decision Analysis (MCDA) called Analytical Hierarchy Process (AHP) analysis, respectively.

Figure 1-1 is a graphic representing the process in which the research and analysis for this thesis was conducted.

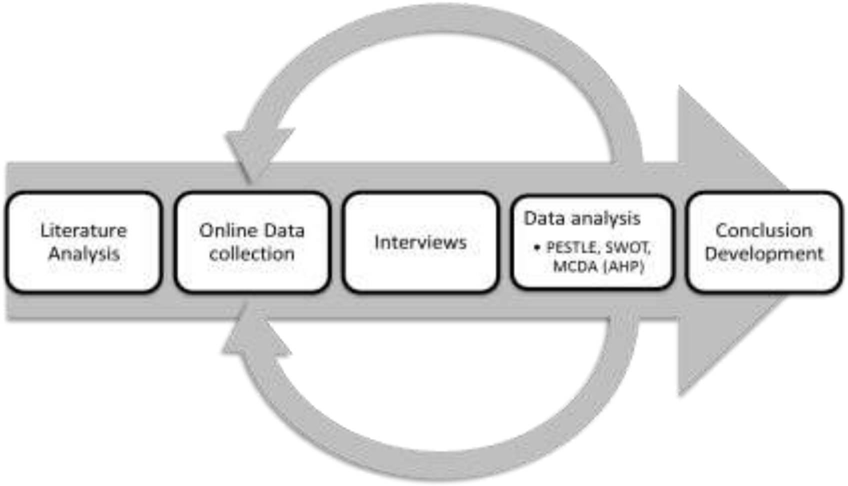

Figure 1-1 Process for research and analysis

The process began with the literature analysis for various reasons. Firstly, the literature review was essential to understand the topic at hand and the dynamics it necessitates. Secondly, it was used to discover what gaps exist in the literature base. Thirdly it provided for the information how to structure the online analysis and the interviews. Lastly it had to come first to fully understand the topic at hand before other research could be conducted effectively.

The process then entailed the online analysis. It was appropriate that the online analysis came next as it provided the base of knowledge for the PESTLE analysis, as well as, AHP analysis. Once the online data was gathered for the analysis the interviews could be conducted. It was important that the interviews were conducted after the online analysis as this allowed for the interviews to build on what was found in the online analysis, as well as, to gain information on areas where there were gaps in the online analysis. The interviews that took place towards the end also helped to confirm and discuss the results of the study.

Once all the information had been fully gathered the PESTLE analysis and the AHP analysis could begin. During the PESTLE and AHP analysis stage further knowledge of the topic was learnt which opened additional thought paths, thus supplementary research needed to be conducted. This cycle continued until the analyses had been conducted thoroughly. The two different analyses then provided the information that was used to draw conclusions in the study. This marked the end of the research and analysis process that was conducted for the research study.

1.6. Delimitations of the overall study

There were three material limitations to this study that became present. Despite these limitations, the study was able to be completed without the possibility of damaged research outcomes.

The first and largest limitation to this study is related to a section of the value chain in the fish-farming market. Collecting first hand data on the consumers was too difficult and timely to perform. Consequently data benefit transfer is used to supplement this.

The second limitation, being an infant sector some data was difficult to find or was not available. There is also little relevant academic literature on the topic of this research, as it is a relatively new field of study, especially when applicable to South Africa. As a result the most relevant and reliable literature and information is found in grey literature, causing a considerable amount of grey literature to be analysed in this article. However, any gaps in the necessary data for the study were filled in during the interview process.

Lastly, during the research period there were constant updates of information that had influence on the findings of the PESTLE analysis. Regular changes needed to be made to accommodate new sources of information which caused a number of setbacks during the research process. Fortunately the analysis methods used did accommodate this.

Chapter 2 : The fish-farming market environment in South Africa

2.1. Introduction

Fish-farming is a topic that is rapidly infiltrating into the realm of sustainable development. It has become acknowledged as a key driver of Gunter Pauli's "Blue Economy" theory, which looks at creating solutions that are both environmentally beneficial and which have financial and wider social benefits (Boto & Phillips 2013). Globally, fish-farming is expanding with leaps and bounds and whether South Africa has the potential or the necessary environment to follow these trends will be crucial.

In order to understand how fish-farming fits into the South African context, this article the following question:

> *What is the nature of the market environment of the fish-farming sector in the South African context?*

The purpose of this question is to understand the market environment for the fish-farming sector in South Africa to understand its potential for sustainable growth.

We first present a literature review to set the context of the study and to provide the academic backing to the study. Secondly, we explain the research methodology and design, which is followed by the results and analysis will be presented and discussed. Lastly, the conclusions from the research will be drawn.

2.2. Literature review

Literature and research on fish-farming is expanding along with the exceptional growth of the sector and has an important role in supporting further developments. The literature around fish-farming has been around for years but has seen resurgence in recent years. This has however seen a new dimension as it has a new general focus on the creation of sustainable food supply chains and the conservation of fisheries as will be seen through the literature presented below.

The relevant literature is analysed with the intent to position the research in the body of knowledge. It will also aim to explain why there has been a revival of literature on the topic of fish-farming, the gaps that exist in the South African literature and the importance of this research study. The literature analysis is then structured according to, firstly, determining the importance of global fisheries and their future; secondly, the potential for fish-farming in sustainable development, and, finally, the potential for fish-farming in South Africa.

2.2.1. Global fisheries their importance and their futures

The ocean is a fundamental element to life on earth and is inseparable from human well-being. It is a source of livelihood for hundreds of millions of people on this planet and is irreplaceable. Once thought to be limitless, but is now under jeopardy from overfishing, pollution, habitat destruction, ocean warming, acidification, as well as, many other global phenomena (Blue Ribbon Panel 2013). Overexploitation of commercial fish stocks in most of the seas is mainly the result of industrial trawling (Perdikaris & Paschos 2011). Whilst demand for aquatic food products increases, production from capture fisheries at a global scale is levelling off, and most of the main fishing areas have reached their maximum yield (The World Bank 2007). If further pressure is placed on global fisheries the damage could become severe to a point at which the ocean's biodiversity will deteriorate and crucial ecosystems systems services will be lost.

Fish has a major importance in global economies and provides significant employment. According to De Graaf and Gabribaldi (2014) the fisheries and aquaculture sector in Africa employs about 12.3 million people and thus maintaining fish supply in a sustainable manner is of much interest to society. Fish also has a role in satisfying the demand of a global growing middle-income group whilst also attending to food security issues for the poorest people around the world. Fish accordingly holds great opportunity to drive development and attend to food securities (World Bank 2013).

The literature indicates that global fisheries are in a poor state and require attention to maintain stability (FAO 2014). It is also clear that demand for fish is increasing, whilst global fisheries are decreasing (World Bank 2013). These increasing demands for fish need to somehow be met in a sustainable manner that does not put further strain on damaged eco-systems.

2.2.2. Fish-farming and sustainable development

Although global fisheries are under immense strain it is not too late for a revival. Increasing aquaculture production is a trend that has seen major advancements in recent years and may help in diffusing the current strain on fisheries. Figure 2-1 shows that aquaculture production is assisting in keeping up with growing demands for fish products.

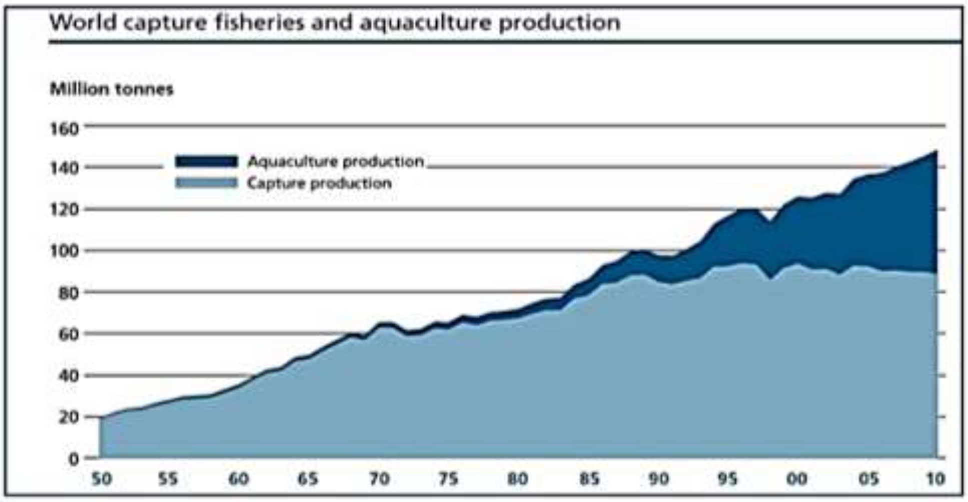

Figure 2-1 World capture fisheries and aquaculture production as of 2012

SOURCE: (Boto & Phillips 2013)

Aquaculture is the farming of aquatic organisms such as fish, shellfish and even plants (Mancini et al. 2010). It refers to the cultivation of both marine and freshwater species and can range from land-based to open-ocean production. Fish-farming is however a sub-section of aquaculture focussed only on finfish species (Lucas 2012).

The use of fish-farming in stimulating economic growth, poverty alleviation, food security, and environmental services is rising globally (Shakouri & Yazdi 2012). At the same time it is important that the threats of unsustainable aquaculture practices are avoided but existing certification standards do not effectively address ecosystem sustainability (Brummett 2013). This highlights a need for improved aquaculture governance and knowledge generation and dissemination to ensure it develops in a sustainable manner (Shakouri & Yazdi 2012).

In recent years fish-farming has become more commonly noted as a sustainable food source. Fish forms a large part of the human diet and is recognised as a healthy source of protein (Igumbor et al. 2012). Aquaculture is also noted as a method of providing fish without placing pressure on sensitive fisheries if done responsibly.

Figure 2-2 in a simplistic manner shows how aquaculture has the potential to improve diets and nutritional statuses of populations through a variety of ways.

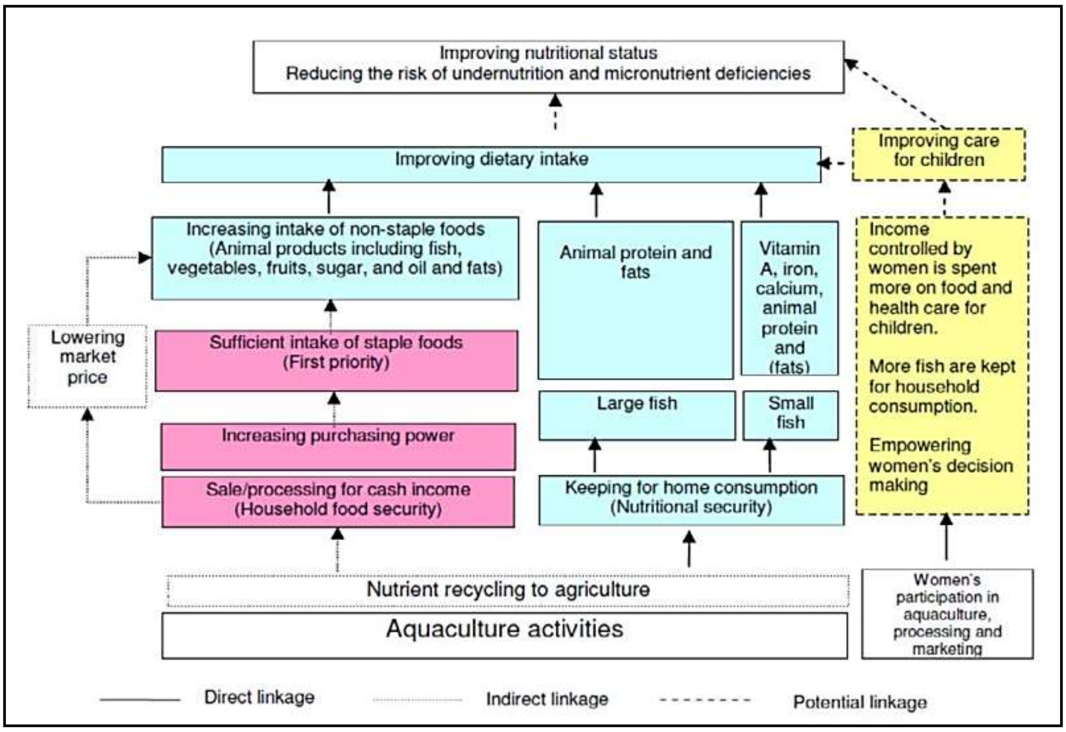

Figure 2-2 The pathway through which aquaculture can contribute to improving nutritional status

SOURCE:(Boto & Phillips 2013)

Firstly, if demand remains constant, increased supply of fish will reduce the market price of fish, which is a very healthy and a nutritional food source (Boto & Phillips 2013). Secondly, Boto and Phillips (2013) have noted that women's participation in aquaculture production tends to be relatively high and consequently it will empower women economically. Women tend to spend more on food and healthcare for children rather than men and more money will thus be spent on improving care for children. Lastly, aquaculture activities generally result in nutrient recycling into agriculture, which could benefit agriculture, if managed properly (Mente et al. 2011). This could lead to improved agricultural outputs and could improve nutritional value of agricultural output and lower the cost of agricultural products. Although this may be somewhat idealised it does show some of the social dynamics of a growing aquaculture sector.

Major seafood companies globally have shown a great interest in securing access to reliable and environmentally friendly supply chains (World Bank 2013). This has stimulated interest in developing production methods that are more sustainable. Aquaculture is in fact among the most sustainable animal production systems (Brummett 2013). Table 2-1 shows various sustainability indicators on animal protein production.

Table 2-1 Comparison of sustainability indicators among animal production systems

	Food conversion (kg feed/kg edible weight)	Protein efficiency (%)	N emissions (kg/ton protein produced)	P emissions (kg/ton protein produced)	Land(tons edible product/ ha)	Consumptive fresh water use (m_3/ton)
Beef	31.7	5	1,200	180	0.24-0.37	15,497
Chicken	4.2	25	300	40	1.0-1.20	3,918
Pork	10.7	13	800	120	0.83-1.10	4,856
Finfish (Average)	2.3	30	360	48	0.15-3.70	5000*

***Note**: Consumptive use is difficult to compare across a wide spectrum of aquaculture production systems. In the vast majority of cases, water outfalls from aquaculture are much cleaner and more easily recycled than for land animals.

SOURCE: (Brummett 2013)

It indicates that fish-farming is in fact a very sustainable protein production system compared to other common forms of protein production. Fish-farming has the best protein efficiency, the most efficient feed supply, the second lowest emissions of potassium and nitrogen, it can be very efficient with land use and although it is uses more water than chicken or pork production in the vast majority of cases water outfalls from aquaculture are much cleaner and more easily recycled than for land animals (Brummett 2013). On the other hand fish products tend to be transported further distances than other protein types which essentially will increase the carbon dioxide emissions in the supply chain.

Although it is argued how aquaculture and fish-farming in particular can truly be sustainable, some researchers remain cautious of accepting fish-farming as a sustainable food source. According to Anne McGinn (1998) there are a number of potential pitfalls in the growth of fish-farming as a source of food. She believes that a revolution of fish-farming and aquaculture may see some of the destructive outcomes that were seen as a result of the agricultural revolution (McGinn 1998). According to Diana (2009) aquaculture can pose a variety of risks. These risks include; the escapement of farmed fish which may cause genetic alterations of wild stocks, the conversion of sensitive land, the effluent effects on water quality, inefficient use of resources when farming fish, and the transfer of diseases or parasites from captive to wild stocks (Diana 2009).

The Gansbaai salmon farms are a South African example of the risks and potential downfalls of fish-farming practices (Scholl & Pade 2005). In this case there were a number of implications that were endangering local endangered and protected wildlife in the area. Various marine species were killed, wounded and harassed by the ocean fish pens that are used to farm the fish. The infrastructure as well as the activity of farming the fish caused major disruptions for wildlife in the area (Scholl & Pade 2005). The marine ecosystem along the Overberg coastline is unique through its diversity and its complexity, adding to its tourism appeal. The environmental damage in the area also translated into damage on the tourism potential of the area (Scholl & Pade 2005).

In this situation the benefits of fish-farming seemed to be outweighed by the negative impacts that it had. It was learnt through the interview process that the farm ended up closing down largely due to poor management and usage of inappropriate equipment that led to unforeseen complications. In particular the poor quality nets that were used led to rapid mussel growth on them that inhibited a flow of water through the sea cages and led to deprived water conditions for the farmed salmon.

Such examples help to understand that fish-farming can be a sustainable food source, but those who partake in it must tread carefully to avoid potential harmful outcomes. It must be noted that utilising fish-farming as a sustainable source of fish is a complex and challenging task and the potential impact needs to be analysed and extensive planning must be done.

In order to ensure that fish-farming practices lead to sustainable development certain challenges need to be met. Fish-farming practices need to create sustainable economic growth, environmental stewardship and guarantee that there is an appropriate distribution of the benefits (Shakouri & Yazdi 2012). A coherent interplay of private investment and stewardship of public goods will help to overcome these challenges. For sustainable fish-farming, there are still many challenges that need to be attended to. Some key areas especially include the empowering of small-scale farmers, providing better quality assurance and of farmed fish products to meet consumer and regulator demands, and to extend the implementation of sustainable practices and management schemes to preserve the fish-farming environment (Shakouri & Yazdi 2012).

2.2.3. The Fish-farming sector in South Africa

There is much literature on the market and demand for fish-farming internationally. However, in the South African context it is an undeveloped area of research. At the moment most of the literature indicates the farming of fish is a good idea, this argument is still highly debatable and is subject to constant revision. Yet, if guided by international trends, the newfound support from government, the growing need for integrated use of resources such as water and the socio-economic needs behind the diversification of food production, then the rapid growth of the aquaculture sector is inevitable (Molewa 2013).

In other parts of Africa there are developed aquaculture markets that can prove to be examples to South Africa as it aims to grow its aquaculture sector. Figure 2-3 show that in 2010 South Africa was ranked 10th in Africa in terms of overall aquaculture output, with Egypt firmly in the top position holding 71.38% of the continent’s production (FAO 2012). On the other hand when compared to the global top ten producers of aquaculture products Egypt features, but is insignificant to China's 61.35% of global aquaculture production.

Africa	Tonnes	Percentage
Egypt	919 585	71.38
Nigeria	200 535	15.57
Uganda	95 000	7.37
Kenya	12 154	0.94
Zambia	10 290	0.80
Ghana	10 200	0.79
Madagascar	6 886	0.53
Tunisia	5 424	0.42
Malawi	3 163	0.25
South Africa	3 133	0.24

World	Tonnes	Percentage
China	36 734 215	61.35
India	4 648 851	7.76
Viet Nam	2 671 800	4.46
Indonesia	2 304 828	3.85
Bangladesh	1 308 515	2.19
Thailand	1 286 122	2.15
Norway	1 008 010	1.68
Egypt	919 585	1.54
Myanmar	850 697	1.42
Philippines	744 695	1.24

Figure 2-3 Top ten aquaculture producers in Africa and the World

SOURCE: (FAO 2012)

South Africa's fish-farming market is thus fairly insignificant on a global scale at this point. In South Africa, as in many parts of the world, natural marine fisheries resources are under severe pressure. To meet the continued demand for fish and seafood this has to be supplied from sustainable aquaculture practices (Molewa 2013). In the face of declining fish stocks in the ocean and South Africa's abundance of marine and freshwater resources South Africa's aquaculture sector appears to have high growth potential due to increasing demand for fish. Figure 2-4 quantifies how aquaculture in South Africa is attending to growing fish demands that are not met by capture fisheries.

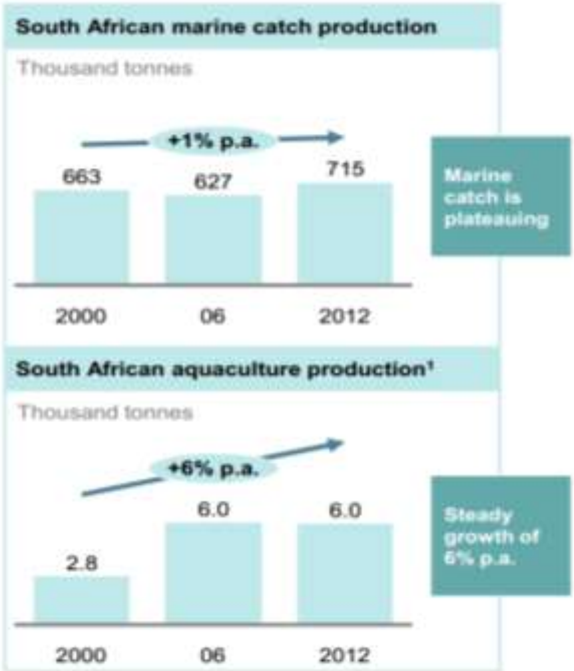

Figure 2-4 South African Marine Catch versus Aquaculture Production

SOURCE:(Republic of South Africa & Aquaculture Lab 2014).

The growth of the fish-farming sector in South Africa also offers a host of socio-economic benefits. It has significant potential for rural development, especially for the marginalised coastal communities (Republic of South Africa & Aquaculture Lab 2014). Growth the sector could also assist South Africa in combatting continuing high levels of underweight and nutritional deficiencies, overweight and obesity among both adults and children which is a rapidly growing public health problem in South Africa (Monteiro & Cannon 2012).

Certain countries, particularly China are in fact showing interest in South Africa's aquaculture sector. A South Africa-China bilateral agreement has been developed in which China is providing technical expertise in order to support South Africa in addressing its skills and technology problems in the field of aquaculture (Tshetlo 2014). The Asian market is in huge demand for fish products, which could be a potential opportunity for export from South Africa (Radebe 2013). Due to the different climatic conditions South Africa could also provide niche fish products for export that are far easier to farm locally than in Asia. This has been seen through South Africa's abalone farming industry that is able to provide top quality abalone to Asia (Radebe 2013).

The aquaculture landscape in South Africa is set to change as development continues to accelerate and expand into all nine of the provinces (Molewa 2013) The literature review suggests that there is growth potential for the fish-farming sector in South Africa, but further research is needed to determine the nature of the market for farmed fish in South Africa.

2.3. Research Design and Methodology

2.3.1. Research Design.

This article uses various types of analysis to try and discover the potential for fish-farming to develop in South Africa. The approach that the research has taken is a pragmatic approach that utilizes both quantitative and qualitative analysis (Denzin 2010). This approach to research is the most appropriate for the study in question as to understand the nature of the fish-farming market it is important to understand the statistics, as well as the various opinions around it. Although this method can be problematic due to conflicts in qualitative and quantitative research (Denzin 2010). In the context of this study there is no conflict between the quantitative and qualitative data that was gathered. Rather, the quantitative and qualitative data is used to complement each other in a way to fully understand the answers to the questions. This poses some difficulties as combining qualitative and quantitative data can result in complex and confusing outcomes (Denzin 2010). Caution was then taken when analysing results of different data types together.

The study takes an exploratory approach to research which is defined as the initial research into a hypothetical or theoretical idea. This is where a researcher has an idea or has observed something and seeks to understand more about it. An exploratory research project is an attempt to lay the groundwork that will lead to future studies, or to determine if what is being observed might be explained by a currently existing theory. Most often, exploratory research lays the initial groundwork for future research (Kowalczyk 2015). The exploratory approach aims to identify the boundaries of the environment in which the problems, opportunities or situations of interest are likely to reside and to identify the salient factors or variables that might be found there and be of relevance to the research (Reiter 2013).

The structure of the data analysis that was conducted took the form of a PESTLE analysis combined with a SWOT analysis to provide a valuable dimension (Kokemuller 2014). A PESTLE analysis is a macro environmental framework used to understand the impact of the external factors on the organisation being studied and is used as strategic analytical technique. The PESTLE analysis was chosen as it fits appropriately into the aims of the study. The reasons why it is appropriate to the study are the following:

1. It is a good method of performing a macro-level analysis of a market (Business Balls 2010).
2. It is multidisciplinary in its nature, which is effective in understanding how every factor will affect the market rather than singularly the economic aspects (Housing Industry Association 2011).

3. It considers the environment and social aspects, which are really important when looking at an agribusiness industry as it is closely reliant on the environment (Agriculture and Horticulture Development Board 2013).

The PESTLE analysis that was used in this research is, however, slightly different from its traditional use. A PESTLE analysis is more commonly used to describe a business's position in an environment to understand where they fit in and what that position means (Agriculture and Horticulture Development Board 2013). In this research the PESTLE analysis was rather used to explain the environment in which an entire sector is situated.

The PESTLE analysis was conducted by consolidating all the research gathered from the literature review, online analysis and interviews in the six different themes including Political, Economic, Social, Technological, Legal and Environmental issues. From this the information was reviewed and the material issues that existed for each theme were highlighted and sorted into four themes including strengths, challenges, opportunities and risks. From this a clear understanding of each of the six themes in PESTLE analysis could be thoroughly understood.

2.3.2. Research Methodology

When gathering research data for this article three different models of data collection were used including: literature review, online analysis, and interviews. This section explains why and how each of the data collection tools was used for the purpose of this study.

The literature review involved analysing different literature sources to understand what dynamics exist in the literature and what research has been done. This was conducted by embarking on a thorough scan of the available literature on fish-farming in South Africa and any relevant themes. Although some of the findings from this are present in the literature review, the majority of the findings were used in the design of the research study.

The literature review was conducted as it was essential in directing the other types of research. It provided the necessary information to help structure the online analysis and the interview framework that was created.

For the online analysis extensive data was collected consisting mostly of grey literature in the form of governmental documents and specialist reports. The reason for the emphasis on grey literature was a result of the quality and nature of academic literature that exists. Through a thorough search of academic search engines it was discovered that there is currently very little literature relating to the theme of this article and the academic literature that does exist tends to focus on a very specific topic which limits its value to this research. Grey literature relating to this research's theme is however far more abundant and relevant. The secondary analysis approach was taken as much of the data that was needed for this research is already available and thus gaining first hand data would have been unnecessary.

Online research and PESTLE analysis of the research allowed comparison between different data sets to discover relevant information needed for the study. When performing the online data analysis the PESTLE analysis structure was used. This meant that the data was categorized into the relevant segments of the PESTLE analysis and then analysed to create conclusions.

The interviews were based in the Western Cape Province due to the region being a hub for fish-farming in South Africa, and it being home to many of the major fish supply and retail companies in South Africa.

The interview process was chosen as a method to gain further information on fish-farming in South Africa first hand. This allowed for additional information and opinion that did not come up in the literature analysis and the online analysis. The interviews were approached with objectivity to avoid biased results and therefore there was no structured set of questions taken into the interviews.

When collecting data for the online analysis section of the research, certain types of literature were focused on to ensure the appropriate quality of the information. Only recent data were used as the information on this topic is changing rapidly and projections of data from five years ago tend to differ from more recent data. Thus when performing the online analysis, the information was generally only used if it was released in the year 2010 or later.

In order to determine the sample for the interviews, key specialists on fish-farming and the fishing industry were identified. The method to identify these individuals began by understanding what sections of the fish industry needed to be understood. To do this an analysis of the value chain for fish in South Africa was conducted.

Once the specific types of people that needed to be interviewed were determined it was necessary to track down who these people were. To do so the method of networking known as snowball sampling was utilized. Although this method has been used informally for much time, it has become known as a formal and authentic approach to sampling in academic research (Handcock & Gile 2011).

The way in which the snowball sampling was conducted began with the attendance of a variety of conferences and meetings. During these meetings and conferences many key companies and personnel for the sake of the interviews were taken note of and engaged with. From these engagements other key companies and personnel were taken note of. After some time a contact list of who should be interviewed was created and further internet searches were conducted to determine if any key personnel were missing from the list.

The key interviews that were then targeted consisted of nine interviews in total for the study with individuals from the following organizations:

- Faculty of Forestry and Agricultural Sciences, University of Stellenbosch
- Department of Animal Sciences, University of Stellenbosch
- WWF: SASSI division
- The Business Place
- Spier Wine Estate
- Woolworths
- Three Streams hatchery

In addition to the interviews, an aquaculture/aquaponics discussion group based in Stellenbosch was attended that consists of individuals starting-up in the aquaculture industry or with research interests. Regular meetings were held to discuss the experiences challenges faced by those entering the aquaculture sector.

2.4. Results

2.4.1. PESTLE Analysis

Within this section the outcomes of the research process will be discussed to understand what they mean for the growth of fish-farming in South Africa.

The research process generated a vast amount of information on the topic but this section will only display the most material findings in the form of a PESTLE analysis. In addition, the results from the PESTLE analysis will be used to discuss the potential for sustainable growth of South Africa's fish-farming sector.

Political Factors

For the growth of the fish-farming sector in South Africa it is important that there is an appropriate political environment that can support it. Political support will help drive the development of the sector and influences relating legislative framework. Furthermore, a disruptive and unsupportive political system will inhibit growth of the sector.

Table 2-2 indicates the political factors in South Africa that will be of most relevance to the successful and sustainable growth of the fish-farming sector in South Africa.

Table 2-2 Political factors of the PESTLE analysis

Political Factors	
Current Strengths	Current Challenges
• Existing trade relations and trade infrastructure for fish export	• Lack of public sector support to start-up farms
Future Prospects	Future risks
• Growing aquaculture agenda within government • Approval of the NAPF	• Potential political instability

Current Strengths

Existing trade relations and trade infrastructure for fish export

Currently, South Africa has a well-established fish export market with much potential. Historically, exports have been derived from its harvest fisheries. This is valuable to the growth of the fish-farming sector as it is likely that the majority of the high value fish that will be farmed in South Africa in the next few years will be exported. The current trade relations and infrastructure that have been developing and strengthening for many years will help provide a platform for farmed fish products to be traded effectively.

A good example of this is cultured abalone in South Africa, which has almost completely replaced the wild harvested products export, and has been accepted as an equivalent product (DTI & Enviro-fish Africa 2007).

Current Challenges

Lack of public sector support to start-up farms

The start-up costs for fish-farming projects are high and pose a major barrier to growth of fish-farming. Start-up costs generally include land purchase, site development, buildings, production facilities, equipment, vehicles and seed or juvenile fish. In addition to this there is currently a lack of public sector support for the start-up of fish-farms within South Africa. This high start-up cost with little public sector support means that it will be a far bigger financial hurdle to enter into the market. This will hinder the growth of new fish-farming projects in South Africa however this is expected to change in the near future.

Future Prospects

Growing fish-farming agenda within government

The past few years have seen aquaculture, and in particular fish-farming, creep onto the government's agenda. Former Forestry and Fisheries Minister, Tina Joemat-Pettersson, has said that the South African government recognized the importance of aquaculture and the role it will play in sustaining production of food fish (Joemat-pettersson 2012). More recently, Minister of Agriculture, Forestry and Fisheries, Senzeni Zokwana, stated that “developing inland fishing is key to food security and marine conservation (DAFF 2014b).

These opinions have also recently been backed up by the launch of the Aquaculture Development and Enhancement Program (ADEP), which has a purpose of stimulating the investment and growth into aquaculture. The objective of the ADEP is to stimulate investment in the aquaculture sector with the intention to increase production, sustain and create jobs, encourage geographical spread and broaden participation (DTI 2013).

The most recent initiative that has been put in place by the South African government is “Operation Phakisa” which is a project launched by the South African presidency to unlock the economic potential of South Africa’s ocean. One of the focusses of “operation Phakisa” is aquaculture and plans have been put in place to increase the sectors revenue from R0.67bn to R3bn, its production by 20,000 tonnes, its jobs from 2,227 to 15,000 and ensure increased participation to support transformation in the sector (Republic of South Africa & Aquaculture Lab 2014). Eight initiatives have been put in place to drive achieve these goals which includes an initiative that will address the selection and implementation of 24 projects, improving both the number and productivity of the new farms, three initiatives that relate to the creation of an enabling regulatory environment, and other initiatives that focus on funding support, increasing skills pool and awareness and improving access to markets (Republic of South Africa & Aquaculture Lab 2014).

Approval of the NAPF

The National Aquaculture Policy Framework (NAPF) has been developed as a government blueprint for the sustainable development of a viable local aquaculture sector. The NAPF was approved in 2012 by Agriculture, Forestry and Fisheries Minister, Tina Joemat-Pettersson, and officially launched in March 2013 by Trade and Industry Minister Rob Davies (SA News 2013). The framework provides a coordinated path for the development of the aquaculture sector and identifies interventions to unlock the potential of the sector.

The NAPF will also attend to fragmented policies, strategies and efforts from various tiers of government and departments to promote aquaculture production in South Africa. If the NAPF is successfully implemented aquaculture production and fish-farming in particular will see rapid sustainable growth in the near future.

Future Risks

Political instability

South Africa’s political risk rating was recently downgraded. Despite having strong political institutions, South Africa is struggling from recurrent strikes, which have become the major means of wage setting, and which weaken the outlook for business and raise financing costs. Industrial action has hit the outlook for business in the country by affecting immediate output and resulting in higher wages, which raise costs. Political stability at the national level can markedly affect investment decisions and the successes of fish-farming ventures. If South Africa continues on this trend of increased political risk it may be a major inhibitor for the development of the fish-farming sector.

Economic Factors

For the growth of South Africa's fish-farming sector it is key that the country's economy is in an appropriate state. The economy should be in a position in which it can nurture the growing sector and it should have space for such a sector to develop. Without these characteristics fish-farming will struggle to develop in an unsuitable economy.

Table 2-3 indicates the economic factors in South Africa that will be of most relevance to the successful and sustainable growth of the fish-farming sector in South Africa.

Table 2-3 Economic factors of the PESTLE analysis

Economic Factors	
Current Strengths	Current Challenges
• High demand for affordable protein and shortages in traditional fishing • Linkages with tourism	• Reluctance of financial institutions to lend to aquaculture ventures • Poor marketing services, marketing structures and market penetration • Lack of an established service sector
Future Prospects	Future risks
• Export opportunities • Stable aquaculture product price predictions	• Exchange rate fluctuations

Current Strengths

High demand for affordable protein and shortages in traditional fishing

Current fishing activities are struggling to keep up with growing demands for fish. This is providing an opportunity for fish-farming to make up the difference. Demand for fish products is high and driven primarily by export markets. Locally, demand is also high and the country generally absorbs as much as can be supplied. With some assurance of a high demand for fish in the next few years fish-farming ventures have some certainty that their product will be sold.

Linkages with tourism

Case-studies have shown that fish-farming has some beneficial linkages with tourism. It can be used as a means of driving tourism and could help in the development of the fish-farming sector. The link is based on two main activities: recreational fishing and an interest in the fish-farming activities itself. In addition, linking fish-farming and tourism could make fish-farming far more profitable by creating awareness of its potential and help market the product.

Within South Africa this strategy is currently used in areas like Dullstroom. Dullstroom has been identified as a premier trout fishing area. People pay to fish the trout and the fish-farmer does not have to harvest the fish him/herself. Some areas globally have also turned fish-farming into a tourist attraction and have started up tours of the fish-farms in which people can go and see how the fish are grown, which, in some cases, has increased profits of a fish-farm by up to 30%.

Current Challenges

Reluctance of financial institutions to lend to aquaculture ventures

In South Africa there is a reluctance of financial institutions to lend to aquaculture ventures as the sector is not well understood and is perceived to be a high risk sector (Republic of South Africa & Aquaculture Lab 2014; DAFF 2013c). Fish-farms generally have high start-up costs and a can take time for the system to run at optimal economic efficiency, but when it does it can be very profitable. This combined with the issue of a lack of support from financial institutions for the start-up of these projects makes it difficult for smaller companies to compete.

Poor marketing services, marketing structures and market penetration

Currently there is very little awareness of farmed fish in South Africa. This is a result of fruitless marketing of farmed fish in South Africa, which limits the penetration of farmed fish into the market. Marketing is however key to the success of a growing industry and needs to be utilized to encourage consumers to try new farmed fish products that they are unfamiliar with.

Within South Africa there is currently a lack of an established service sector for the fish-farming sector. This poses as a major barrier as the necessary services required for fish-farming are more difficult to attain and this raises transaction costs of these services (DTI & Enviro-fish Africa 2007). Without a sufficient service sector in South Africa, farmed fish products will generally be more expensive to produce locally than in other parts of the world.

Future Prospects

Export opportunities

In terms of the export markets, an opportunity exists to export whole fresh high value line fish species such as kob and yellowtail to the European markets. Major fishing companies have a track record of exporting fresh fish to Europe, and have established respected brands and relationships with buyers. South African abalone is a well-established premium product in Asia with a firm and growing demand linked to the strong economic growth rate and increasing personal wealth in China (DTI & Enviro-fish Africa 2007). In contrast, the export prospects for oysters, mussels, trout, and tilapia are poor; due to relatively high local production costs and small volumes (DTI & Enviro-fish Africa 2007).

Table 2-4 shows that the top countries that import fish products from South Africa apart from Spain and have grown in their import value over the period of 2008-2012.

Table 2-4 List of importing markets for fish and aquatic invertebrates exported by South Africa in 2012

Importers	Trade indicators							
	Exported value 2012 (USD thousand)	Trade balance 2012 (USD thousand)	Share in South Africa's exports (%)	Exported growth in value between 2008-2012 (%, p.a.)	Exported growth in value between 2011-2012 (%, p.a.)	Ranking of partner countries in world imports	Share of partner countries in world imports (%)	Total import growth in value of partner countries between 2008-2012 (%, p.a.)
World	435435	306866	100	0	-10		100	7
Spain	76047	70148	17.5	-11	-11	4	5.4	-2
Hong Kong, China	59670	59343	13.7	6	1	10	3.2	11
Italy	58340	58338	13.4	-2	-25	6	4.3	2
United States of America	27435	24574	6.3	3	5	2	13.6	5
Portugal	27067	26468	6.2	7	-6	17	1.8	1
Australia	25580	24944	5.9	9	8	24	0.8	13
China	22638	10240	5.2	65	-40	3	5.6	13
Japan	16734	15159	3.8	-16	-14	1	14.2	6
France	13047	13007	3	-4	-27	5	4.8	3
Angola	10739	10739	2.5	65	13	51	0.2	35
Cameroon	10559	10559	2.4	101	-37	40	0.2	10
Mozambique	9934	4251	2.3	15	55	88	0	10
Netherlands	9115	9085	2.1	14	19	15	2.3	8
United Kingdom	8801	6531	2	-20	-9	12	2.5	1

SOURCE:(DAFF 2013A)

This growth indicates a positive outlook for export opportunities out of South Africa in the near future.

High price predictions

Fish product prices are projected to rise strongly over the coming decade as a result of strong demand, rising production costs and slowing production growth with continuing price volatility associated with supply swings. As seen in Figure 2-5 the price of aquaculture products are also predicted to rise strongly over the next 9 years.

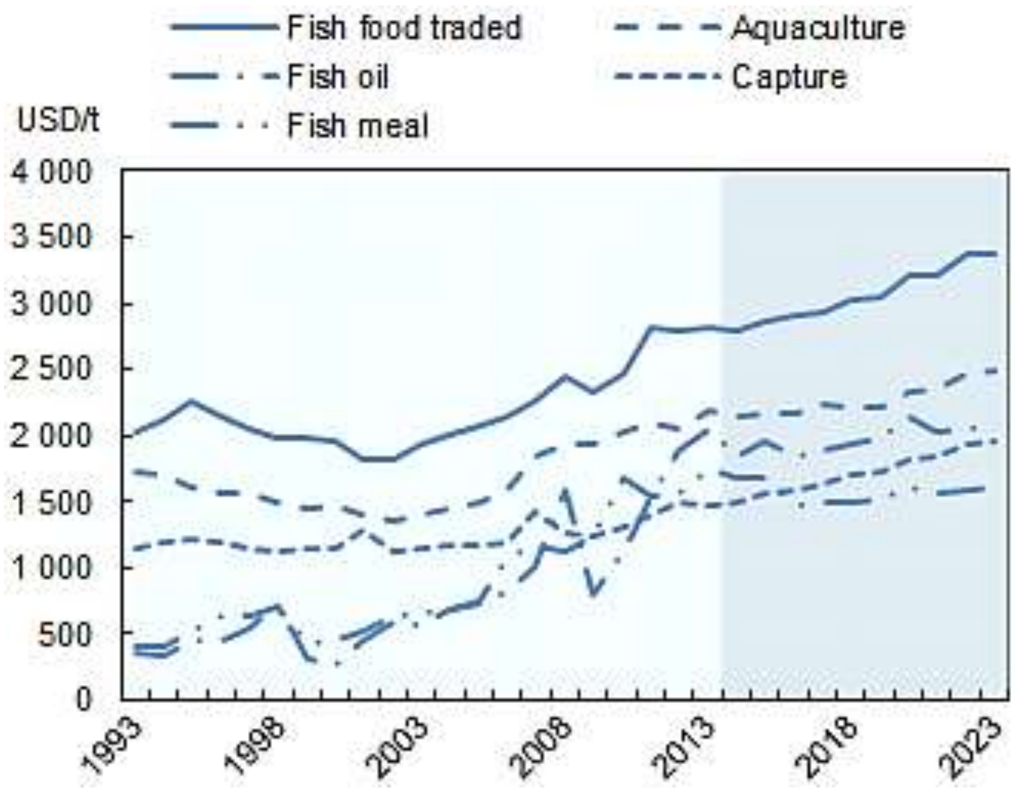

Figure 2-5 Forecasted nominal price rates of fish products

SOURCE: (OECD & FAO 2014)

This prediction of strong growth in aquaculture products will surely heed comfort in the minds of those investing in fish-farming ventures.

Future Risks

Exchange rate fluctuations

Although there is a growing demand for fish globally, the potential for South Africa to take advantage of this is largely hinged on exchange rates with key countries, in particular the Rand/US Dollar exchange rate and the Rand/Euro exchange rate.

Strengthening of the South African Rand in combination with high fuel prices in the 2006-2008 years resulted in many fishing companies declining or being sold to bigger operators who could absorb the risk (FAO 2010). The latter part of 2007 into 2008 saw a weakening Rand and lower oil prices and a subsequent improvement in export sales of fish and fewer sales on the local market (FAO 2010). In 2009 the global recession also impacted demand of fish products from South Africa, in particular to Europe and the United States, resulting in many big suppliers being forced to cold store products or sell at sub- economic prices (FAO 2010).

Fluctuating exchange rates in the future could impact largely on exports of fish out of South Africa and this uncertainty may reduce the confidence of aquaculture ventures particularly aimed at exporting products.

Sociological Factors

The formation of fish-farms across South Africa will have a wide impact on the people living in their vicinity. Some impacts will be beneficial to the public and others will not. Society's reaction to these impacts could prove to be a driver or an inhibitor of growth of the fish-farming sector in South Africa.

Table 2-5 indicates the social factors in South Africa that will be of most relevance to the

Table 2-5 Social factors of the PESTLE analysis

Social Factors	
Current Strengths	Current Challenges
• Business trying to be more sustainable	• Occurrences of public rejection to fish-farms
Future Prospects	Future risks
• Growing Consumer awareness of sustainable fish supply	•

Current Strengths

Business trying to be more sustainable

Recent years in South Africa have seen trends in large-scale companies striving to be more sustainable. This has been largely driven by growing consumer awareness and the arrival of the King III report putting pressure on these businesses to report their business actions. In the agri-business sector, business is looking for more efficient and environmentally friendly production methods. Well managed fish-farming will fall under this category and will be promoted by businesses in need of a steady supply of fish.

Current Challenges

Occurrences of public rejection to fish-farms

There have been some cases of rejection to the development of fish-farms within South Africa which raises an additional hurdle to clear. Public participation is an essential step in the planning of a large scale fish-farm and the impacts of these farms as well as a lack of understanding of the potential risks of fish-farms can make this step challenging.

In Mossel bay a proposed fish-farm approximately 2.5km off shore has raised some questions (The Fish Site 2009). The farm has proposed to have 36 cages up to 100m long. Communities in the area have shown great concern over the potential impacts this farm could have on the visual appearance of the area and consequently the impact on the areas tourism (Oelofse 2009).

Approximately 360km further along the coast in Port Elisabeth a 700 ha fish-farm proposal has recently been accepted, which has also been met with some public distaste (Njobeni 2014). Members of the public have shown concern over the farms potential to entice sharks into an area that is currently a hub for surfing and other water activities. In addition the proposed farm has been suggested to able to produce up to 7 tons of faeces a day which would accumulate due to the relatively low water movement in the area (Millers Local 2014). Much of the public outcry however is for the relocation of the farm to an area that is not 2km offshore from a main beach and not a total ban of the farm.

Future Prospects

Growing Consumer awareness of sustainable fish supply

Consumer awareness in South Africa around the state of fisheries has grown in recent years. The southern African sustainable seafood initiative (SASSI) plays a key role in the development of consumer awareness. They have implemented a range of initiatives to help guide consumers to make ethical choices when consuming fish. This is placing some pressure on retailers and restaurants to supply more environmentally sustainable options in the form of sustainably farmed fish or species that have not been exploited.

Figure 2-6 indicates the growth of awareness of SASSI and their efforts in the past four years and has shown that awareness of SASSI has quadrupled over this period.

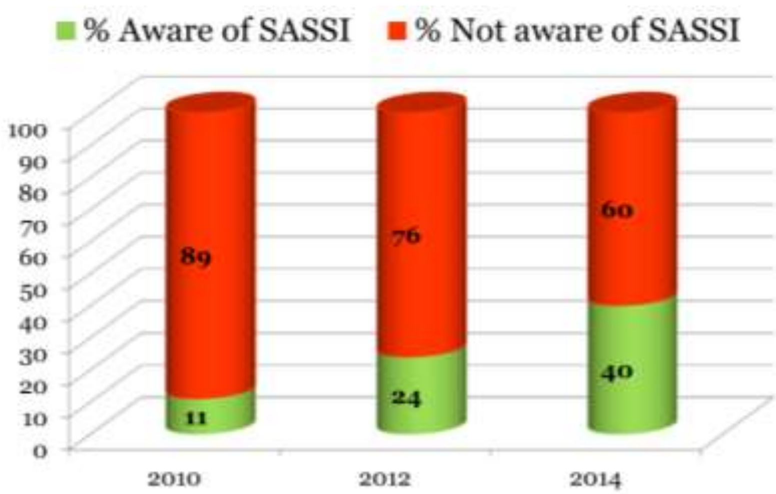

Figure 2-6 Awareness of SASSI

SOURCE: (BASSON 2014)

This poses an opportunity for aquaculture to create a supply of sustainably farmed fish for a population with a more environmentally friendly taste.

Technological

Fish-farming is a sector that requires a high level of technical expertise and research support. The technological capacity of a country should contribute to the success of fish-farming by uncovering new farming methods, suitable species and other innovations that will improve the process.

Table 2-6 indicates the economic technological factors in South Africa that will be of most relevance to the successful and sustainable growth of the fish-farming sector in South Africa.

Table 2-6 Technological factors of the PESTLE analysis

Technological Factors	
Current Strengths	Current Challenges
• Pilot and research programs in progress • Increasing examples of successful fish-farms locally and internationally	• Limited human capacity • Energy supply issues
Future Prospects	Future risks
• Creation of Directorate of Aquaculture for research purposes • Increasing technological improvements for fish-farming	• Inability to compete with international technology levels

Current Strengths

Pilot and research programs in South Africa

Officials have earmarked aquaculture as a sector which needs to undergo significant research. Table 2-7 shows that as of 2010 in South Africa there has been a variety of species that are undergoing research and pilot studies.

Table 2-7 Fish species under study in South Africa as of 2010

Common name	Scientific name	Study scale
Mozambique tilapia	Oreochomus mossambicus	Pilot
African Sharptooth catfish	Claris gariepinus	Pilot
Freshwater mullet	Myxus capensis	Pilot
Southern mullet	Liza Richardson	Pilot
Flathead mullet	Mugil cephalus	Pilot
Atlantic salmon	Salmo salar	Pilot/ Research
Dusky kob	Argyrosomus japonicas	Pilot
Silver kob	Argyrosomus inodorus	Pilot
Yellowtail	Seriola lalandi	Pilot
White stumpnose	Rhabdosargus globiceps	Research
Spotted grunter	Pomadasys commersonii	Research
Yellowbelly rockcod	Ephinephelus marginatus	Research

SOURCE:ADAPTED FROM (DAFF 2011)

These studies are providing potential farmers with the necessary information on which species they should consider when planning a fish-farm. As these studies unfold more species will become available for fish-farming which will help diversify the farmed fish supply that South Africa is producing. This information will facilitate the growth of both the marine farmed fish and freshwater farmed fish sectors.

Increasing examples of successful fish-farms locally and internationally

Increasing examples of successful fish-farms locally and internationally are essential for the wide spread growth of fish-farming across South Africa. Fish-farms globally and particularly in Asia are becoming major sources of protein and are showing promising results.

Locally in the Eastern Cape Oceanwise has developed an onshore Dusky Kob fish-farm which is currently the country's largest farmed fish producer (Burgess 2013). The operation is poised for exports to a lucrative Chinese market and is looking to become a profitable endeavour. This has sparked proposals for other operations of a similar nature in the region.

These successful examples are important for the growth of aquaculture as it provides lessons to others that wish to do the same. These examples will encourage confidence in fish-farming ventures across South Africa.

Current Challenges

Limited human capacity

A successful aquaculture sector should be built on a strong educational and training foundation that improves the knowledge and skills of all people involved in the sector. There is a particular need to provide a balance of practical and theoretical approaches to train farmers and to provide more skilful and innovative staff (DAFF 2013c). Currently in South Africa skills and practical expertise related to aquaculture are very low which poses a major barrier to the initiation of the sector's growth.

Energy supply issues

Fish-farms and in particular re-circulating aquaculture systems usually depend on mains electricity for pumping, aeration and filtration. These life-support systems are almost always required on a 24-hour basis for all fish-farms (James 2014). When the power goes out and these systems are turned off, within twenty minutes fish stocks on a farm can begin to die off (James 2014). Electricity is also usually the second highest operational cost of a fish-farm.

It is accordingly important that there is a reliable, cheap source of power to these fish-farms. Recent years have nonetheless seen major issues coming up in South Africa's electricity supply. A lack of attention to investing in the country's power capacity in the past has led to a situation in which the grid cannot always handle the demand pressure. This has resulted in two main problems which may inhibit the growth of the fish-farming sector in South Africa. Firstly as seen in Figure 2-7 the price of electricity has been increasing aggressively which results in heightened costs to run a farm.

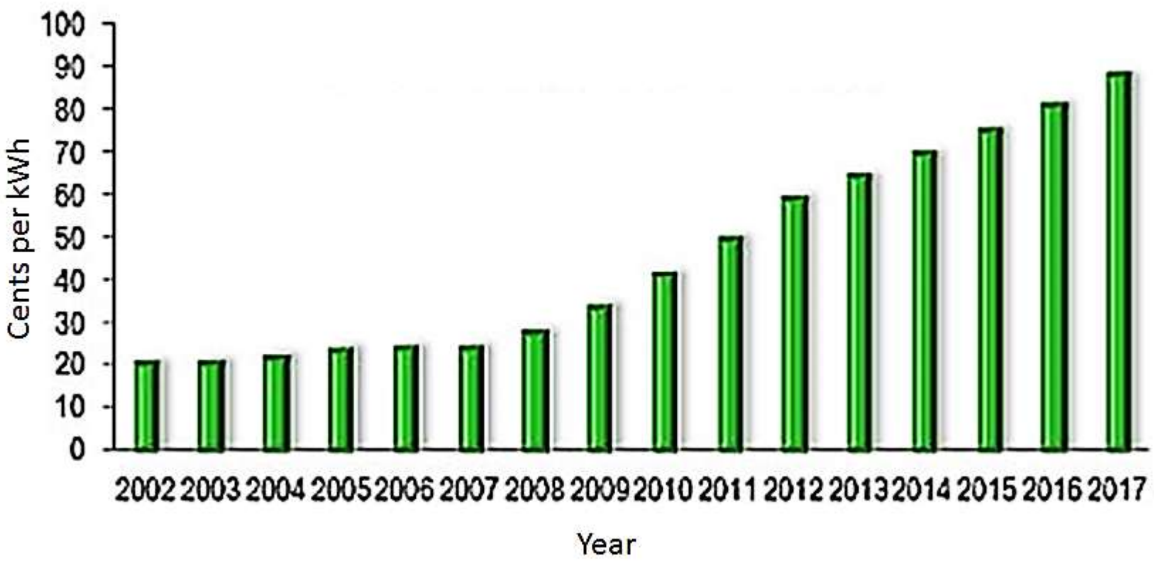

Figure 2-7 Forecasted average electricity price in South Africa

SOURCE: (RAMAYIA 2013)

Secondly the pressure on the grid has led to common occurrences of power outages. These two factors can cause a fish-farm to become too risky and expensive to run.

Future Prospects

Creation of Directorate of Aquaculture for research purposes

The Department of Agriculture, Forestry and Fisheries recently established a new directorate of aquaculture research. The purpose of this directorate is to support competitive and sustainable development of aquaculture in South Africa. In particular three main areas will be focused on including; firstly research into the culture of finfish and invertebrate species, secondly improvement of biosecurity of aquaculture activities, and thirdly broadening the understanding of interactions between the environment, economics and aquaculture in South Africa(DAFF 2014a). This directorate should provide valuable knowledge into fish-farming which could be utilized by fish-farmers.

Increasing technological improvements for fish-farming

Research into fish-farming is increasing the feasibility and efficiency of fish-farming activities. Contemporary fish-farming has adopted new methods to avoid problems of past fish-farming efforts. Examples of these new methods include aquaponics with fresh water fish-farms that present opportunities to maximize efficiency of resources on a fish-farm, and galvanized steel cages which allow for the mobility of off shore fish-farms for a number of benefits. These innovations allow for those wishing to develop fish-farms to deal with some of the common challenges faced in the past.

Future Risks

Inability to compete with international technology levels

Due to the relatively high production costs of South African farmed fish products, it is unlikely that local producers will be competitive with certain species. The massive rise in the low cost production of tilapia in China has made frozen fillets available as an international commodity at prices as low $1.50-1.80/kg (DTI & Enviro-fish Africa 2007). South African producers are thus looking to the fresh fish market where higher unit prices can be obtained for whole fish or premium quality fresh fillets. A number of South Africa’s marine species are highly valued in the market and the outlook for marine aquaculture is particularly positive as an increasing number of species are commercialized (DTI & Enviro-fish Africa 2007).

It is therefore vital that South Africa can find its particular strengths and niches if it is to compete on the global market. If this competitive advantage is not found then international markets with higher technological availabilities will dominate the market.

Legal

The legal environment in South Africa can either restrict or accommodate the growth of fish-farming. It is in the interest of the fish-farming sector for South Africa to align its legislature with their needs.

Table 2-8 indicates the legal factors in South Africa that will be of most relevance to the successful and sustainable growth of the fish-farming sector in South Africa.

Table 2-8 Legal factors of the PESTLE analysis

Legal Factors	
Current Strengths	Current Challenges
• Increased fishing catch limitations and regulatory bodies	• Overregulated and complex legislation compared to other protein production types
Future Prospects	Future risks
• Fish-farming is becoming further accommodated into law	•

Current Strengths

Increased fishing catch limitations

According to the Marine Living Resources Act of 1998, a right to commercial fishing access needs to applied for (Joemat-pettersson 2013). If accepted a total allowable catch will be given. A total allowable catch does however depend on the remaining stocks and are in place to protect species under stress through population management (Joemat-pettersson 2013).

These total allowable catches are placing huge difficulties on fishing businesses as they need to adapt to methods of fishing that minimize bycatch to maximize the amount of desired fish they catch. These limitations are reducing the profits of these fishing activities and are improving the desirability of attaining fish through farming rather than fishing.

Current Challenges

Aquaculture overregulated compared to other protein production types

The Department of Agriculture, Fisheries and Forestry has a stated intention to encourage participation in aquaculture and related activities. This is a complicating factor as a large number of laws and policies presently apply to the sector and several different government authorities are involved in its administration. The general view is that this is an uncoordinated legal framework and overregulation is hampering the development of the sector (DAFF 2013b). For fish-farming to be able to grow effectively a set of laws attaining to the sector should be developed to guide the sector in an appropriate manner.

Future Prospects

Potential aquaculture act planned

The growing aquaculture related agendas of South Africa's leaders are influencing law in South Africa in a manner that is further accommodating its growth. At the moment marine aquaculture is regulated by the Marine Living Resources Act, 1998 (Act No. 18 of 1998) whilst there is no main legislation governing the freshwater aquaculture sector (DAFF 2013c). Different government departments are responsible for implementing different pieces of legislation and this has created a fragmented regulatory framework for the aquaculture sector (DAFF 2013c). Fortunately a new aquaculture act is likely to be developed and if this new act is developmental in its nature it will have major benefits to the development of the aquaculture sector and the fish-farming sector in particular.

Environmental

Fish-farming comes into direct contact with the environment and as a result has a direct impact on it. The relationship goes both ways in that the state of the natural environment will determine the success of a fish-farm. South Africa has rich natural resources however it does face some environmental challenges that may limit fish-farming development.

Table 2-9 indicates the environmental factors in South Africa that will be of most relevance to the successful and sustainable growth of the fish-farming sector in South Africa.

Table 2-9 Environmental factors of the PESTLE analysis

Environmental Factors	
Current Strengths	Current Challenges
	• Lack of space and suitable water • Lack of good quality feed locally
Future Prospects	Future risks
• Decreasing stock for fishing	• Climate change

Current Challenges

Lack of space and suitable water

One of the major inhibitors of aquaculture in South Africa is the lack of ideal space on land, in lakes, rivers, estuaries in coastal bays for fish-farming activities and a limited supply of suitable water. There is also much competition for these areas from other agricultural, recreational and residential activities. Additionally South Africa has a high energy coastline with limited naturally protected sites which provide little suitable sites for coastline aquaculture (DAFF 2013c).

Water temperatures in South Africa are also not ideal for many farmed species however there are many new indoor technologies being developed which help deal with this challenge (Molewa 2013).

Lack of good quality feed locally

Feed is the biggest operating cost by quite a bit when running a fish-farm hence its availability and price can determine the success of a fish-farm. In addition if feed is not managed properly it can destroy more fish than it produces. It is therefore essential that there is a sustainable supply of good quality feed locally in South Africa for aquaculture to expand.

Globally there have been improvements in this area as seen in Figure 2-8 which shows a decrease in the fish meal and fish oil used to feed aquaculture while the amount of aquaculture fed is still increasing.

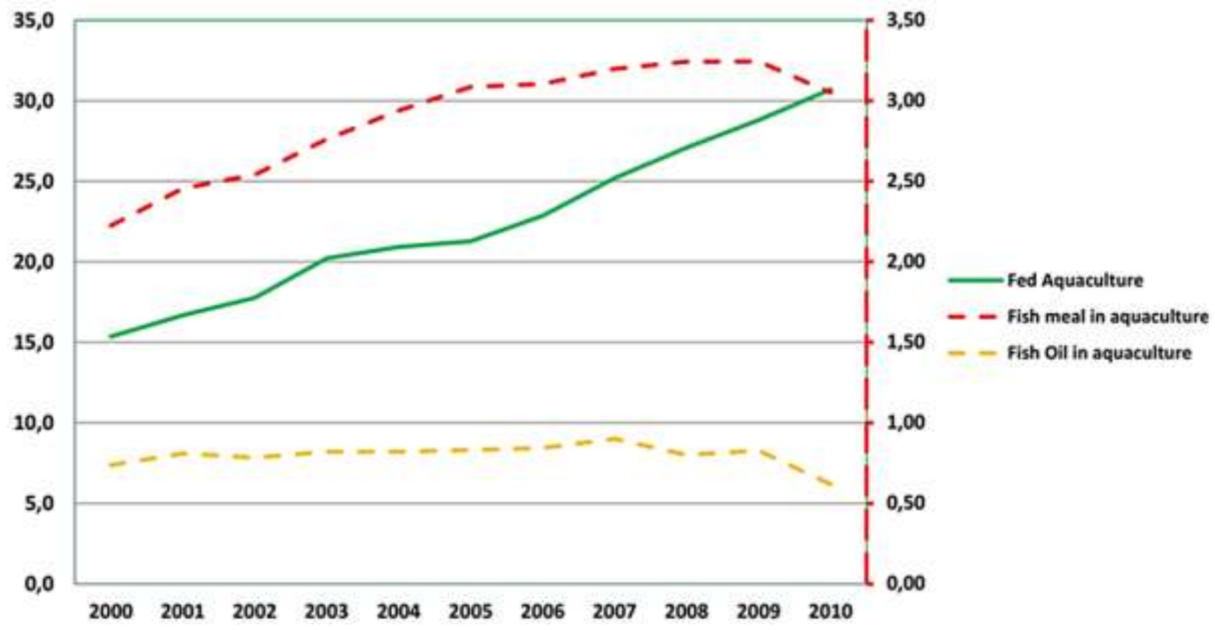

Figure 2-8 Global aquaculture production with fishmeal and fish oil usage 2000-2010 tonnes millions

SOURCE:(JACKSON 2012)

In South Africa however there are very few feed production companies that have the capability of producing good quality and environmentally responsible feed. Furthermore importing feed is also met with challenges. The problem with importing some fish feeds is that they deteriorate with time so a feed production plant is needed close to the area of the fish-farm which poses a situational constraint.

Future Prospects

Decreasing stock for fishing

Wild fish stocks globally are rapidly decreasing and are largely depleted. This has a number of unfavourable implications for the fishing sector which poses further opportunities for fish-farming. Boats have to go further out and spend more time looking to find the stock they are looking for which increases operational costs. In addition restrictions on catch amounts and species caught are making fishing more of a challenge. This trend is unfavourable for the fish industry but may have some benefits for the fish-farming sector. With further complexities affecting the fishing sector, farming of fish will become a more viable alternative source of fish.

Future Risks

Climate change

A major risk to the fish-farming sector's growth is the prospect of climate change. There are three potential threats that relate to the fish-farming sector that climate change brings. Firstly there will be an increased likelihood of natural disasters including floods, droughts, and freak storms. These can easily destroy a fish-farm. Secondly climate change is likely to lead to less available water for fresh water fish-farms which is usually require a steady water supply (Bostock et al. 2010). Thirdly Unsuitable fish-farming conditions are probable through changes in temperature.

The global expansion of fish-farming will also contribute towards climate change on some level and may be limited to prevent further contribution of humanity to climate change (Shelton 2014).

2.5. Conclusion

As discovered in the PESTLE analysis, there are certain key opportunities for the development of the fish-farming sector in South Africa. With political support, economic opportunity and growing technological skills the fish-farming sector appears to be in a good position for growth. Figure 2-9 indicates that this growth is happening and that from 2002 to 2011 there has been a significant increase in the value of aquaculture products produced in South Africa.

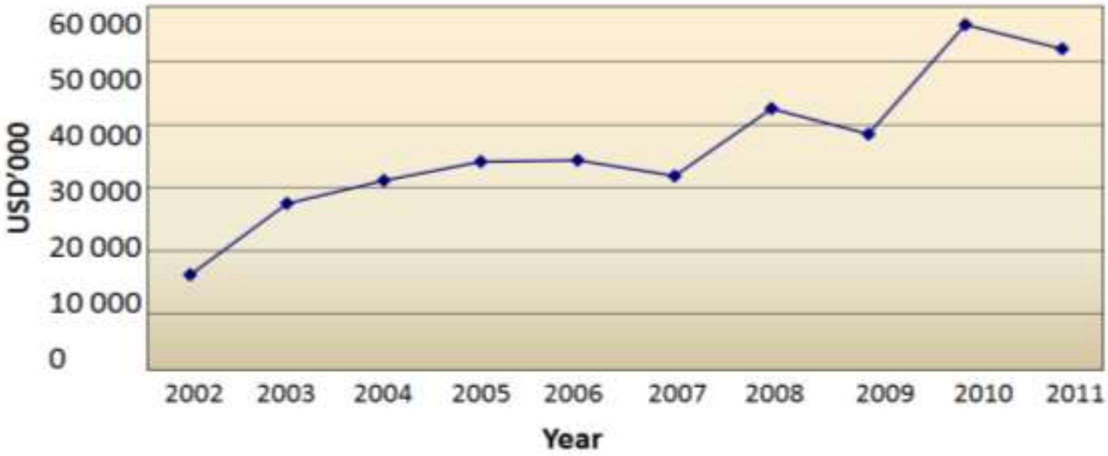

Figure 2-9 Gross value of aquaculture production in South Africa

SOURCE:(DAFF 2013A)

This growth has nonetheless been expected to be even more significant but has been hindered by key challenges and risks facing the sector. These key challenges and risks are multifaceted. They originate from various areas including South Africa's current lack of political support, the countries unaccommodating economy, its social complexities, its relating underdeveloped technological sector, a legal environment that covers the sector in red tape, and an environment that is not entirely suited to the expansion of a fish-farming sector. South Africa is consequently still far behind many countries when fish-farming is concerned and requires a range of multifaceted initiatives to lower these barriers. Overcoming these obstacles will open the doors to utilise the opportunities available.

Chapter 3 : The suitable species for fish-farming in the South African context

3.1. Introduction

Fish-farming in South Africa is an opportunity that can become highly beneficial or very destructive. The outcome of an expanding fish-farming market in South Africa is largely dependent on the approach that is taken and in particular the species of fish that are used for cultivation. Knowing exactly what species will be the most beneficial for fish-farming in South Africa will help enable the country to expand the sector. Deciding which species are the most suitable is a difficult and a multifaceted task, however, this article attempts to overcome this challenge. The research question that this article then asks is the following:

> *Which species of fish are the most suitable for the sustainable growth of fish-farming in South Africa?*

The question will aim to establish what species should be used for fish-farming in South Africa and what advantages the potential species have to drive the sector.

The article begins, firstly, with a literature review to set the context of the study, secondly, the article goes into an explanation of the research methodology and design and, lastly, the results from the research and analysis is presented and discussed.

3.2. Literature review

Due to fish-farming's infant state in South Africa the academic literature that is available is similarly unfledged. In addition available literature that exists tends to be of a finely tuned scientific nature. This literature review was used to absorb knowledge from the existing literature to build a platform of understanding for the study.

In particular the literature review has three focal areas including; the importance of choosing the right species for fish-farming, the current scenario of species used in South Africa for cultivation and an introduction to the species which appear to be the best for the sustainable growth of the fish-farming sector in South Africa and will be used in the study.

3.2.1. Choosing the right species

Choosing the right species for a fish-farming project is essential to the success of the fish-farm and the impact the farm will have. The choice of culture species is closely linked with the objectives of the development and the context in which the species will be farmed (Baluyut 1989). Not all fish species are suitable for aquaculture and some cultivable species are more appropriate for large-scale, commercial aquaculture rather than for small-scale operations. In many situations it may even be beneficial to farm a variety of species rather than one particular species to achieve the desired outcome.

The choice of species for culture should depend on a number of key considerations including the availability of suitable sites for culture, the biological characteristics of the indigenous or introduced/exotic species, their suitability for culture, and their acceptability in the local or international markets, and the availability of technology and other requirements for their culture (Kolkovski et al. 2012). In addition to these considerations, specific biological and other attributes of the fish should be considered to understand if they are suitable for cultivating under the proposed conditions. An example of this is experienced when farming in a water-stressed area, as it is important to find a fish species that is more stress tolerant to poor water quality and does not need to be farmed in flow-through systems or sea cages (Kolkovski et al. 2012).

A common conundrum when choosing which the most suitable species are is that it will often lead to a choice between two situations. Firstly, a fish that has an established market or would be easy to market but is difficult or expensive to produce, and secondly, a species with a high biological feasibility for production but the associated market demand may not be ideal (Appleford et al. 2012). The strengths of the species need to be weighed against the weakness to decide if the species is suitable for achieving the desired outcome of a fish-farm.

If the species has been widely cultured previously in the region then the culture techniques are likely to be well developed and cultivation will be relatively simple (Appleford et al. 2012). On the other hand species that have not been cultivated widely in the area require pilot projects to test the feasibility of the species before it can be determined as effective. This would add much more of a challenge to cultivating the species and those pioneering the species will take up majority of the risk and financial burden involved. It is therefore important to look at case studies to see how a species performs and what challenges may face each particular species (Rural Fisheries Programme 2010).

Each species has particular spill over effects that effect the socio-environmental system that the farm exists in(Tisdell 2005). If the species is to drive sustainability it is important that these negative spill over effects are reduced and positive spill over effects are enhanced. If this is not taken into account then the introduction of a species may cause more harm than good. A classic example of this is the tragedy of the commons that resulted at Lake Victoria in East Africa. In this example the Nile Perch species was introduced into the lake to cultivate a population for commercial fishing reasons (Balirwa 2007). The introduction of the Nile Perch led to great damage to indigenous species of fish living in the lake (Balirwa 2007). The impact of this however extended beyond the lake itself as it led to a disruption in the sustainable socioeconomic benefits of the lake which provided livelihoods and food to the local communities (Balirwa 2007).

3.2.2. Current species choices in South Africa

The varieties of species that are being used in South Africa for fish-farming purposes are constantly expanding. Furthermore many studies and pilot programs are in the pipeline, that are collecting data on the different species and how they perform in fish-farms. This section briefly explains what the current fish-farming species profile in South Africa looks like at this point. It does this by looking at the Marine, Brackish and Freshwater species separately.

Marine species

The use of marine species for fish-farming in South Africa is relatively uncommon at this point largely due to the challenges associated with cultivating these species. Figure 3-1 shows the distribution of marine aquaculture practices across South Africa and expectedly the map only indicates sporadic occurrences of marine fin-fish aquaculture in South Africa.

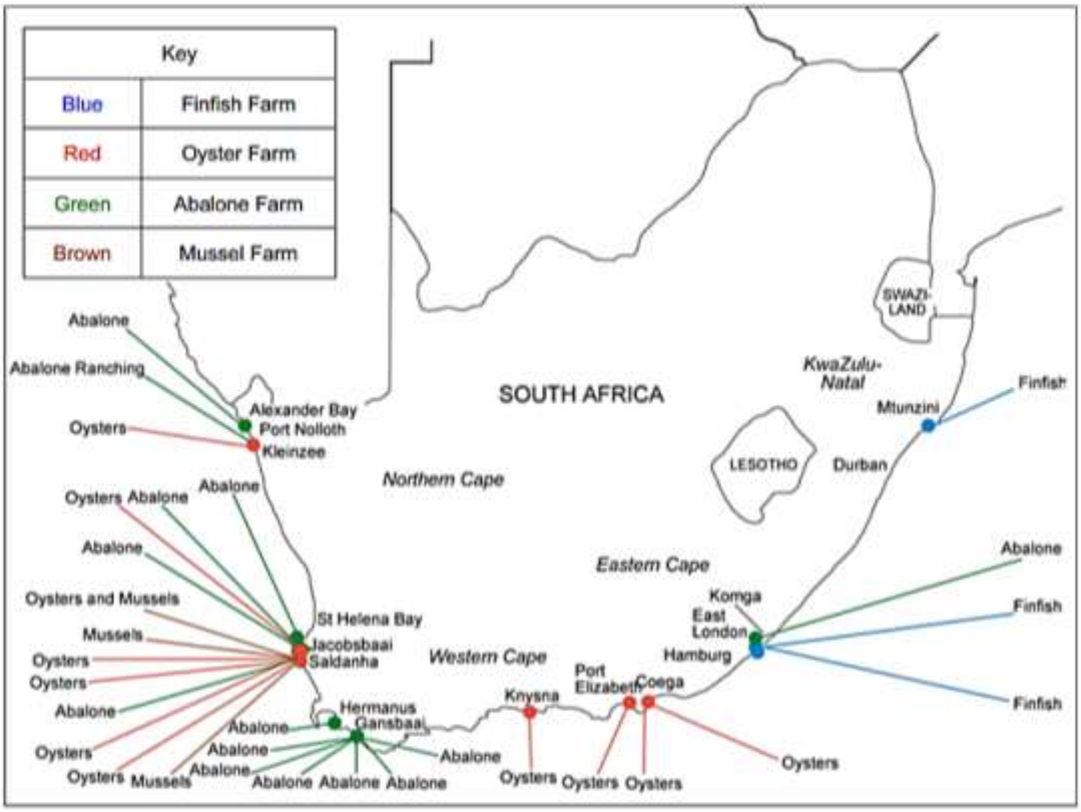

Figure 3-1 Mariculture farms in operation during 2011

SOURCE: (DAFF 2012)

Table 10 shows the species used in South Africa and shows their current operational scale. The table indicates that currently marine fish species are either in pilot programs or in a research stage except for Dusky Kob which are farmed commercially in the Eastern Cape. This shows that although most species for marine fish-farming are yet to reach commercial operational scale, there are plans for a variety of species to reach this level.

Table 3-1 Marine finfish species and their operational scale in South Africa during 2011

Common name	Scientific name	Operational Scale
Dusky kob	Argyrosomus japonicus	Commercial
Yellowtail	Seriola lalandi	Pilot
White stumpnose	Rhabdosargus globiceps	Research
Spotted grunter	Pomadasys commersonnii	Research
Yellowbelly rockcod	Epinephelus marginatus	Research
Atlantic Salmon	Salmo salar	Research

SOURCE: ADAPTED FROM (DAFF 2012)

Some marine species internationally have proven highly profitable and sustainable as seen by the Scottish Salmon farming which is one of Scotland's most successful industries (Scottish Salmon Producers Organisation 2013). The challenges around marine fish-farming however can be overwhelming which may be a reason for their uncommon occurrence in South Africa at this point. In particular some marine species have been criticized as having overwhelming environmental risks and that they are unsustainable in their production characteristics. This is mostly to do with the high cost feed supply needed for some of these species and that these farms at times consume more protein matter than they produce. There is however much research being done into improving the feed technologies for fish-farming and there are many international companies for example Aller Aqua that produce fish feed that comply with particular environmental management protocols and are conducting research into improving the efficiency of fish-feed (Aller Aqua 2015).

Improvements in technical skills and know-how around fish-farming of marine species in South Africa will open up doors to methods of fish-farming that reduce the necessary feed supply and environmental impacts. These improvements have been occurring in leaps and bounds (Ramsden 2013). From crude beginnings, fish-farming is now at a point where detailed scientific research can significantly change the outcome of farming (Ramsden 2013).It must not be forgotten that marine fish-species hold massive potential if these challenges are overcome and thus it is appropriate that many marine species of fish are going through research or pilot programs.

According to Figure 3-2 there was a significant portion of investment into the farming of marine finfish in 2011 which indicates that the growth of marine finfish-farming sector is impending in South Africa.

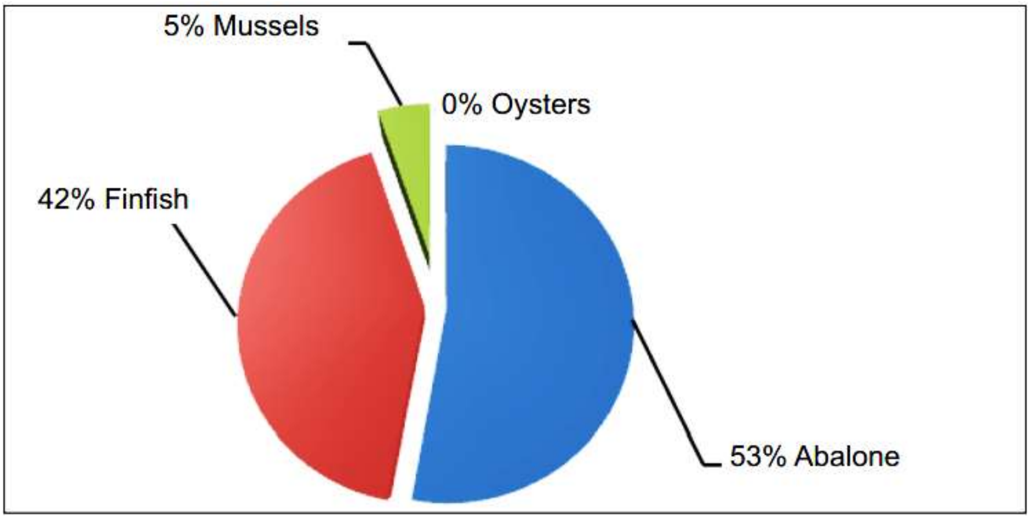

Figure 3-2 South African marine aquaculture capital investments made by sub-sector in 2011

SOURCE:(DAFF 2012)

Fresh water species

In South Africa the occurrences of fresh-water species in fish-farming are far more common than that of marine species(DAFF 2013a). Figure 3-3 indicates that there is some distribution of fresh water fish-farms across South Africa but the occurrences tend to clump in three main areas including Gauteng, the Western Cape and the northern Mozambican borders of Mpumalanga.

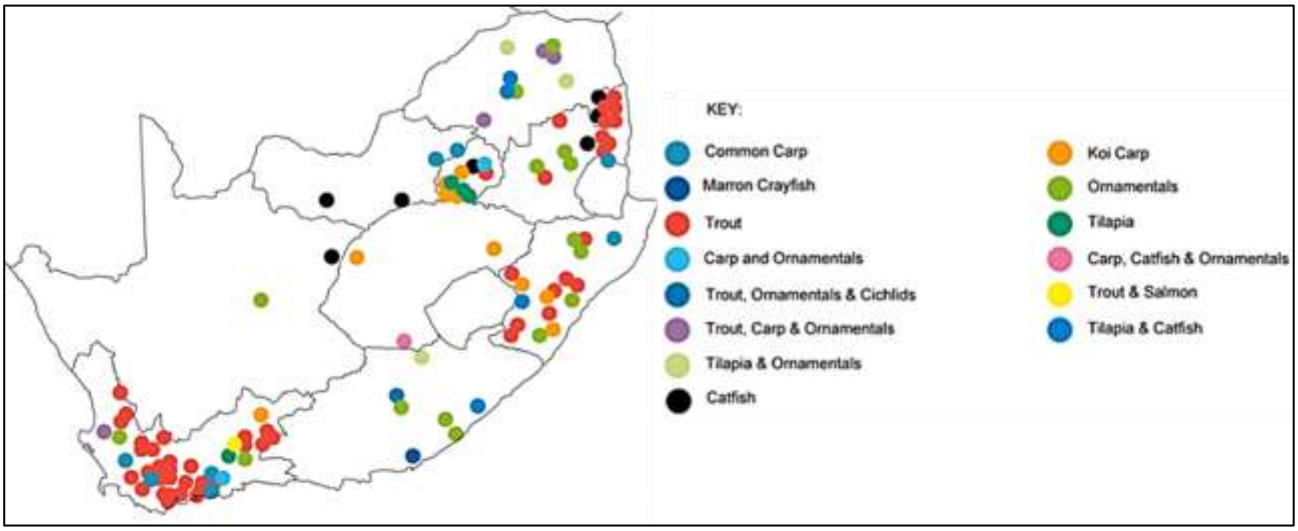

Figure 3-3 Freshwater aquaculture species and distribution in South Africa in 2011

SOURCE: ADAPTED FROM (DAFF 2012)

Table 11 further shows the emphasis on fresh water species in fish-farming as it shows that many fresh water species are already at a stage of commercial scale while there are some other species in pilot studies. The table indicates that the research on the species has already been performed which opens the opportunity for these species to be utilized.

Table 3-2 Freshwater finfish species and their operational scale in South Africa during 2011

Common name	Scientific name	Operational Scale
Rainbow trout	Oncorhynchus mykiss	Commercial scale
Brown trout	Salmo trutta	Commercial scale
Mozambique tilapia	Oreochromis mossambicus	Pilot scale
Nile Tilapia	Oreochromis niloticus	Commercial scale
Redbrest Tilapia	Tilapia Rendalli	Commercial scale
African Sharptooth catfish	Clarias gariepinus	Pilot scale
Common carp	Cyprinus carpio	Commercial scale
Largemouth bass	Micropterus salmoides	Commercial scale
Freshwater mullet	Myxus capensis	Pilot scale
Southern mullet	Liza richardsoni	Pilot scale
Flathead mullet	Mugil cephalus	Pilot scale
Cichlids Family	Family Cichlidae	Commercial scale
Atlantic Salmon	Salmo salar	Pilot Scale

SOURCE: ADAPTED FROM (DAFF 2012)

Currently fresh water species are well used in comparison to marine species but many marine and fresh water species with great potential are still in the pilot stage and have yet to have a commercial impact.

3.2.3. Species showing potential in South Africa

The current species profile in South Africa is therefore heavily weighted in the direction of fresh water species; however increased future usage of marine species is likely due to research and pilot studies that are being conducted by both private sector institutions as well as governmental organisations. A balanced usage of fresh and marine species is very possible in the future, and both fresh water and marine species are showing promise of great potential for fish-farming in South Africa

When analysing the literature base on the cultivated fish species in South Africa the following seven species stood out as having the most potential for driving the sustainable growth of fish-farming in South Africa. The following are made up of four freshwater species, one brackish water species and two marine water species. These are used as the samples for the study.

Fresh Water Species

African Sharptooth Catfish (Clarias gariepinus)

The farm-raised catfish industry in the United States has shown great value through long term growth and has contributed significantly to economic development of rural economies (Hanson et al. 2013). African Sharptooth Catfish can be produced most economically in tropical and subtropical countries, which indicates that in within certain parts of South Africa the African Sharptooth Catfish could be a very suitable candidate for farming (NDA 2012). In contrast to this, Henk Stander (2007), a researcher in aquaculture at Stellenbosch University, has explained the rise and fall of the Catfish industry in the South Africa's past. Although the fish are ideal for production and have a good flavour, they are difficult to sell (Stander 2007). He has indicated the problem with the local market is that they find the African Sharptooth Catfish unappealing in its appearance detracts people from eating it, but with the right marketing in place African Sharptooth Catfish could be a great option for fish-farming in South Africa(Stander 2007).

Nile Tilapia (Oreochromis niloticus)

The organisation, Lake harvest (2013) argues that Tilapia is "the fish of the future". In the past 20 years, research has been undertaken in the field of Tilapia farming to such an extent that Tilapia farming has become commercially viable and is becoming popular in many countries within Europe, Africa and both the Americas (Elsenburg 2012). Many academics however have argued the difficulties of Tilapia farming in South Africa relating to temperature but according to James (2012) Tilapia farming in South Africa can be very successful if a few fundamentals are followed. Such fundamentals include maintaining an efficient filtration system, ensuring the whole system is robust and simple, and electricity costs need to be kept low. In the context of Thailand, Tilapia has been earmarked as a sustainable choice largely due to its low environmental impact in the area and its high economic yields and this could apply to the South African context in the same manner, if certain challenges are overcome.

Rainbow Trout (Oncorhynchus mykiss)

Trout farming is not a new practise in South Africa by any means but its potential as a sustainable food source is a growing concept. Trout farming dates back over 400 years in Europe, about 150 years in the United States and about 100 years in South Africa (Elsenberg 2012). In South Africa, Trout farming consists of about 35 small-scale production units that produce around 1,800 million tonnes annually (Stander & Brink 2009).

Trout farming has an added benefit in that it can be used as a form of eco-tourism as Trout fishing is a common recreational activity (Stander & Brink 2009). There are, however, a number of challenges with Trout farming including seasonally limited fresh water sources and environmental conditions that are not ideal for Trout farming in most parts of South Africa (Stander & Brink 2009). If these challenges can be addressed, Trout farming will become even more successful in South Africa.

Common Carp (Cyprinus carpio)

The Common Carp is one of the oldest domesticated species of fish for food. Culture of Common Carp in China dates back to at least the 5th century BC, although domestication began much later

(Flajšhans & Hulata 2007).The Common Carp was a luxury food in the middle and late Roman period, and it was consumed during fasting in the middle Ages (Holtan 2011). In contrast Common Carp in South Africa has a negative ideology with many consumers largely due to their bottom-feeder habits. Statistical data also indicate that common Carp production may have come close to its limit (Flajšhans & Hulata 2007). Despite these negatives in the South African context the common Carp could be used as an inexpensive source of protein to feed the masses of undernourished citizens. During 1980's in South Africa there were in fact programmes to farm common Carp for food in rural areas and to develop livelihoods, but these programmes seem to have faded (Rouhani & Britz 2004).

Brackish species

Atlantic Salmon

The farming of Atlantic salmon began in the 19th century as a means of stocking waters to enhance wild returns for anglers and now worldwide production of Atlantic Salmon has reached 1 000 000 tonnes annually (FAO Fisheries and Aquaculture Department 2014e). Locally there have some attempts to farm the species and pilot programs have been developed but it is a complicated species to farm due to its brackish characteristic (DAFF 2012). Atlantic Salmon are naturally found in the cold waters of the North Atlantic some distance from South Africa's shores, but certain cold Western Cape currents help to replicate their natural habitats.

Marine species

Yellowtail (Seriola lalandi)

The history of yellowtail culture in Japan began over 70 years ago (Nakada 2008). Before that, fishers cultured undersized fish in ponds and sold them when they reached marketable size. Currently Yellowtail stocks off the coast of South Africa are in a healthy state and form a large part of the country's fishing haul(SASSI 2014).

Farmed fish have a different environmental impact to wild-caught fish and It has even been argued that currently farmed yellowtail are considered less sustainable than the wild line-caught option (SASSI 2014). However as natural stocks of yellowtail decline and farming methods for yellowtail become more efficient and environmentally friendly, farming yellowtail will become a viable option.

Dusky Kob (Argyrosomus japonicus)

In South Africa, Kob is sought after by both commercial and recreational fishermen alike. Over the past 5 years, the fish stock has been declining rapidly and It is estimated that 95% of the stocks have disappeared due to commercial exploitation (Otgaar 2012).

Recent years have however seen examples of successful Dusky Kob farms in South Africa particularly in the Eastern Cape (Burgess 2013). Pressure on wild Dusky Kob stocks, seems to ensure a good future demand for Dusky Kob producers that can offer a regular alternative to wild-caught fish (Burgess 2013). Dusky Kob produced on land has also been listed as a 'Green' best choice by the Southern African Sustainable Seafood Initiative(SASSI 2014).

3.3. Research design and methodology

3.3.1. Research design

This article uses a variety of analysis methods and styles of analysis to discover which species are the best for fish-farming in the South African context. The analysis method used for this article is a sub-section of Multi-criteria decision analysis (MCDA) called Analytic Hierarchy Process (AHP). According to Belton and Stewart (2003) MCDA is a structured technique which seeks to take explicit account of multiple criteria in helping researchers to organise and analyse complex decisions.

The AHP provides the same benefits as do MCDA models in terms of focusing the decision makers attention on developing a formal structure to capture all the important factors likely to differentiate a good choice of an option from a poor one (Department for Communities and Local Government 2009). AHP develops a linear additive model as seen in Figure 3-4, which indicates samples that will be compared, as well as, what they will be compared against.

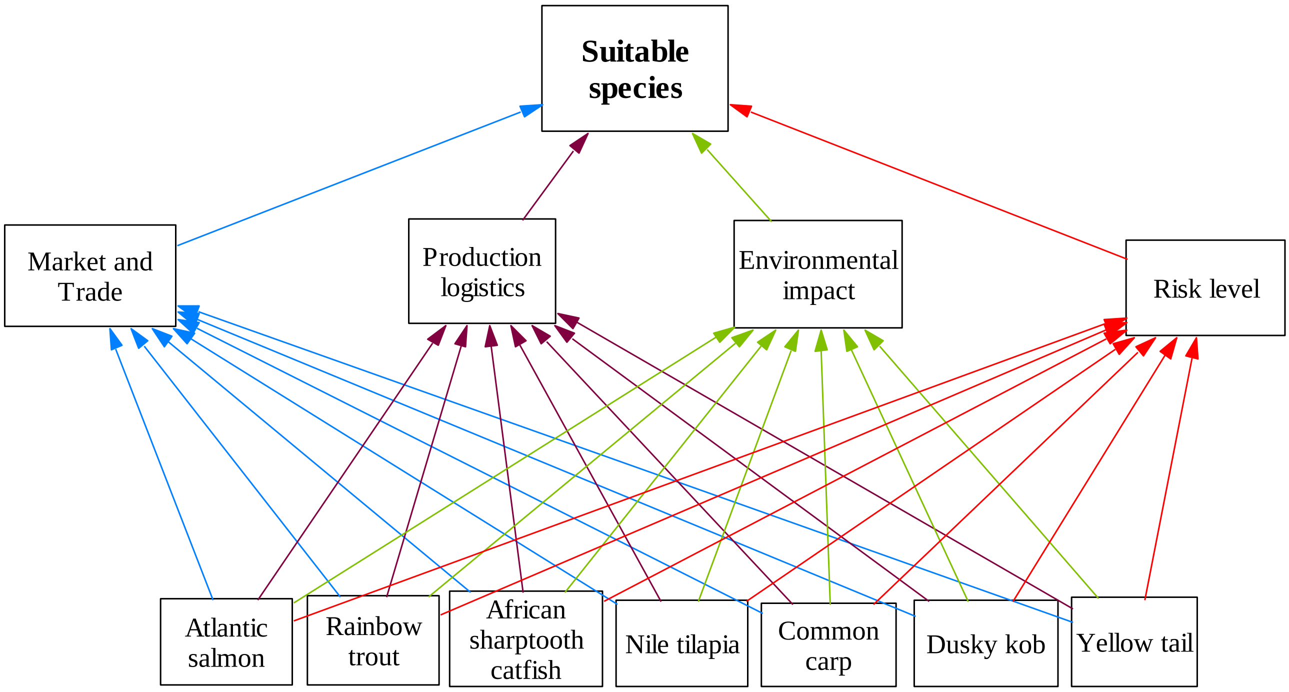

Figure 3-4 Analytical Hierarchy Process Analysis Structure

In its standard format AHP, uses procedures for deriving the scores achieved by alternatives which are based, respectively, on comparisons between criteria and between options (Department for Communities and Local Government 2009). Thus, in assessing scores, the decision maker is asked a series of questions, each of which asks how well one particular criterion is scored (Department for Communities and Local Government 2009). The individual criteria are divided into four different categories that aimed to analyse which fish species will be the best for the sustainable growth of the fish-farming sector in South African. The first criteria category incorporates the market and trade factors of the fish species. This is essential to understand if there is a place in the market for the farming of the particular fish species in South Africa. The second category of criteria consists of the production logistics that need to be considered when farming a particular species. This category will essentially assess the costs and difficulties involved in the production process of farming a particular species. The third category of criteria assesses the environmental impact that the farming of a particular species is likely to have. The farming of fish directly impacts the environment one way or another however certain species and methods of farming those species will determine the length of this impact (Hinrichsen 2006). The fourth category of criteria assesses the potential risk involved with farming a particular species of fish. Anything with high possible reward is likely to have risks attached to it and these risks should be carefully understood.

Once the information from the data gathering was collected it was adopted into the table format which has a rating system to derive a score for each category, as seen in Table 3-3. The author conducted the scoring by comparing each of the species with one another across each individual criterion according to the data that was collected during the research process. Appendix 1 further explains each individual criterion that falls under the four categories. Each criteria category was weighted equally as they are seen as equally important in determining the suitability of a fish species for sustainable cultivation.

Table 3-3 Category table market and trade example

	Species	African Sharptooth Catfish	Nile Tilapia	Rainbow Trout	Common Carp	Yellowtail	Dusky Kob	Atlantic Salmon
Criteria	Local demand vs Supply	-0.5	0.5	1.0	-0.5	0.5	0.5	0.5
	Export demand vs supply	0.0	-0.5	0.0	-1.0	0.0	0.0	0.0
	Market value of the species	-0.5	0.0	1.0	-1.0	0.5	1.0	1.0
	Expected future trends in market	0.5	1.0	0.5	-1.0	0.5	1.0	0.0
	score	-0.13	0.25	0.63	-0.88	0.38	0.63	0.38

Table 3-3 shows that a rating is given to each species across each criterion, which could either be very good, good, average, bad, or very bad. All ratings are relative to the other species and not a general rating. For example giving a good environmental rating does not mean it is good for the environment but rather, it is good in comparison to the other species. The rating was then translated into a numerical value, with a score of -1 given for a very bad rating, a score of -0.5 given for a bad rating, a score of 0 given for an average rating, a score of 0.5 given for a good rating and a score of 1 given for a very good rating. The scores were then added up and a total score was given for each category which was then used to give each species a score across all four categories.

Once all these results have been determined the particular species which according to the criteria would be the best for fish-farming in the South African context are determined. There is however more than one fish species that could be considered the best for fish-farming in South Africa due to the nature of the economy, the environment, society and global influences.

3.3.2. Research Methodology

Three different models of data collection were used for this article including; literature review, online analysis and interviews. This section discusses why and how each of the data collection tools was used for the purpose of this study.

This involved reviewing different literature to understand what complexities exist in the literature and what research has been put together. The literature review was also important in forming criteria for assessing the fish species. This was conducted by scanning all the available literature on fish species and fish-farming in South Africa and other relevant themes.

During the online analysis a range of data was collected from numerous online sources consisting mostly of grey literature in the form of governmental documents and specialist reports. This allowed for a collection and analysis of all the required information that was needed for analysing each particular species of fish.

The interview process was chosen as a method to gain further information and opinion on fish-farming species in South Africa as well as to discuss results of the study. This allowed for additional information and outlook that did not come up in the literature analysis and the online analysis. The interviews were approached with impartiality to avoid biased results and therefore there was no structured set of questions taken into the interviews. The interviews were primarily based in the Western Cape due to the region being a hot spot for fish-farming in South Africa.

When gathering data for the online analysis section of the research, a sampling method was used to ensure quality of the data. Only current data was used as the information on this topic is changing rapidly and new information is released regularly. Therefore when performing the online analysis, the information was only used if it was released in the year 2010 or later except in certain cases where the information was still relevant.

In order to determine the sample for the interviews, key specialists on fish-farming and the fishing sector were identified. The technique to identify these individuals began by understanding what segments of the fish-farming sector needed to be understood. To do this an analysis of the value chain for fish in South Africa was conducted.

After the types of people that needed to be interviewed were determined the next step was to track down who these people were. To do so the method of networking known as snowball sampling was used.

The snowball sampling was conducted began with the author attending of a variety of conferences, workshops and meetings relating to aquaculture. During these events many key companies and personnel for the sake of the interviews were taken note of and engaged with. From these engagements other key companies and personnel were taken note of. After some time a contact list of who should be interviewed was created and further internet searches were conducted to determine if any key personnel were missing from the list.

The key interviews that were then targeted consisted of nine interviews with individuals from the following organizations;

- Woolworths
- Three Streams
- Faculty of Forestry and Agricultural Sciences, University of Stellenbosch
- Department of Animal Sciences, University of Stellenbosch
- WWF: SASSI division
- The Business Place
- Spier Wine Estate

An aquaculture/aquaponics think-tank based in Stellenbosch was also attended that comprised of individuals starting-up in the aquaculture sector or with research interests. Meetings were held to discuss the experiences challenges faced by those entering the aquaculture sector.

The fish types that were chosen for the AHP analysis were determined through the literature analysis. The species that were chosen had to be finfish that are used for food due to the aim of the study. The fish that seemed to have the most support from the literature base were chosen. A mix of fresh water and marine species for the final selection was also noted as preferable when analysing the literature.

3.4. Results

This section of the article presents the results that were generated during the research process and discusses what these results mean when deciding which fish are the best for fish-farming in the South African context. It begins with the AHP analysis which is used to portray the results of the research and compare the results of the different fish species. Once this has been done the overall results of the fish species will be discussed and the best fish species for fish-farming according to the study will be discussed. After the results will be discussed and further interpreted to understand which species provide the biggest opportunity for the sustainable growth of South Africa's fish-farming sector.

3.4.1. Analytical Hierarchy Process Analysis

There is a main assumption that must be noted before confronting the AHP analysis. The way in which a species of fish is farmed has influence on how it will perform in the criteria. In addition there are normally different ways in which you can farm a fish species. For the sake of this study the following farming methods seen in Table 13 were used for each fish species.

Table 3-4 Assumed farming method for each species

Fish Species	Farming Method
African Sharptooth Catfish	Pond Culture
Nile Tilapia	Pond Culture
Rainbow Trout	Raceways
Common Carp	Pond Culture
Atlantic Salmon	On Land Hatchery Pond, On Sea Cages For Adults
Yellowtail	On Land Hatchery Pond, On Sea Cages For Adults
Dusky Kob	On Land Recirculating System

These methods were chosen as they are likely to be the most common methods of farming which would be used to farm each fish species. These are likely to change in the next few years due to pilot programs and research which may make different farming methods more suitable to utilize.

The Market and Trade

If there is no opportunity in the market place for a species, producing the fish will be of no value. It is also important that the market values the species at a high enough level to cover the production costs and still make a profit. Certain species target different segments of the market and this category will determine if there is an appropriate market for these species.

Table 14 indicates the scores that have been given to each species when judged on their relating market and trade factors.

Table 3-5 Score summary of market and trade criteria

	Species	African Sharptooth Catfish	Nile Tilapia	Rainbow Trout	Common Carp	Yellowtail	Dusky Kob	Atlantic Salmon
Criteria	Local demand vs Supply	-0.5	0.5	1.0	-0.5	0.5	0.5	0.5
	Export demand vs supply	0.0	-0.5	0.0	-1.0	0.0	0.0	0.0
	Market value of the species	-0.5	0.0	1.0	-1.0	0.5	1.0	1.0
	Expected future trends in market	0.5	1.0	0.5	-1.0	0.5	1.0	0.0
	score	-0.13	0.25	0.63	-0.88	0.38	0.63	0.38

African Sharptooth Catfish

Marketing of African Sharptooth Catfish in South Africa has proven to be problematic due to the inability of producers to sell their product at a higher price than production costs. African Sharptooth Catfish is largely unknown in the South African market place and marketing efforts have been unsuccessful (WCADI 2012). In the past this resulted in a collapse of the market for the species in South Africa (FAO Fisheries and Aquaculture Department 2014a).

There is potentially an untapped black urban market for Catfish, provided the price is low and a distribution network is established (WCADI 2012; DTI & Enviro-fish Africa 2007). African immigrants from Nigeria, Democratic Republic of Congo and other countries will readily buy Catfish which is a traditional dish but this market is expected to be relatively small. On the other hand it has also been predicted that the market for the species will grow in the next few years and production could reach a value of up to R150 million (NDA 2012). Much of this is likely to be export Asian countries struggling to keep up with their domestic demand.

Nile Tilapia

The tilapia industry is still in its infancy in South Africa, but investing in tilapia farming can be a lucrative investment with potential as a quality source of protein. The biggest constraint to tilapia farming at present is the lack of a market for the fish. Fish traders in local communities are the biggest suppliers for now as the industry's low production cannot fulfil the needs of the formal markets. The industry has formed a producers' association which will promote, develop and drive the industry as well as create a reliable supply of Tilapia (James 2012). The global market for tilapia is currently a challenge for South Africa as in parts of Asia producers are producing large quantities with low costs making it difficult for an infant market like South Africa to compete (Elsenburg 2012).

Rainbow Trout

Rainbow Trout in South Africa is a high-value food fish with an established market (Rural Fisheries Programme 2010). Although costs to produce Rainbow Trout in South Africa are higher than in Europe, the sector manages to keep competitiveness and stability, particularly with value-added products(Stander & Brink 2009). According to Weaver (2013) South Africa has seen the development of a "trout loyal" sector within the local market which was not affected by the sudden drop in salmon prices that were experienced world-wide around the second quarter of 2012. There has been a 72% increase in investment within the industry over the past five years which illustrates the confidence within the industry of its potential to grow (Weaver 2013). It has been speculated that the market has not been fully untapped at this point.

Common Carp

Common Carp were thought to hold aquaculture potential for many years but their poor acceptance as an eating fish has impacted their commercial production. It appears that the commercial market for Common Carp is insignificant and unlikely to take-off in South Africa but if marketed effectively Common Carp may have a potential in informal markets. The low production cost of the fish could fulfil a high demand for cheap protein in South Africa but consumers and cultural perceptions of the fish pose as an overwhelming obstacle (Rural Fisheries Programme 2010).

Yellowtail

According to SASSI (2014)the fishery of Yellowtail is operating at or close to an optimal yield level, with no expected room for further expansion of harvest. Yellowtail is a well-known South African species and is the second most commonly caught species the line fishery, after Snoek (SASSI 2014). Farmed Yellowtail is a versatile eating fish, which has been successful in various overseas markets and in particular Australia and Japan (Nakada 2008). In 2009 348tonnes of Yellowtail were caught off South Africa's shores and it is possible that this current supply and a growing demand of yellowtail could be substituted and supplemented by farmed yellowtail in the near future (WCADI 2012).

Dusky Kob

Kob have been heavily targeted by commercial line-boat fisheries as it is a well sort after fish, leading to a collapse in the population (Cawthorn et al. 2011) . Today the kob species is considered threatened, but not yet critically endangered (Otgaar, 2012). Dusky Kob currently makes up the majority of farmed marine finfish in south Africa with five recorded operations as of 2009 (Eastern Cape Development Corporation 2009). The species is yet to become very present in the global market and domestic markets for Dusky Kob are not very well understood at this point (WCADI 2012). An example of the potential market of the species is seen by Oceanwise, a company based in the Eastern Cape, which is producing farmed Dusky Kob for Woolworths who are able to sell it as a premier product at a high price(Woolworths 2014). If farmed Dusky Kob can take off in this high income market it will become a lucrative option for cultivation. There are however still questions about whether the public will be willing to pay more for the farmed product over the wild caught product.

Atlantic Salmon

The local market for Atlantic Salmon in South Africa is relatively small at this point but has been described as vibrant (WCADI 2012). On the other hand the product has been commoditized internationally and has seen production expansion in recent years. The development of an infant local market in South Africa is likely to be met with much competition from abroad. The market for locally farmed Atlantic Salmon will hinge predominantly on the price of the fish compared to imported fish. Globally the market outlook for the salmon industry looks positive, and salmon prices are expected to remain high on the back of expected slower production growth (FAO Globefish 2014).

Production Logistics

Species for fish-farming are generally chosen on their ability to perform well under farmed production and for their low production costs. Due to fish-farming's infancy in South Africa and subsequent lack of technology and research it is important that species that are produced easily are chosen.

Table 15 indicates the scores that have been given to each species when judged on their production logistics.

Table 3-6 Score summary of production logistics criteria

	Species	African Sharptooth Catfish	Nile Tilapia	Rainbow Trout	Common Carp	Yellowtail	Dusky Kob	Atlantic Salmon
Criteria	Feed requirements and feed availability	0	1	-0.5	1	-1	-1	-1
	Growth rate	0.5	0.5	0	0.5	0.5	0	0.5
	Availability of suitable locations	0.5	0.5	-0.5	0.5	-0.5	0.5	-0.5
	Reproduction characteristics or Seed availability	-0.5	1	0	0.5	-0.5	-0.5	-0.5
	Level of research and development of farming the species	0.5	0.5	0.5	0.5	-0.5	0	-0.5
	Water usage	-0.5	-0.5	1	-0.5	1	0.5	0.5
	Start-up costs	0.5	0.5	0	0.5	-0.5	-1	-0.5
	Energy usage	-0.5	-0.5	-0.5	-0.5	0.5	-1	0.5
	Management input	-0.5	0.5	-0.5	0.5	-0.5	-0.5	-0.5
	score	0.00	0.39	-0.06	0.33	-0.17	-0.33	-0.22

African Sharptooth Catfish

African Sharptooth Catfish is a fast-growing species which is also tolerable to temperature and water quality change (Rural Fisheries Programme 2010). African Sharptooth Catfish experience optimum growth rates between 25-33 °C and are thus only suited to the warmer climates of South Africa(Rural Fisheries Programme 2010). There are some additional challenges to farming African Sharptooth Catfish. Firstly, the species has difficulties attached to its reproduction which in farming environments require specialized breeding techniques, secondly, the species experiences cannibalism amongst its juveniles and needs to be farmed at high densities to avoid this, thirdly, there is a relatively high feed cost associated with catfish, fourthly, African Sharptooth Catfish generally require a daily water exchange rate of 25%, and lastly, farming Catfish requires high management input to sort species according to size (Rural Fisheries Programme 2010). Culture technology for African Sharptooth Catfish farming is however well developed, and these challenges have mostly been solved (DTI & Enviro-fish Africa 2007).

Nile Tilapia

Tilapia are associated with fast growth rates when in optimal temperatures between 20-25°c (Rural Fisheries Programme 2010).Once mature they reproduce every few months and the adults tend to take good care of their eggs and fry unlike most other aquaculture species(Rural Fisheries

Programme 2010). The species does however have some difficulties as they tend to mature early and over-reproduce in ponds which can lead to stunting of growth and they struggle to grow in temperatures below 20°c (Rural Fisheries Programme 2010). Nile tilapia are herbivores and do well in very enriched waters, usually enriched through organic fertilizers (FAO Fisheries and Aquaculture Department 2014d). Feed costs for tilapia production are therefore relatively low compared to most aquaculture species.

Rainbow Trout

When farming Rainbow Trout there has been a move away from low-cost-high-risk cage culture production systems with new farms and already established farms opting rather for intensive recirculation systems. Local improvements in recirculation technology and the availability of this technology to the local sector has facilitated this move which helps to deal with the shortages of adequate fresh water in South Africa (Weaver 2013). Trout farming in South Africa is limited to certain areas as they prefer cooler temperatures between 12-18°c and come under stress when water temperatures exceed 21°c (Rural Fisheries Programme 2010). They are restricted to Drakensburg mountains and the Midlands in KwaZulu-Natal, in higher regions of Mpumalanga, and the Western Cape (WCADI 2012). Fingerlings are unfortunately only obtainable from hatcheries but they are easy to spawn and there are currently fingerling suppliers in South Africa (Rural Fisheries Programme 2010). Rainbow Trout can also be cultivated at relatively high densities, which reduces the size of the farm needed.

Common Carp

Common Carp hold much production potential due to their wide temperature tolerances. The species also feed mainly on plant material which reduces feed costs (Rural Fisheries Programme 2010) . They are fast-growing, very easy to breed and grow, are able to grow in high densities and can survive a wide range of water qualities(Rural Fisheries Programme 2010). Additionally Common Carp can reach up to 1kg in a growing season when in optimal temperatures of 23-30°C (FAO Fisheries and Aquaculture Department 2014b).

Yellowtail

Optimal temperatures for Yellowtail culture are between 20-25°c and the species is thus suited to many parts of the South African coastline and the species grows well under cage culture conditions (WCADI 2012). Fry and fingerling production require complex land based hatchery systems including a live feed production facility. Under optimal conditions the species can grow up to 1.5kg in 8 months (WCADI 2012). Feed for Yellowtail is relatively costly compared to freshwater species and consists of wild-caught and plant or vegetable protein (SASSI 2014). Sea cage farms are usually cheaper to establish and operate than onshore farms with equivalent production capabilities and provide more attractive financial returns on invested capital however, the suitability of the site is an important factor (YSI Environmental 2008). In addition it is still much cheaper to catch yellowtail than to farm it.

Dusky Kob

Optimal culture temperatures for Dusky Kob are warmer waters above 25°c and the species is thus suited to be farmed in the Eastern Cape or KwaZulu-Natal region(WCADI 2012). In the Eastern Cape species grow an average of 1.1kg in 12 months and they do well under tank or pond culture. Feed for Dusky Kob is relatively expensive compared to freshwater species and consists of wild-caught and plant or vegetable protein (SASSI 2014). Farming Dusky Kob in an on Land Recirculating System enhances the energy input required for production as the system requires water to be pumped through but once in motion little pumping is needed if managed effectively (Nazar et al. 2013). As seen with Yellow tail, it is still cheaper to catch wild caught Dusky Kob than to farm the fish.

Atlantic Salmon

Atlantic Salmon perform well under cage culture and in South Africa they would likely be cultivated in marine sea cages with a freshwater component for the breeding cycle to occur (WCADI 2012). Under optimal conditions the fish grow fast and can reach 1kg in 6 months (WCADI 2012). Optimal growing culture temperature are between 14-16°c and are thus suited to the Western Cape Coastline but the coastline has infrequent suitable sites in the form of geographically sheltered locations that protect cages from the high energy coastline with Saldanha being the only notable suitable site (WCADI 2012). Atlantic Salmon like most marine species have a particularly high feed input as it is made up mostly of fishmeal and fish oil(FAO Fisheries and Aquaculture Department 2014e).

Environmental Impact

Fish-farming practices as with other agricultural practices have the capability to damage and pollute ecosystems. Different species and the way in which these species are farmed determine the impact of a fish-farm. The impact of fish-farm on the environment is split into two categories including the resources that the farm uses up and the spill over from the farm, in the form of escapees and effluents.

Table 16 specifies the scores that have been given to each species when judged on their environmental impact.

Table 3-7 Score summary of environmental impact criteria

	Species	African Sharptooth Catfish	Nile Tilapia	Rainbow Trout	Common Carp	Yellowtail	Dusky Kob	Atlantic Salmon
Criteria	Effluent discharge	0	0	-0.5	0.5	-1	0.5	-1
	Eating habits	-0.5	1	0	1	-1	-1	-1
	Water consumption	-0.5	-0.5	0.5	-0.5	1	0.5	1
	Impacts on biodiversity	0.5	0.5	0.5	0.5	0	0.5	-0.5
	Impacts on natural stocks	0	0.5	0	0	0	0.5	-0.5
	Habitat destruction	0.5	0.5	0	0.5	0.5	0.5	-0.5
	score	0.00	0.33	0.08	0.33	-0.08	0.25	-0.42

African Sharptooth Catfish

Farming of African Sharptooth Catfish has the challenge of cannibalism amongst juveniles. This cannibalism is avoided by stocking the pond at high densities however this brings up different problems (FAO Fisheries and Aquaculture Department 2014a). When farming African Sharptooth Catfish in high density conditions the feed input required is needed to be more which is generally made up of 35-42% of crude protein (Rural Fisheries Programme 2010). In addition when farmed under intense conditions part of the water needs to be dumped regularly to avoid pollution of the water. This leads to wastage of water and if polluted the water can have other harmful effects on the environment. The environmental impact of farming the fish does however depend on how well the farm is monitored and regulated. African Sharptooth Catfish have also been known to be extremely invasive if they find their way into nearby water systems (WCADI 2012).

Nile Tilapia

Tilapias grow well on feed with lower protein levels and higher carbohydrate levels than the other analysed species (FAO Fisheries and Aquaculture Department 2014d). Tilapias are considered to be low on the food chain and this allows for their feed to be more environmentally friendly than other species. Pond culture of tilapia does however require a portion of the water to be dumped regularly to ensure that the water does not become polluted from excess feed and fish excretions. If this dumped water is not discarded responsibly then it may find its way into water systems and pollute them.

Rainbow Trout

Rainbow Trout are carnivorous fish, and therefore farming of trout requires artificial feed input which is partially made up of wild caught fish as the protein source (Weaver 2013). Farming rainbow trout through raceways also impacts on the environment as it diverts river water from its natural course which can impact the biodiversity of the river system. Poor management of the raceways can lead to escapees entering the river and pollution through uneaten feed, faeces and chemicals from disease treatment (FAO Fisheries and Aquaculture Department 2014c). However the trout industry in South Africa has been working very hard towards improving their practices and therefore trout farming usually happens in a reasonably responsible manner (SASSI 2014).

Common Carp

In South Africa Common Carp is an alien species and can be very invasive if it finds its way into water systems, however if farmed in ponds that are excluded from other water sources this risk is low. Common Carp farming at times can in fact be environmentally beneficial, as it can be utilized to help maintain aerobic bottom conditions in a body of water (FAO Fisheries and Aquaculture Department 2014b). Common Carp are peaceful omnivorous fish which consume a range of different natural foods, but Common Carp are flexible and opportunistic feeders that can switch from preferred to alternative diets according to the food availability (Hoole 2001). This makes feeding them a stress-free task relative to most other aquaculture species, and reasonably environmentally friendly.

Yellowtail

In South Africa yellowtail farming projects are currently using open cages at sea (Eastern Cape Development Corporation 2009). When using this method it is difficult to control the effect this production has on the surrounding environment. Feed input is required for production and any feed which is not eaten accumulates on the seafloor along with the faeces from the fish, this creates an increase in nutrients in a localized area which leads to nitrification and a depletion in oxygen in the area (Tanner & Fernandes 2010). Furthermore the feed companies do not have policies in place that pertain to sourcing feed ingredients from sustainable stocks at present (SASSI 2014). This system is also open to the sea and therefore there is a potential risk of escapes and disease transfer to the wild population (SASSI 2014).

Dusky Kob

On land farming of Dusky Kob has been noticed by the Southern African Sustainable Seafood Initiative as an environmentally sustainable option (SASSI 2014). Dusky Kob is an indigenous species which has become over fished and fishing of the species should be haltered. Dusky Kob farming using an on land recirculating system can be very environmentally responsible, and it can use up to 99 percent less water than other aquaculture systems and reduce the amount of waste discharge from the farm (Nazar et al. 2013). As with Yellowtail, feed companies do not have policies in place that pertain to sourcing feed ingredients from sustainable stocks at present and it is up to the farmer to ensure the fish are fed in a responsible manner(SASSI 2014).

Atlantic Salmon

Atlantic salmon has for long been notorious for its environmental impact when farmed. There are three reasons why this fish is not environmentally sustainable. Firstly, Atlantic Salmon farms release high levels of waste in the form of faeces and uneaten feed which pollutes surrounding water sources, secondly, escapees from the farms have had impacts on wild stocks through disease spread, and lastly, production of the fish relies on fish oil and fishmeal for feed which results in these farms absorbing more fish in their production than the amount of fish produced

(FAO Fisheries and Aquaculture Department 2014e). It is estimated that to produce 1kg of salmon requires 2-2.5kg of wild caught fish and thus is eating up more fish than it produces (Scholl & Pade 2005). Although this is not always the case and it largely depends how they measure its feed requirement. On the other hand the fresh water component of breeding restricts escapees from creating a naturalized population (WCADI 2012).

Risk Level

This section deals with the probability of problems to occur when farming a particular species of fish. Fish-farming is a risky venture which can result in disasters for the fish-farm and local inhabitants. It is important that species are chosen that have little risk associated with farming them to avoid failure of the venture and a burden on society.

Table 17 shows the scores that have been given to each species when judged on their risk level.

Table 3-8 Score summary of risk level criteria

	Species	African Sharptooth Catfish	Nile Tilapia	Rainbow Trout	Common Carp	Yellowtail	Dusky Kob	Atlantic Salmon
Criteria	Risk of disease spread	0	0.5	-0.5	0.5	0	0.5	-0.5
	Hardiness of the species	1	1	-0.5	0.5	0	0.5	0
	Risk to tourism	0	0	1	0	-0.5	0	-0.5
	Risk of predators and theft.	0.5	1	0	0.5	-0.5	0.5	-0.5
	Risk of escapement	0	0.5	0.5	0.5	-0.5	0.5	-0.5
	Success rate of previous farming attempts	-0.5	0	1	-0.5	0	0.5	-0.5
	score	0.17	0.50	0.25	0.25	-0.25	0.42	-0.42

African Sharptooth Catfish

African Sharptooth Catfish are hardy fish that can withstand changing living conditions but if water is not exchanged frequently enough then disease outbreak is likely (WCADI 2012). There is some risk of escapement with the species as they can breathe out of water and can maneuver from one water source to another if they are able to get out. Globally African Sharptooth Catfish-farms have seen much success but within South Africa a difficult market environment and high production costs has seen many failures of these operations (NDA 2012).

The production of this species is unlikely to pose any major risks to tourism in its vicinity unless they are able to escape and damage local biodiversity. When farming African Sharptooth Catfish majority of the predation happens amongst the fish themselves and can cause stress levels of the fish to increase which can lead to unwanted phenomena. Other predators include predominantly humans or birds (De Graaf & Janssen 1996).

Nile Tilapia

Nile tilapia are robust, disease resistant fish with particularly hardy bodies (Rural Fisheries Programme 2010). The species does not pose any realistic threats to the tourism industry at this point and is becoming more and more accepted by the public. Tilapias are prolific breeders and in aquaculture conditions can rapidly increase populations of small fish, rather than a stable population of harvest-size animals. In this situation certain predators are actually farmed alongside tilapia to reduce the number of small fish. Predation of smaller fish is thus normally not a problem. Successful tilapia farms are becoming more and more common in South Africa and neighboring states and through this, better farming methods are being developed to improve the overall success of farming the species.

Rainbow Trout

Rainbow Trout are susceptible to disease, and struggle in poor conditions (WCADI 2012). Rainbow Trout do not pose a risk to local tourism industries and can in fact contribute positively towards tourism as it is noted as a premier fish for recreational angling purposes (Rouhani & Britz 2004). The species is therefore noted as having potential to contribute towards ecotourism in an area (Stander & Brink 2009). Trout are a high value product and thus theft is possible if the farm is not protected effectively. Rainbow Trout farms in South Africa have generally been very successful in the past and history shows little risk of farm failure if the fundamentals of trout farming are followed.

Common Carp

Common Carp are a disease resistant species and are considered to be hardy (Rural Fisheries Programme 2010). Common Carp species particularly in Europe are popular as an angling fish and have been used to improve tourism of those areas. It is a relatively low cost fish and is unlikely to be a major target for theft. Risk of escapement of the species is very low if farmed in ponds or tanks but if they find their way into nearby water sources they can be a major threat to indigenous biodiversity. Common Carp aquaculture has been practiced for a very long time and the production of the species has proved to be very successful but markets for the fish have hampered the success of these farms.

Yellowtail

Yellowtail, as is typical of many marine species, cannot tolerate a wide fluctuation in the salinity of water, high turbidity, or pH fluctuation outside the narrow range 7.5 to 8.5 (Fielder & Heasman 2011). Predation is possible with on sea cages in the form of birds and water-based predators however cases of theft are not common at this point. Escapees are very possible if poor equipment is used when farming fish in on sea cages and this can pose risks to wild stocks of yellowtail if escapees spread diseases. Proposed sea cage farms for Yellowtail and other marine finfish situated off the coasts of South Africa have been met with some distaste from communities. There are claims that they will affect tourism in the areas due to the sisual and environmental impacts that these farms will have(The Fish Site 2009). In Australia there has been much success with the farming of Yellowtail in on sea cages, however in South Africa such operations are still in their initial stages and it is hard to judge their success at this point (Fielder & Heasman 2011).

Dusky Kob

Dusky Kob are relatively hardy fish with few disease problems when raised in good quality water (Fielder & Heasman 2011). Ninety percent of the water at Oceanwise is recirculated, helping to minimize the risk of disease within the system(Burgess 2013). Dusky Kob farmed on land in a recirculating system is unlikely to have a significant impact on tourism particularly if waste is disposed of responsibly. Risk of predation, theft and escapement are very low when farmed in an on land recirculating system (Nazar et al. 2013). In addtition, Oceanwise is illustrating that Dusky Kob farmed in an on land recirculating System can be done successfully in South Africa(Burgess 2013).

Atlantic Salmon

Atlantic Salmon are vulnerable to bacterial and viral diseases, and also to infestation by parasites, particularly sea lice(The Atlantic Salmon Trust 2014). The species thus needs to be closely monitored to avoid disease or parasite outbreaks. Predation is possible with on sea cages in the form of birds and water predators however cases of theft are not common at this point. Escapees are very possible when farming fish in on sea cages.

As with Yellowtail proposed sea cage farms for Atlantic Salmon are likely to be met with some distaste from communities. A past Salmon farm off Gansbaai was described as an ecological disaster and received much criticism from environmentalists (Scholl & Pade 2005). Globally the farmed Atlantic Salmon industry has had many success stories however locally there are no real examples of successful salmon farms.

3.4.2. Combined results

From the AHP analysis that was conducted a set of final results have been established on how each species performed. Appendix 2 shows the overall scores that each species scored when put up against the criteria that was generated. Overall the scores revealed the results shown in Figure 3-5 which indicates that Nile tilapia is currently the best species for cultivation in South Africa whereas Atlantic Salmon is the worst.

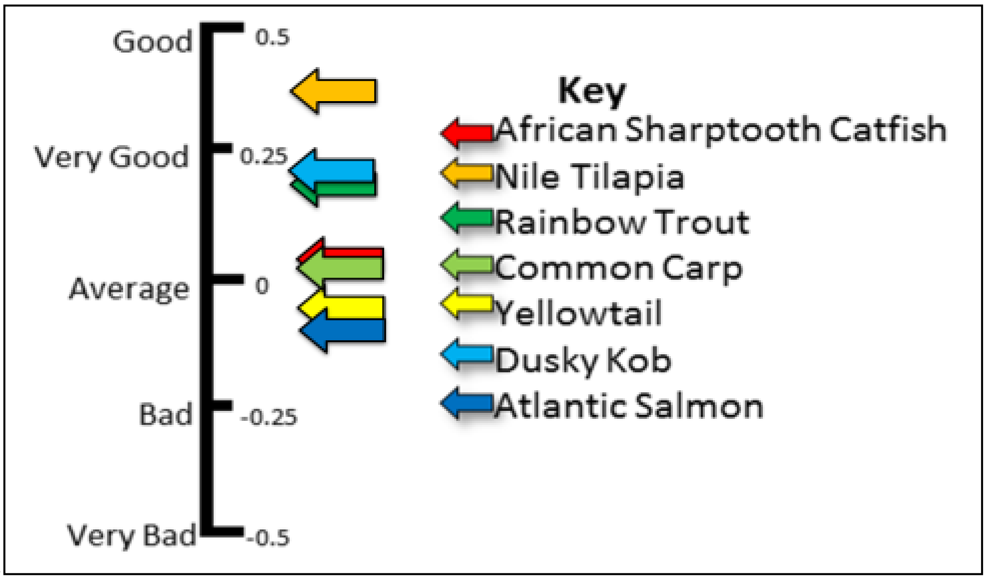

Figure 3-5 Positional results from the AHP analysis

What the overall scores do not tell us is where each species fell short and where they excelled. Figure 3-5 in comparison with Figure 3-6 however reveals why each species has performed as it did.

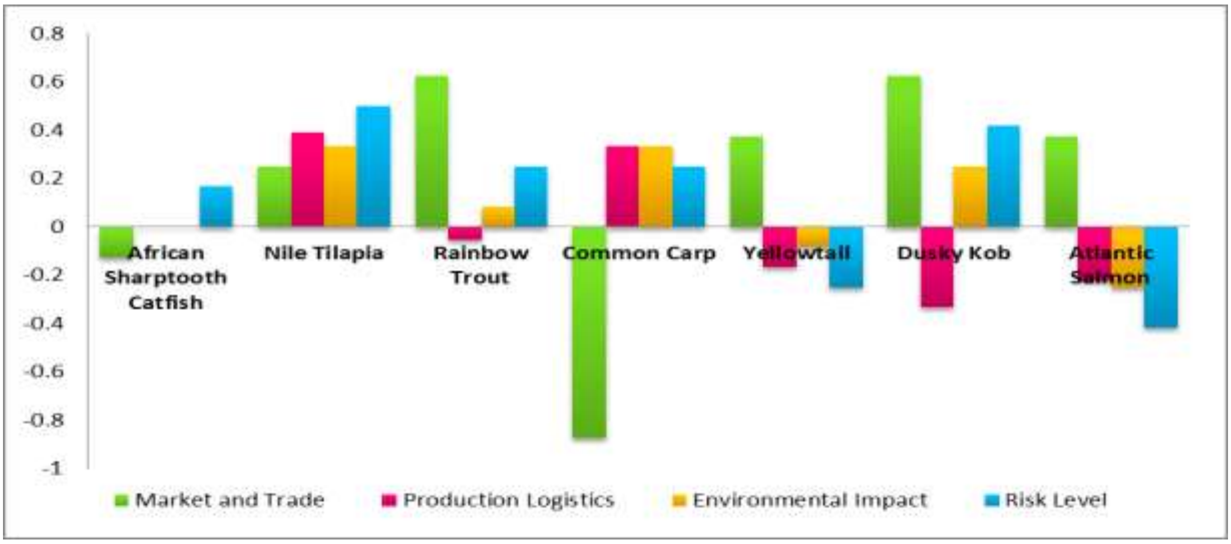

Figure 3-6 Species results by category

Comparison between 3-5 and Figure 3-6 discloses that Atlantic salmon and African Sharptooth Catfish are poor choices for the development of aquaculture in South Africa. Atlantic Salmon have an overwhelming impact on the environment and the farming of the fish is expensive and riddled with risks at this point. African Sharptooth Catfish on the other hand are relatively easy to produce with an average environmental impact but the market for African Sharptooth Catfish production is unsuitable. Common Carp and Yellowtail performed averagely according to the criteria. Common Carp were penalized heavily for their poor market characteristics whereas Yellowtail mostly fell short due to the risk factors involved with farming this species. Dusky Kob and Rainbow Trout performed well in the analysis and were noted as good options for cultivation in South Africa. Trout were noted to have a good Market and were relatively risk free when farmed. Dusky Kob also were indicated to have a good market but were noted to have some difficulties and high expenses with their production. The highest scorer of the analysis was the Nile Tilapia which did relatively well across the board with no particular weaknesses area. It could therefore according to the criteria be considered a well-balanced species for the sustainable development of the fish-farming sector in South Africa.

3.5. Conclusion

Although the criteria is helpful and provides some value it should not be taken as finality. Once the results are generated a further step is required which involves interpreting the results to understand what they truly mean and how they can be used to guide decisions .The criteria should not be used in isolation to decide if a species is a viable option for the sustainable development but rather help as a guide, and to help point out areas of strength and weakness of a particular species.

Thus from interpreting the results of the study it can be said the fresh water fish-farming sector should utilize predominantly Rainbow Trout and Nile Tilapia. In warmer areas, Nile Tilapia should be considered and in areas with colder water, Rainbow Trout should be considered. The potential of these species to drive fish-farming's development are yet limited as Rainbow Trout has a major constraint in that there are few suitable sites for its cultivation, and Nile Tilapia will have to attend only to local markets and will constantly be under pressure from global markets producing cheaper Tilapia products in big quantities.

At the moment the key species to drive South Africa's fish-farming sector appears to be the Dusky Kob as the country is pioneering the farming of this species and is able to replicate optimal conditions in a controlled system. Yellowtail which performed badly due to its environmental impact and risk factor is likely to become viable in the near future due to current research efforts which allow for similar results as Dusky Kob farming. Currently there is still the issue of these farmed products costing more that wild caught products but this problem will become less significant in the near future. In the longer term when more research has been conducted other indigenous marine species such as Grunter and Geelbek, and White Stumpnose could also be cultivated to diversify the supply of farmed fish and add stability to the sector.

It appears that indigenous marine finfish-farming can prove to be a high value competitive industry for South Africa locally as well as for export purposes much like South Africa's lucrative and fast-growing farmed abalone industry. If farming these species takes off it is likely that South Africa will be able to drive the sustainable growth of an infant but lucrative fish-farming sector by creating a niche market.

Chapter 4 : Overall Conclusions and Recommendations

4.1. Overall findings of the study

As time goes on the potential for South Africa to develop a sustainable fish-farming sector becomes more and more clear. Confidence of the private sector is growing and now the country seems more ready for fish-farming's expansion that it has ever been before but there are still certain constraints that exist. If these constraints are reduced South Africa is will be well positioned for bottle neck growth of its fish-farming sector.

Although this should be seen with much optimism there are stills many risks to the sector that need to be acknowledged. It is essential that now the sector is guided appropriately to ensure that it can bring benefit to the country as a whole and avoid overutilization of valuable natural resources at the cost of the entire country. It is thus up to key role players to take the necessary steps to ensure that this can happen and that the ethos of sustainable development can be hinged upon. The sector also needs the private sector to take the initiative to develop and form partnerships with government to form cooperation between them. Those willing to seize this opportunity should not do so blindly as although there is much opportunity the sector is still somewhat plagued by risk.

If these challenges are met the uprising of a niche sector focused on producing indigenous marine finfish is possible. The next few years will also reveal secrets due to current research and pilot programs which will drive this niche market. Additional species will become available for viable cultivation that can assist the growth of the sector. This will help facilitate South Africa's national goals of developing its blue economy in an effort to drive nation-wide sustainable development.

The findings of the study thus come together to highlight key areas of focus that should be enhanced or remedied in order to bring about the sustainable growth of a possible key sector in the South African economy.

4.2. Recommendations

In order to minimize these barriers to fish-farming's growth a number of interventions can be put in place. The following are examples of potential interventions that can be put in place to overcome the challenges the fish-farming sector faces in South Africa:

1. The development of industrial development nodes comprising water, land and infrastructure suitable for aquaculture, as seen in the Eastern Cape.

2. The development of legislation specifically for aquaculture practices to overcome existing regulations and an obstructive bureaucracy.

3. Providing access to support measures, particularly with respect to support for sector level development and joint industry actions, and the development of the necessary services and infrastructure required to develop an internationally competitive production sector.

4. Creating a dedicated fish-farming research and development program to establish production technology for high priority species that can reduce the challenges to farming these species and optimize efficiency.

5. Developing a national fish-farming training strategy to address the anticipated skills requirements of the growing sector.

6. Launching a national marketing campaign to create awareness and demand for farmed fish.

7. The creation of a platform where industry and government can come together to solve issues in the sector and share valuable knowledge and know-how.

8. Making relevant information developing a fish-farm available to the public to reduce the research and pilot cost burden.

9. Broadening the understanding of interventions that could heighten production efficiency and reduce spill over effects from a fish farm including recirculating water systems, aquaponics, and integrated farming methods.

10. The promotion of a fish-farming service sector to reduce transaction costs.

Such interventions may overcome the challenges that have hampered expected growth of the fish-farming sector and promote the diversification of available species that can be used to drive the sustainable growth of fish-farming in South Africa.

4.3. Suggestions for further research

This research study has a sub-focus to act as a step towards further research opportunities in an effort to stimulate a growth of research and literature on aquaculture. This study thus acts as a base as to which further more in-depth studies can stream from. Some potential areas for research that stream from this research study include the following:

1. Necessary steps to prepare South Africa for a growing aquaculture sector.

2. Sustainable feed supplies for fish-farms and in particular the use of fly-farms and vegetable proteins to substitute high protein feeds sourced from wild caught fish.

3. The use of renewable energy usage in on land, as well as, on sea fish farms to reduce costs, environmental impacts and in particular risks of power outages that can rapidly dismantle a fish-farm operation.

4. A similar study with a focus on other segments of aquaculture and species other than finfish including; Abalone, Bivalves, Marron, Sea weed and Rock lobster.

5. The use of fish in integrated farming methods to further understand how it can increase yields, reduce effluent and reduce costs in agricultural production.

Further research into these topics will advance opportunities for the aquaculture sector in South Africa to develop and improve.

References

Agriculture and Horticulture Development Board, 2013. *AHDB PESTLE analysis and outcomes 2014 / 5 political " GREEN GOVERNMENT ," * Available at: http://www.ahdb.org.uk/publications/documents/PESTLEAnalysisPlanningAid2013.pdf.

Aller Aqua, 2015. Research and Development: Knowledge in every bag. *Aller Aqua*. Available at: http://aller-aqua.com/cms/front_content.php?idcat=4&changelang=3 [Accessed January 16, 2015].

Appleford, P., Lucas, J.S. & Southgate, P.C., 2012. General Principles. In J. S. Lucas & P. C. Southgate, eds. *Aquaculture: Farming aquatic animals and plants*. Wiley-Blackwell, p. 48.

Balirwa, J.S., 2007. Review article Ecological , environmental and socioeconomic aspects of the Lake Victoria ' s introduced Nile perch fishery in relation to the native fisheries and the species culture potential : lessons to learn. *African journal of Ecology*, 45, pp.120–129. Available at: http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2028.2007.00753.x/pdf.

Baluyut, E., 1989. *Aquaculture systems and practices: A selected review*, Rome. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CCMQFjAA&url=http://www.fao.org/docrep/t8598e/t8598e00.htm&ei=YnUUVMi4AYep7AaY24D4Aw&usg=AFQjCNETAfldMyEAKc-x6yYYc2YY0ts61w&sig2=6Z2KWW4DNhY0IjtgBUbFWQ&bvm=bv.75097201,d.ZGU.

Basson, J., 2014. Market-driven incentives for better production practices in fisheries. , pp.1–54.

Belton, V. & Stewart, T.J., 2003. *Multi-Criteria Decision Analysis: An integrated approach* 2nd ed., Massachusetts: Kluwer Academic Publishers.

Blue Ribbon Panel, 2013. *Indespensible ocean: Aligning ocean health and human well-being*, Available at: http://www.globalpartnershipforoceans.org/sites/oceans/files/images/Indispensable_Ocean.pdf.

Bostock, J. et al., 2010. Aquaculture: global status and trends. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, 365(1554), pp.2897–912. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2935128&tool=pmcentrez&rendertype=abstract [Accessed July 10, 2014].

Boto, I. & Phillips, S., 2013. Fish-farming: The new driver of the blue economy. In *Brussels Rural Development Briefings*. Brussels, pp. 1–51. Available at: https://brusselsbriefings.files.wordpress.com/2013/07/cta-reader-322.pdf.

Brummett, R., 2013. *Growing aquaculture in sustainable ecosystems*, Available at: http://www.cbd.int/financial/greenmarkets/g-wb-aquaculture.pdf.

Burgess, M., 2013. Pioneering Dusky Kob production in SA. *Farmers Weekly*, 00, pp.1–3. Available at: http://www.farmersweekly.co.za/article.aspx?id=42486&h=Pioneering-Dusky-Kob-production-in-SA [Accessed August 7, 2014].

Business Balls, 2010. *PEST Market Analysis Tool*, Available at: http://www.businessballs.com/pestanalysisfreetemplate.htm.

Cawthorn, D.-M., Steinman, H.A. & Witthuhn, R.C., 2011. Evaluating the availability of fish species on the South African market and the factors undermining sustainability and consumer choice. *Food Control*, 22(11), pp.1748–1759. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0956713511001368 [Accessed August 7, 2014].

DAFF, 2013a. *A profile of the South African market value chain*, Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CBwQFjAA&url=http://webapps.daff.gov.za/AmisAdmin/upload/Aquaculture%20market%20value%20chain%20%20profile%202013....pdf&ei=2i4UVMvHD_Sg7AaXt4GABQ&usg=AFQjCNEt0Li1T2yeal-xIReu9GRwUVnZTg&sig2=S1Hw_IEmKV2jn6U0kphi8w&bvm=bv.75097201,d.ZGU.

DAFF, 2011. Aquaculture Species and Distribution in South Africa Presentation outline. , pp.1–11. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CBwQFjAA&url=http://www.nstf.org.za/ShowProperty?nodePath=/NSTF%20Repository/NSTF/files/Workshops/2011/Aquaculturespecies.pdf&ei=UC8UVNSkHoPQ7Aa0w4CoBw&usg=AFQjCNFD4P1eajyxBKpkrJFlCCQklQXmvQ&sig2=TdBfReHYQcEx023Gk5KZbg&bvm=bv.75097201,d.ZGU.

DAFF, 2014a. Fisheries research and development. *The Department of Agriculture Forestry and Fisheries*, pp.1–2. Available at: http://www.daff.gov.za/daffweb3/Branches/Fisheries-Management/Fisheries-Research-and-Development/-AquacultureR [Accessed March 20, 2014].

DAFF, 2013b. Legal guide for the aquaculture sector in South Africa. , (1st). Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=http://webapps.daff.gov.za/AmisAdmin/upload/The%20User%20Friendly%20Legal%20Guideline%20for%20the%20Aquaculture%20Sector%20in%20South%20Af.......pdf&ei=eC8UVO_VOaTA7AaBtYDIBw&usg=AFQjCNE2coU_vOWRJ-DByW3lMuKUpXdNHg&sig2=S7duEgTJpDcAXV-h1jqN4A&bvm=bv.75097201,d.ZGU.

DAFF, 2014b. Minister Senzeni Zokwana says developing inland fishing key to food security and marine conservation in the Eastern Cape province. Available at: http://www.gov.za/speeches/view.php?sid=47466 [Accessed August 24, 2014].

DAFF, 2013c. *National aquaculture policy framework for South Africa 2013*, Cape Town. Available at:

https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CBwQFjAA&url=http://www.gov.za/documents/download.php?f=200957&ei=5y8UVJPJKJPQ7Aax-YCoAw&usg=AFQjCNEbNGA5FmYAkRRPMw77DQU9yFv-5A&sig2=GiIGRjTVAJgJYqHCHg7wVA&bvm=bv.75097201,d.ZGU.

DAFF, 2012. *South Africa's Aquaculture Yearbook 2012*, Cape Town: The Department of Agriculture Forestry and Fisheries. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=http://www.nda.agric.za/doaDev/sideMenu/fisheries/03_areasofwork/Aquaculture/AquaDocumentation/Aquaculture%20Annual%20Reports/AQUACULTURE%20YEARBOOK%202012.pdf&ei=SDAUVIb3C7TG7AazrYGQCg&usg=AFQjCNG1RKnz5olRAYJWex-K-M3N4TChQA&sig2=oGkB3AnFj2cBjOXVhAsecQ&bvm=bv.75097201,d.ZGU.

Denzin, N.K., 2010. Moments, Mixed Methods, and Paradigm Dialogs. *Qualitative Inquiry*, 16(6), pp.419–427. Available at: http://qix.sagepub.com/cgi/doi/10.1177/1077800410364608 [Accessed December 11, 2013].

Department for Communities and Local Government, 2009. *Multi-criteria analysis: A manual*, London. Available at: http://eprints.lse.ac.uk/12761/.

Diana, J.S., 2009. Aquaculture Production and Biodiversity Conservation. *BioScience*, 59(1), pp.27–38. Available at: http://www.jstor.org/stable/25166597 [Accessed November 21, 2013].

DTI, 2013. Aquaculture development and enhancement programme will encourage investment , growth in South Africa. *The Department of Trade and Industry*, (April), p.1. Available at: http://www.dti.gov.za/editmedia.jsp?id=2656 [Accessed December 22, 2013].

DTI & Enviro-fish Africa, 2007. *A study on the status of aquaculture production and trade in South Africa*, Pretoria. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=http://www.nda.agric.za/doaDev/sideMenu/fisheries/03_areasofwork/Aquaculture/AquaDocumentation/Volume2_StatusAquaProdTradeSA.pdf&ei=cTAUVKnvOIfT7AbgsYGoDw&usg=AFQjCNG3JtLM3HukXwDfygYGlXKubv1NcQ&sig2=6QZt65wzxM3u9qq4n5mHcQ&bvm=bv.75097201,d.ZGU.

Eastern Cape Development Corporation, 2009. *Finfish Mariculture in the Eastern Cape*, Eatern Cape. Available at: http://www.ecdc.co.za/ecdc/files/documents/Fisheries/Finfish Brochure_Aug 09.pdf.

Elsenberg, 2012. *Trout production*, Stellenbosch. Available at: http://www.elsenburg.com/trd/animalprod/akwa/downloads/troutmarket.pdf.

Elsenburg, 2012. *Tilapia: Potential markets*, Stellenbosch. Available at: http://www.elsenburg.com/trd/animalprod/akwa/downloads/tilmarket.pdf.

FAO, 2010. *The Republic of South Africa Fishery and Aquaculture Country Profile*, Available at: http://www.fao.org/fishery/facp/ZAF/en.

FAO, 2014. *The State of World Fisheries and Aquaculture 2014*, Rome.

FAO, 2012. *World fisheries and aquaculture*, Rome. Available at: http://www.fao.org/docrep/016/i2727e/i2727e00.htm.

FAO Fisheries and Aquaculture Department, 2014a. *Clarias gariepinus*, Available at: http://www.fao.org/fishery/culturedspecies/Clarias_gariepinus/en.

FAO Fisheries and Aquaculture Department, 2014b. *Cyprinus carpio*, Available at: http://www.fao.org/fishery/culturedspecies/Cyprinus_carpio/en.

FAO Fisheries and Aquaculture Department, 2014c. *Oncorhynchus mykiss*, Available at: http://www.fao.org/fishery/culturedspecies/Oncorhynchus_mykiss/en.

FAO Fisheries and Aquaculture Department, 2014d. *Oreochromis niloticus*, Available at: http://www.fao.org/fishery/culturedspecies/Oreochromis_niloticus/en.

FAO Fisheries and Aquaculture Department, 2014e. *Salmo salar*, Available at: http://www.fao.org/fishery/culturedspecies/Salmo_salar/en.

FAO Globefish, 2014. Salmon - June 2014. *FAO Globefish*. Available at: http://www.globefish.org/salmon-june-2014.html [Accessed August 27, 2014].

Fielder, D.S. & Heasman, M.P., 2011. *Hatchery Manual for the production of Australian Bass , Mulloway and Yellowtail Kingfish*, Available at: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/397470/Fielder_Heasman-Hatchery-Manual-for-the-production-of-Australian-Bass,-Mulloway-and-Yellowtail-Kingfish_FINAL.pdf.

Flajšhans, M. & Hulata, G., 2007. *Common carp - Cyprinus carpio*, Available at: http://www.imr.no/genimpact/filarkiv/2007/07/common_carp.pdf/en.

De Graaf, G. & Gabribaldi, L., 2014. *The value of African fisheries*, Rome.

De Graaf, G. & Janssen, J., 1996. *Handbook on the artificial reproduction and pond rearing of the African Catfish: Clarias Gariepnus in Sub-Saharan Africa*, Rome. Available at: http://www.nefisco.org/downloads/Clarias.PDF.

Handcock, M.S. & Gile, K.J., 2011. Comment: On the concept of snowball sampling. *Sociological methodolody*, 41(1), pp.367–371. Available at: http://onlinelibrary.wiley.com/doi/10.1111/j.1467-9531.2011.01243.x/abstract.

Hanson, T.R., Nguyen, G. V. & Jolly, C.M., 2013. Comparative advantages of the U.S. farm-raised catfish industry: a cross-regional analysis. *Aquaculture Economics & Management*, 17(1), pp.87–101. Available at: http://www.tandfonline.com/doi/abs/10.1080/13657305.2013.747228 [Accessed February 10, 2014].

Hinrichsen, E., 2006. *Guideline to the Authorisation Requirements for Aquaculture in the Western Cape*, Stellenbosch. Available at: http://www.westerncape.gov.za/text/2007/11/2_guideline_to_the_authorisation_requirements_for_aquaculture_in_the_western_cape_edition1_oct07.doc.

Holtan, M.B., 2011. *Plasma melatonin profiles in Common carp (Cyprinus carpio) exposed to indoor photoperiods*. Norwegian University of Science and Technology. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CCMQFjAA&url=http://www.diva-portal.org/smash/get/diva2:441766/COVER01.pdf&ei=ixMUVOHyEsyf7AblkoDoDA&usg=AFQjCNFJpd2NF2wRg-hLgwkmdqqsFFihnA&sig2=HrzJjb5Zu3CZW7TtSdaXxw&bvm=bv.75097201,d.ZGU.

Hoole, D., 2001. *Diseases of carp and other cyprinid fishes* 1st ed., Malden, Maryland: Blackwell Science/Fishing News Books. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0CDkQFjAB&url=http://onlinelibrary.wiley.com/doi/10.1002/9780470999752.fmatter/pdf&ei=zhMUVN75CM_T7AaW_4H4Bg&usg=AFQjCNFBiBHNPhdxMAlW0jSSPSSQ6667AA&sig2=cCRXXYg74xlZoGsXRLPyzg&bvm=bv.75097201,d.ZGU.

Housing Industry Association, 2011. *PESTLE analysis*, Available at: https://www.academia.edu/6086948/February_2011_Edition_Housing_Industry_Association_an_inTroducTion_To.

Igumbor, E.U. et al., 2012. "' Big Food ,'" the consumer food environment , health , and the policy response in South Africa. *PLoS medicine*, 9(7), pp.1–7. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CC4QFjAA&url=http://www.plosmedicine.org/article/info%3Adoi%2F10.1371%2Fjournal.pmed.1001253&ei=SBQUVJzfBanD7AbM34DgDw&usg=AFQjCNG0o5QmrmByvD2I46eiFrwnaUr4yQ&sig2=TFuxxLo9PjbsfchMWbJrtw&bvm=bv.75097201,d.ZGU.

Jackson, A., 2012. Feeds – FIFO Feeding fish to fish and sustainable aquaculture IFFO the Marine Ingredient Organisation What goes into fish feed ? In *Aquaculture in Motion*. Brussels: IFFO. Available at: file:///C:/Users/mahieal/Downloads/1145+jackson+iffo.pdf.

James, N., 2014. Solar power could save your fish farm. *Farmers Weekly*. Available at: http://www.farmersweekly.co.za/article.aspx?id=55064&h=Solar-power-could-save-your-fish-farm [Accessed June 6, 2014].

James, N., 2012. Tilapia farming can be done in SA. *Farmers Weekly*, 00(October), pp.8–10. Available at: http://www.farmersweekly.co.za/article.aspx?id=30272&h=Tilapia-farming-can-be-done-in-SA [Accessed December 10, 2013].

Joemat-pettersson, T., 2012. Government recognises importance of aquaculture. *SA News*, (March), pp.1–2. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CBwQFjAA&url=http://www.sanews.gov.za/south-africa/govt-recognises-

importance-aquaculture&ei=sxUUVI2CCK_n7Aa15IDYDQ&usg=AFQjCNHNpA9sxwewmRKD7GMMESKkDzh0sw&sig2=aLBtboSyJ [Accessed March 2, 2014].

Joemat-pettersson, T., 2013. *Marine Living Resources Amendment Bill: Draft*, Department of Agriculture, Forestry and Fisheries. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0CCYQFjAB&url=http://www.gov.za/documents/download.php?f=190905&ei=oRQUVI_2DefA7AaqhIGYBA&usg=AFQjCNEJ8y7zweftyY173HlilGMuAT4G5w&sig2=2YIpSGT2vsOUxlaF-ycPfw&bvm=bv.75097201,d.ZGU.

Kokemuller, N., 2014. Relationships between PEST and SWOT. *Chron*, pp.1–2. Available at: http://smallbusiness.chron.com/relationships-between-pest-swot-10083.html [Accessed February 18, 2014].

Kolkovski, S. et al., 2012. Desert Aquaculture. In *Aquaculture: Farming Aquatic Animals and Plants*. Wiley-Blackwell.

Kowalczyk, D., 2015. Purposes of Research: Exploratory, Descriptive & Explanatory. *Education portal*. Available at: http://education-portal.com/academy/lesson/purposes-of-research-exploratory-descriptive-explanatory.html [Accessed January 16, 2015].

Lake harvest, 2013. Fish of the Future. *Lake Harvest*, p.1. Available at: http://lakeharvest.com/fish-of-the-future [Accessed December 10, 2013].

Lucas, J.S., 2012. Introduction. In *Aquaculture: Farming Aquatic Animals and Plants*. Wiley-Blackwell.

Mancini, L., Aulincino, F. & Marcheggian, S., 2010. Multi-criteria approach for the environmental impact assessment of inland aquaculture. *Ann Ist Super Sanita*, 46(3), pp.317–322. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CCMQFjAA&url=http://www.ncbi.nlm.nih.gov/pubmed/20847468&ei=3hQUVI67Kqry7AaNjYCIBA&usg=AFQjCNErCi9xr2sBh_cT208g7P_Nmoyndw&sig2=4_RtYEPKGmZIhZUefMRuYg&bvm=bv.75097201,d.ZGU.

McGinn, A.P., 1998. Blue revolution: The promises and pitfalls of fish farming. *World History Context*, (April), pp.1–13. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0CCQQFjAB&url=http://www.worldwatch.org/system/files/EP112A.pdf&ei=cBUUVIrbOOWf7Aby3oCQDg&usg=AFQjCNF-OdtIIAfN0HB5_I5EKQdGPwlCTg&sig2=ignGfHZ0j8p6C7sxe6MVyw&bvm=bv.75097201,d.ZGU.

Mente, E. et al., 2011. Nutrition in organic aquaculture: an inquiry and a discourse. *Aquaculture Nutrition*, 17(4), pp.798–817. Available at: http://doi.wiley.com/10.1111/j.1365-2095.2010.00846.x [Accessed February 8, 2014].

Millers Local, 2014. Fish farm given the green light. *Millers Local*. Available at: http://www.millerslocal.co.za/millerslocals-blog/fish-farm-given-green-light [Accessed August 30, 2014].

Mohammed, E.Y. & Wahab, A., 2013. *Direct economic incentives for sustainable fisheries management: The case of Hilsa conservation in Bangladesh*, Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&cad=rja&uact=8&ved=0CDIQFjAC&url=http://www.eftec.co.uk/keynotes/envecon-2014/7-3-essam-yassin-mohammed/download&ei=7xUUVKeVDuzH7AbJ_YCoAQ&usg=AFQjCNG6klS4YpxPwlY8-mEYQPGtQuTgqQ&sig2=g0aDz3VIj_hCs8F4ZtCfag&bvm=bv.75097201,d.ZGU.

Molewa, B., 2013. *Environmental impact assessment guideline for aquaculture in South Africa*, Department of Environmental Affairs.

Monteiro, C.A. & Cannon, G., 2012. The impact of transnational “big food” companies on the South: a view from Brazil. *PLoS medicine*, 9(7), p.e1001252. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3389019&tool=pmcentrez&rendertype=abstract [Accessed November 7, 2013].

Nakada, M., 2008. *Capture-based aquaculture of yellowtail*, Rome. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CCEQFjAA&url=http://www.fao.org/3/a-i0254e/i0254e10.pdf&ei=BRcUVNjdFebX7AaOiYC4Dg&usg=AFQjCNFVaym8Go9W1AQSsVS9GXHnm0_xYQ&sig2=G0oaAFX8NIEn_yerR-zKAQ&bvm=bv.75097201,d.ZGU.

Nazar, A.K., Jayakumar, R. & Tamilmani, G., 2013. *Recirculating aquaculture systems*, Tamil Nadu. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CBwQFjAA&url=http://eprints.cmfri.org.in/9712/1/AKA_Nazar.pdf&ei=4xcUVMDiLOSe7AbEzIHADA&usg=AFQjCNErNam-i9JQVZ8tK8lRQtSczTDdsw&sig2=b-sdL1eHm2KTCf0B7_6gtw&bvm=bv.75097201,d.ZGU.

NDA, 2012. *African sharptooth catfish Clarias gariepinus*, Available at: http://www.nda.agric.za/doaDev/fisheries/03_areasofwork/Aquaculture/AquaAndEnvironment/C 1gariepinus final BRBA.pdf.

Njobeni, A., 2014. *RE: Algoa bay sea based aquaculture development zones, Port Elizabeth, Eastern Cape*, Port Elizabeth. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CBwQFjAA&url=http://www.nda.agric.za/doaDev/sideMenu/fisheries/03_areasofwork/Aquaculture/SEA-BASED%20ADZ/Annexure%20D5%20Public%20Meeting%20and%20Minutes.pdf&ei=JRgUVPLzAabb7AagwoDYAw&usg=AFQjCNH0_6OaAlvaBtaeX2YtKdqkQnepLQ&sig2=rEuBmPmsDs8MdJ386AjSPQ&bvm=bv.75097201,d.ZGU.

OECD & FAO, 2014. *OECD-FAO Agricultural Outlook 2014*, Available at: http://www.oecd-ilibrary.org/oecd-fao-agricultural-outlook-

2014_5jz6wnmj0l31.pdf;jsessionid=24ff102jqkorc.x-oecd-live-02?contentType=/ns/Book,/ns/OECDBook&itemId=/content/book/agr_outlook-2014-en&mimeType=application/pdf&containerItemId=/content/serial/19991142&accessItemIds=.

Oelofse, J., 2009. Copyright Avusa Media Limited All rights reserved. *The Herald*. Available at: http://www.rummage.co.za/mossel-bay-fish-farming-plan-still-in-balance_article_op_view_id_4510 [Accessed August 28, 2014].

Otgaar, M., 2012. Kob – Kabeljous. *Fish SA*, pp.1–5. Available at: http://fishsa.co.za/species/kob-argyrosomus-japonicus/ [Accessed August 7, 2014].

Perdikaris, C. & Paschos, I., 2011. Aquaculture and fisheries crisis with the global crisis. *Interciencia*, 36(1), pp.76–80. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0CCkQFjAB&url=http://www.interciencia.org/v36_01/076.pdf&ei=axkUVL6DEcvo7AafyIDoBw&usg=AFQjCNH66DBa1nmAN97Mu4CRdRF2YnTflQ&sig2=00y_vYt_pzfWRKJ-TlIUCg&bvm=bv.75097201,d.ZGU.

Radebe, H., 2013. SA moves to nurture aquaculture sector. *Business Day Live*, (11), pp.2–3. Available at: http://www.bdlive.co.za/business/agriculture/2013/03/19/sa-moves-to-nurture-aquaculture-sector [Accessed March 17, 2014].

Ramayia, J., 2013. NERSA allows yearly 8% electricity price increase for 2013-2018. *Urban Earth*. Available at: http://urbanearth.co.za/articles/nersa-allows-yearly-8-electricity-price-increase-2013-2018 [Accessed August 25, 2014].

Ramsden, N., 2013. From “ goldrush mentality ” to sustainable food source : aquaculture ’ s evolution. *Undercurrent News*, p.1. Available at: http://www.undercurrentnews.com/2013/05/22/from-goldrush-mentality-to-sustainable-food-source-aquacultures-evolution/ [Accessed December 10, 2013].

Reiter, B., 2013. The Epistemology and Methodology of Exploratory Social Science Research : Crossing Popper with Marcuse. *The Dialectics of Citizenship: Exploring Privilege, Exclusion, and Racialization*, pp.1–23.

Republic of South Africa & Aquaculture Lab, 2014. *Operation Phakisa: Unlocking the Economic Potential of South Africa’s Oceans*, Available at: file:///C:/Users/mahieal/Documents/EY LAPTOP/SI/thesis/Final Push/Extra research/OPOceans Aqua Final Lab Report.pdf.

Rouhani, Q.A. & Britz, P.J., 2004. *Contribution of aquaculture to rural livelihoods in South africa: A baseline study*, Gezina. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CCMQFjAA&url=http://db3sqepoi5n3s.cloudfront.net/files/docs/090902catrlinsa.pdf&ei=BBoUVJv0MtLG7AbWmIGYCA&usg=AFQjCNFqE-AUx-S07J57Jws0qUEr-zCn5g&sig2=ovYQ0Am5OITGMhrZEcA_4A&bvm=bv.75097201,d.ZGU.

Rural Fisheries Programme, 2010. *A Manual for Rural Freshwater Aquaculture*, Grahamstown. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=http://www.nda.agric.za/doaDev/sideMenu/fisheries/03_areasofwork/Aquaculture/AquaDocumentation/ManualRuralFreshwaterAquaculture.pdf&ei=lRoUVLW_FIXQ7AbQ7oCQDA&usg=AFQjCNECRoxvMs0bvKbIM_1XZlAE7dkQwQ&sig2=XzsferOCZOgeLZvyI2shmw&bvm=bv.75097201,d.ZGU.

SA News, 2013. SA national aquaculture policy framework approved. *SA News*, (May), pp.1–2. Available at: http://www.sanews.gov.za/south-africa/national-aquaculture-policy-framework-approved [Accessed December 10, 2013].

SAPA, 2007. R100m for fish farm projects. *News 24*, p.1. Available at: http://www.news24.com/SciTech/News/R100m-for-fish-farm-projects-20071101 [Accessed December 10, 2013].

SASSI, 2014. SASSI Database. Available at: http://www.wwfsassi.co.za/?m=5&s=5 [Accessed July 8, 2014].

Scholl, M.C. & Pade, N., 2005. *Salmon farming in Gansbaai: An ecological disaster*, Gansbaai. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0CCUQFjAB&url=http://www.whitesharktrust.co.za/media/salmonfarm/documents/salmonfarming.pdf&ei=6hoUVMLxH6WJ7AbclIGwAQ&usg=AFQjCNHXBFHZ7KYLKMNc6fdJZkOQCl_Wxw&sig2=cxXXso1NeOKmCsdO5G-EOA&bvm=bv.75097201,d.ZGU.

Scottish Salmon Producers Organisation, 2013. *Scottish Salmon Farming*, Perth. Available at: http://scottishsalmon.co.uk/wp-content/uploads/2014/06/ScottishSalmonFarmingASustainableIndustry-web.pdf.

Shakouri, B. & Yazdi, S.K., 2012. The sustainable marine aquaculture. *Advances in Environmental Biology*, pp.18–24. Available at: http://www.aensiweb.com/old/aeb/2012/9-12.pdf.

Shelton, C., 2014. *Climate change adaption in fisheries and aquaculture*, Rome. Available at: http://www.fao.org/3/a-i3569e.pdf.

Stander, H., 2007. *The Sharptooth Catfish (Clarias gariepinus)*. University of Stellenbosch. Available at: http://www0.sun.ac.za/aquaculture/uploads/articles/Catfish Farming.pdf.

Stander, H. & Brink, D., 2009. Trout Farming In South Africa: Expanding local markets work with ecotourism. *Global Aquaculture Advocate*, (December), pp.38–40. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CCkQFjAA&url=http://www0.sun.ac.za/aquaculture/uploads/articles/StanderNov09-layout%20(2).pdf&ei=di4UVKK9BKn07AbE14DwCQ&usg=AFQjCNGaJz0MGBjrWAiF1Xs2fQvfQBNAiA&sig2=mQGeqzoDsaCGjlDy2TeuYg&bvm=bv.75097201,d.ZGU.

Tanner, J. & Fernandes, M., 2010. Environmental effects of yellowtail kingfish aquaculture in South Australia. *Aquaculture Environment Interactions*, 1(2), pp.155–165. Available at: http://www.int-res.com/abstracts/aei/v1/n2/p155-165/ [Accessed August 7, 2014].

The Atlantic Salmon Trust, 2014. Diseases and Parasites. *The Atlantic Salmon Trust*. Available at: http://www.atlanticsalmontrust.org/policies-and-research/diseases-and-parasites.html [Accessed August 7, 2014].

The Fish Site, 2009. Mossel bay tourism up in arms over fish farm. *The Fish Site*, (May), p.1. Available at: http://www.thefishsite.com/fishnews/9784/mossel-bay-tourism-up-in-arms-over-fish-farm [Accessed February 23, 2014].

The World Bank, 2007. *Changing the face of the waters: The promise and challenge of sustainable aquaculture*, Washington, DC: The World Bank. Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0CCQQFjAB&url=http://documents.worldbank.org/curated/en/2007/01/8822592/changing-face-waters-promise-challenge-sustainable-aquaculture&ei=rzAUVKWuIoXH7Ab7uYHIBQ&usg=AFQjCNECP7XQYpeGlOgADxbNZBFgsl-cdA&sig2=8GbqkYV52yR_81BtCijSfg&bvm=bv.75097201,d.ZGU.

Tisdell, C., 2005. *The environment and the selection of aquaculture species an systems: An economic analysis*, Brisbane.

Tshetlo, P.T., 2014. *An analysis of the implementation of the South Africa-China bilateral agreement: A case study of the South African agricultural technology demonstration centre*. University of South Africa.

WCADI, 2012. *Draft western cape aquaculture market analysis and development programme/strategy*, Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=http://www.aasa-aqua.co.za/site/wp-content/uploads/2010/10/Wcape_Aquaculture_Market_Analysis_and_Strategy_Final_Draft_for_Industry_Input11.pdf&ei=4TAUVK37OLSp7Aay1YEQ&usg=AFQjCNHZw-X1FVx855GiYEgmxXozoIH4cg&sig2=cBSl1W5DBQK8aksh8_42hA&bvm=bv.75097201,d.ZGU.

Weaver, R., 2013. *Overview of the South African Trout production industry for 2012 – 2013*, Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=http://www.aasa-aqua.co.za/site/wp-content/uploads/2010/10/Sector-Report-May-2013.pdf&ei=BDEUVILyGYvy7AayzoHgCA&usg=AFQjCNG2IFnqlr9z8xOmxCHH83kQlKbo0g&sig2=wYgAgUp0MwmuF4VB_HhLGQ&bvm=bv.75097201,d.ZGU.

Woolworths, 2014. Fishing for the future: Farmed Kabeljou. *Woolworths*. Available at: http://www.woolworths.co.za/store/fragments/corporate/corporate-index.jsp?content=../article/article&contentId=cmp201568 [Accessed September 1, 2014].

World Bank, 2013. *Fish to 2030: Prospects for fisheries and aquaculture*, Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=http://www.fao.org/docrep/019/i3640e/i3640e.pdf&ei=LDEUVJ7VLoq47AaVkIGACQ&usg=AFQjCNG2PfWx4moxoaRxHM0ybAonaNov8A&sig2=UZJLmM2WrjAmmf_1SSJEJQ&bvm=bv.75097201,d.ZGU.

YSI Environmental, 2008. *Considerations for Sea Cage Aquaculture in Marine Environments*, Available at: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CCMQFjAA&url=http://www.ysi.com/media/pdfs/A563-Considerations-for-Sea-Cage-Aquaculture-in-Marine-Environments.pdf&ei=TzEUVJTXNaip7AbijIGgBA&usg=AFQjCNFOfTaRtaX04BwYxUDoBMmNEwlXOg&sig2=-9rQ7vDTyFNbxgT6Yff9gw&bvm=bv.75097201,d.ZGU.

Appendices

Appendix 1 Table with brief explanations of what each criterion assesses

Category: Market and Trade			
Criteria	Local demand vs Supply	Explanation	This criterion analyses the current local demand and available supply of a particular fish species to indicate if there is opportunity in the market.
	Export demand vs supply		This criterion analyses the current global demand and available supply of a particular fish species to indicate if there is opportunity in the market.
	Market value of the species		This criterion analyses the value at which the market perceives a particular fish species. This will indicate what type of price a particular fish could be sold for.
	Expected future trends in market		This criterion analyses what the expected future trends are for the market of a specific fish species.
Category: Production Logistics			
Criteria	Feed requirements and feed availability	Explanation	This criterion analyses the costs that are involved with feeding a particular fish species as well as the availability of appropriate feed in South Africa.
	Growth rate		This criterion analyses the growth rate of the specific species under optimal conditions. It also takes into the required marketable sizes and how long a species takes to reach it.
	Availability of suitable locations		This criterion assesses the availability of suitable sites for fish-farming activities to take place within South Africa.
	Reproduction characteristics or Seed availability		This criterion analyses the reproduction characteristics of fish species and the challenges of reproducing the species. With most fish species hatcheries are necessary and in such a situation this criteria will also assess the difficulties of running a hatchery.
	Level of research and development of farming the species		This criterion analyses the current availability of research and development associated with a particular species.
	Water usage		This criteria analyses the water costs involved in the production of the fish species
	Start-up costs		This criterion assesses the costs of setting up a fish-farm operation for a particular species.

Criteria	Explanation
Energy usage	This criterion accounts for the amount of energy input required to run a farming operation for a particular species.
Management input	This criterion analyses the amount of labour and skills needed to manage the production of the species effectively.
Category: Environmental Impact	
Effluent discharge	These criteria assess the amount of effluent that is discharged into water systems from the farming of a fish species.
Eating habits	This criterion critiques the eating habits of a particular fish species and the impact its feed has on the natural stocks.
Water consumption	This criterion analyses the amount of water that is used up when cultivating a fish species and the ability of the system to reuse its water.
Impacts on biodiversity	This criterion analyses the impact that farming the species can have on the biodiversity in its surrounding location.
Impacts on natural stocks	This criterion analyses the impact that farming the species can have on the wild stocks of that species.
Habitat destruction	This criterion assesses the impact that farming a species will have on surrounding habitats and natural ecosystems.
Category: Risk Level	
Risk of disease spread	This criteria analyses the potential of a species to contract diseases and spread them to other fish
Hardiness of the species	This criterion analyses a species ability to cope with and survive through poor living conditions.
Risk to tourism	This criterion assesses the risk that the farming of a particular fish may have on a tourism industry in its vicinity.
Risk of predators and theft.	This criterion analyses the risk of fish mortalities as a result of predators or theft.
Risk of escapement	This criterion analyses the risk of fish escaping from a farm.
Success rate of previous farming attempts	This criterion analyses the success rate of other attempts to farm a particular species to determine risk of failure.

Appendix 2 Table with overall scores from the AHP analysis

Species	African Sharptooth Catfish	Nile Tilapia	Rainbow Trout	Common Carp	Yellowtail	Dusky Kob	Atlantic Salmon
Market and Trade	-0.13	0.25	0.63	-0.88	0.38	0.63	0.38
Production Logistics	0.00	0.39	-0.06	0.33	-0.17	-0.33	-0.22
Environmental Impact	0.00	0.33	0.08	0.33	-0.08	0.25	-0.25
Risk Level	0.17	0.50	0.25	0.25	-0.25	0.42	-0.42
score	0.01	0.37	0.23	0.01	-0.03	0.24	-0.13