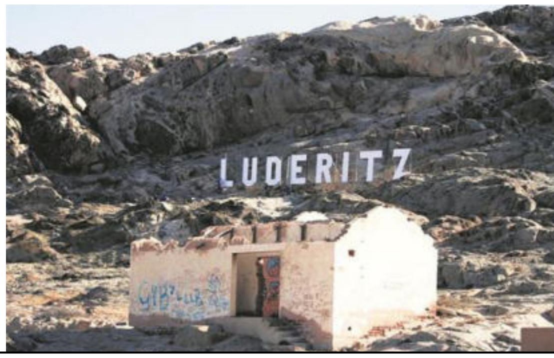
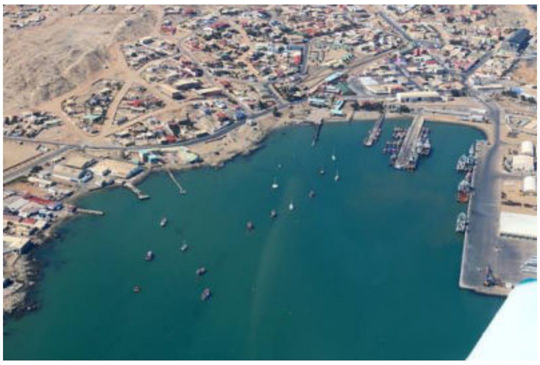
Environmental Impact Assessment for Marine Aquaculture (Mariculture) Developments in Lüderitz




IMPACT ASSESSMENT SCOPING REPORT

March 2023

APP NUMBER - 221127000496

Prepared for:

Ministry of Fisheries and Marine Resources
Private Bag 13355
Windhoek
Namibia
Tel: +264 61 205 3911

Prepared by:

KPM Environmental Consulting
P.O. Box 26328
Windhoek, Namibia
Tel: +264 85 747 2222
Email: kpm.consulting@iway.na

Table of Contents

LIST OF ACRONYMS

AIDS	Acquired Immune Deficiency Syndrome
CRR	Coments and Response Report
DEA	Department of Environmetal Affairs
DEISR	Draft Environmental Impact Scoping Report
EA	Environmental Assessment
EAP	Environmental Assessment Practitioner
EISR	Envirronmental Impact Scoping Report
ECC	Environmental Clearance Certificate
ECO	Environmental Control officer
EIA	Environmental Impact Assessment
EMA	Environmetal Management Act
ESMP	Environmental and Social Management Plan
FEISR	Final Environmental Impact Scoping Report
I&AP	Interested and Affected Parties
IUCN	International Union for Conservation
MEFT	Ministry of Environment, Foretsry and Tourism
MFMR	Ministry of Fisheries and Marine Resources
NPC	National Planning Commission
PPP	Public Participation Process
SADC	Southern African Development Community
USAID	United States Agency for International Development

1 Introduction

1.1 Project Background

The Ministry of Fisheries and Marine Resources (MFMR) in collaboration with the Benguela Current Commission (BCC) undertakes to develop marine aquaculture in Namibia specifically in the coastal towns of Swakopmund, Walvis Bay (in Erongo Region) and Lüderitz in Kharas Region.

The marine aquaculture -
optimally in relation to the potential and expectations for economic growth, job creation and poverty reduction. It remains a priority for the Namibian Government and even more so now as a viable climate change adaptation option in the fisheries sector.

The marine aquaculture operates in the above-mentioned towns, within the nutrient rich Benguela Current Large Marine Ecosystem (BCLME). This presents the sector with competitive advantages for the prospective operators as it is highly beneficial for the filter feeders such as oysters and mussels but can also be disastrous at times due to low oxygen and unfavourable events such as sulphur eruptions which may cause mortalities among bivalves.

The Environmental Impact Assessment (EIA) study was undertaken to unlock the potential for prospective operators to be able to operates aquaculture farms offshore and onshore without the prolonged requirements of conducting the impact assessment process. This study, therefore, would enable the Ministry of Environment, Forestry and Tourism (MEFT) to approve the operations of mariculture activities in the three identified coastal areas. Prospective operators would thus only be required to submit their site-specific Environmental Management Plan (EMP) to apply for environmental clearance certificates (ECCs).

The Ministry of Fisheries and Marine Resources (MFMR) herein referred to as the proponent in collaboration with the Benguela Current Convention (BCC) appointed KPM Environmental Consulting to undertake the Environmental Assessment (EA) exercise with the intention to obtain an Environmental Clearance Certificate (ECC) for the above-mentioned aquaculture (mariculture) development activity in Lüderitz. The competent authority is the Ministry of Environment and Tourism: Department of Environmental Affairs (MEFT: DEA).

1.2 Project Location

The proposed mariculture development will be implemented in the three (3) coastal towns of Swakopmund, Walvis Bay and Lüderitz and associated islands.

The proposed mariculture development project for Lüderitz is located off-shore around the Seal Island, Penguin Island and nearby the Lüderitz Proper. Lüderitz is a coastal townin southwestern Namibia and it is one of the major towns in Karas Region. The colourful and unique town of Lüderitz in Namibia is perched where the rocky Atlantic Ocean coastline meets the Namib Desert.

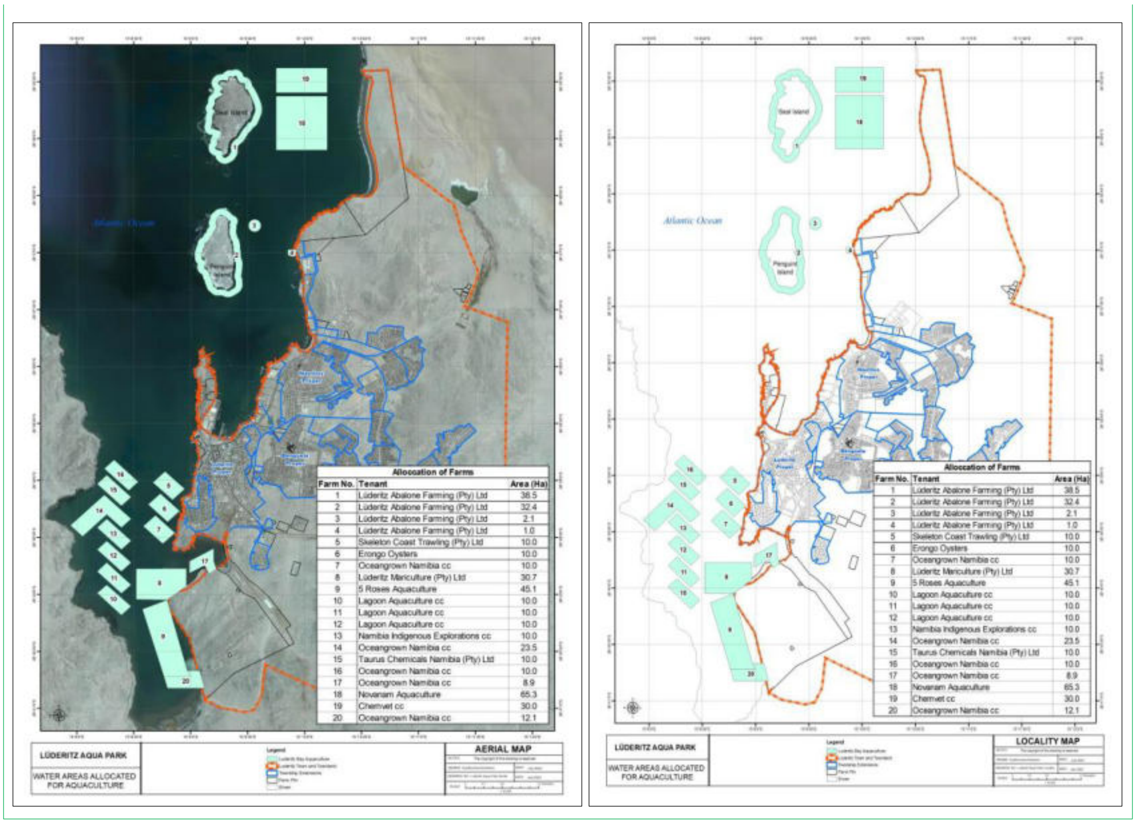


Figure 1: Proposed areas earmarked for Aquaculture in Lüderitz

1.3 Terms of Reference and Scope of the Project

The Terms of Reference (ToR) for the study were developed by the project proponent, the Ministry of Fisheries and Marine Resources with technical and financial support from the Benguela Current Commission.

The Terms of Reference provide the scope under which this study should be carried out. The Terms of Reference highlighted the scope of work for the independent environmental consultant to conduct an environmental assessment and propose management plans for the demarcated aquaculture parks, inclusive of areas earmarked for land-based mariculture. The scope of work includes existing and emerging projects that are, and would be in Lüderitz and associated islands.

The Terms of Reference also proposed six (6) species to be included in the study such as Pacific Oyster *(Crassostrea gigas),* Black Mussels, *(Choromytilus meridionalis),* Scallops *(Argopecten purpuratus),* Abalone *(Halotis midae),* Kelp/seaweed *(Laminaria and Ecklonia)* and West Coast Lobster *(Jasus lalandii),* and any other species which might be identified during the study.

The Terms of Reference also indicated that the study is aimed at removing the barriers to mariculture development which is to secure an Environmental Clearance Certificate (ECC) from the Ministry of Environment, Forestry and Tourism. The ToR also indicates the condition for setting up and operationalisation of the mariculture farms/parks that it can only be done once an ECC has been obtained.

1.4 ASSUMPTIONS AND LIMITATIONS

In undertaking this project and compiling the Environmental Impact Scoping Report, the following assumptions and limitations apply:

- Assumes the information provided by the proponent is accurate and discloses all information available.
- The study was undertaken under the assumption that there were prior intergovernmental arrangements between the Ministry of Environment, Forestry and Tourism and the Ministry of Fisheries and Marine Resources as

proponents to agree on the expectation and what the proponent wants to achieve after the study.

This assumption was clarified at the Inception Meeting and in consultation with Ad-hoc Committee, it was agreed that the study will assess the entire town as opposed to an ordinary EIA which would focus on a specific project.

-

surroundings as well as Swakopmund overall were however taken into consideration (this is in accordance with the Town Planning Scheme for the Lüderitz Municipality).

2 LEGAL ENVIRONMENTAL FRAMEWORK

1.5 Introduction

Namibia has several legislations dealing with environmental issues. Environmental legislation determines the objectives guiding, and the strategies to be used to strengthen the respect for environmental values, considering the existing social, cultural, and economic situation. The foundation for the Namibian environmental policy framework is Article 95 (l) of the Constitution. It stipulates that the state shall actively promote and maintain the welfare of the people by adopting policies which

ial ecological processes and biological diversity of Namibia and utilization of living natural resources on a sustainable basis for the benefits of all Namibians (The Namibia Constitution).

The State is further committed to actively promoting and maintaining the environmental welfare of all Namibians by entrenching the principles of sound environmental management practice in the Namibian Constitution and formulating and institutionalizing policies that can realize the sustainable development objectives (Ruppel, 2013).

1.6

To give effect to articles 91(c) and 95(l) of the Constitution of Namibia, general principles for sound management of the environment and natural resources in an integrated manner were

of 1994. The Environmental Management Act was approved in 2007 to give statutory effect to the Policy and gazetted on 27 December 2007 as the Environmental Management Act (Act No. 7 of 2007), Government Gazette No. 3966. Part 1 of the Environmental Management Act describes the various rights and obligations that pertain to citizens and the Government alike, including an environment that does not pose threats to human health, proper protection of the environment, broadened *locus standi* on the part of individuals and communities, and reasonable access to information regarding the state of the environment. The following are 13 principles of environmental management set out in Part 2 of the Act:

- Renewable resources shall be employed on a sustainable basis for the benefit of current and future generations of Namibians.
- Ensuring that community involvement in natural resource management and sharing in the resulting benefits shall be promoted and facilitated in all possible ways.
- Public participation in decisions affecting the environment and human wellbeing shall be promoted.
- Fair and equitable access to natural resources shall be promoted.
- Ensure that equitable access to sufficient water of acceptable quality and adequate sanitation shall be promoted and the water needs of ecological systems shall be fulfilled to ensure the sustainability of such systems.
- There shall be prior environmental assessment of projects and proposals which may significantly affect the environment or result in the use of natural resources.
- Sustainable development shall be promoted in projects pertaining to land-use planning.
- Ensure that
  including its biodiversity, shall be protected and respected for the benefit of current and future generations.
- Any activities that may have the potential to generate waste and polluting substances shall adopt the best practicable environmental option to reduce such generation at source.
- The polluter pays principle shall be applied.
- Reduction, reuse and recycling of waste shall be promoted.
- Certain institutions were established to provide for a Sustainable Development Commission and Environmental Commissioner.

As the organ of state responsible for management and protection of its natural resources, the MEFT: DEA is obligated to pursuing these principles of environmental management.

The Act also provides for ensuring that there are opportunities for the timeous participation of interested and affected parties throughout the assessment process in matters affecting their lives. These opportunities are detailed in the report in terms of how interested and affected parties were consulted and informed about the proposed mariculture development for Lüderitz and associated islands.

2.1.1 EIA Regulations GN 28, 29, and 30 of EMA promulgated on 6 February 2012

Regulations for Environmental Impact Assessment, in terms of the Act, were

human environment that is the landscape and natural, cultural, historical, aesthetic an

As the organ of the state responsible for the management and protection of its natural resources, the Ministry of Environment, Forestry and Tourism (MEFT) is committed to pursuing these principles of environmental management.

The EIA Regulations promulgated in terms of the EMA identify some of the listed activities, which could significantly have a negative effect on the environment. These activities require an ECC from the competent environmental authority, prior to commencing. The following activities identified in the EIA Regulations (**Table 2**) apply to the proposed project:

Table 1: List of triggered activities identified in the EIA Regulations which apply to the proposed project

ACTIVITY DESCRIPTION	DESCRIPTION OF RELEVANT ACTIVITY	DEVELOPMENT ACTIVITIES THAT RELATES TO THE APPLICABLE LISTED ACTIVITY
Activity 7.1 (Agriculture and Aquaculture Activities)	Construction of facilities for aquaculture production, including mariculture and algae farms where the structures are not situated within an aquaculture development zone declared in terms of the Aquaculture Act, 2002.	The proposed project entails the development and demarcation of mariculture farms within aquaculture zones.
Activity 7.2 (Agriculture and Aquaculture Activities)	The declaration of an area as an aquaculture development zone in terms of the Aquaculture Act, 2002.	The project entails the declaration and demarcation of Aquaculture Parks or zones.

This Environmental Impact Assessment process will be undertaken in accordance with the EIA Regulations. Figure 3 below shows a Flow Diagram which illustrates an outline of the EIA process to be followed.

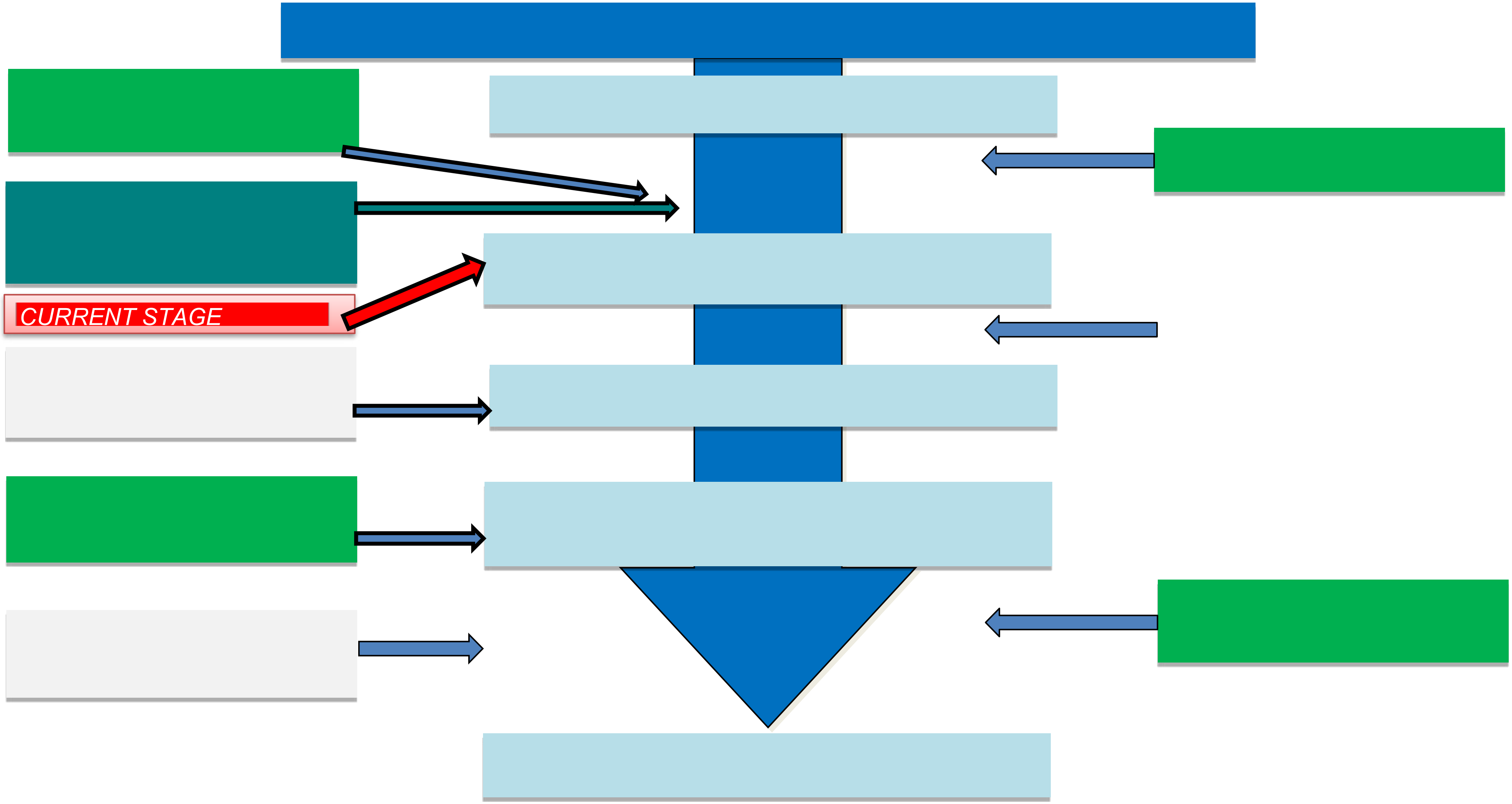


Figure 2: EIA Flow Diagram

1.7 ENVIRONMENTAL IMPACT ASSESSMENT POLICY

the environmental consequences of development projects and policies are considered, understood, and incorporated into the planning process. The term interpreted to include biophysical, social, economic, cultural, historical, and political components. The Policy defines the required steps for an EIA, the required contents of an EIA report, the need for post-implementation monitoring, and the system of appeals. All these aspects have since been taken up in the subsequent Environmental Management Act (EMA) and the accompanying Regulations, which were drafted in response to the Environmental Assessment Policy.

1.8 ENVIRONMENTAL GUIDELINES

Under section 5 of the EMA, it is highlighted that if a proposal or activity is likely to affect people, the following guidelines should be considered in Scoping / Environmental Assessment (EA):

- The location of the development in relation to interested and affected parties (I&APS), communities or individuals;
- The number of people likely to be involved;
- The reliance of such people on the resources likely to be affected, the resources, time and expertise available for scoping / EA;
- The level of education and literacy of parties to be consulted;
- The socio-economic status of the affected community (Lüderitz);
- The level of organisation of the affected community;
- The degree of homogeneity of the public involved;
- History of any previous conflict or lack of consultation;
- Social, cultural or traditional norms within the community; as well as
- The preferred language used within the community.

The MEFT also released a Draft Procedures and Guidelines for conducting EIAs and compiling EMPs in April 2008. These guidelines outline the procedures and principles that are to be followed. It will be consulted throughout the EIA process to ensure an effective process and an EMP that addresses all identified impacts.

1.9 NAMIBIA VISION 2030

The principles that underpin Vision 2030, a policy framework for -term national development, comprise the following:

- Good governance;
- Partnership;
- Capacity enhancement;
- Comparative advantage;
- Sustainable development;
- Economic growth;
- National sovereignty and human integrity;
- Environment; and
- Peace and security.

Vision 2030 states that natural environments are disappearing quickly. As a result, the solitude and natural beauty that many areas in Namibia provide are becoming sought after commodities and must be regarded as valuable natural assets.

Vision 2030 furthermore emphasises the importance of promoting healthy living which takes into account that the majority of Namibians are provided with basic services. The importance of developing Wealth, Livelihood and the Economy is also emphasised by Vision 2030.

1.10 BIODIVERSITY LEGISLATION AND POLICIES

The policies below which are aimed at biodiversity, may also be relevant for the proposed project:

- Convention on Biological Diversity (2000)
- Namibian Water Corporation Act (1997)
- Pollution and Waste Management Bill (Draft)
- Soil Conservation Act (1969)
- United Nations Framework Convention on Climate Change (1992)
- Water Resources Management Act (2004)

The applicability of the aforementioned policies and legislation has been explored in further detail during this EIA phase, based on the findings of the impact assessment and specialist investigations.

1.11 SOCIAL POLICIES

2.1.2 The Ministry of Environment, Forestry and Tourism (MEFT) Policy on HIV & AIDS

The relevance of this policy for the proposed project stems from the fact that there is a likelihood that construction activities may entail the establishment of a temporary construction workforce within the proximity of the project area in Lüdritz. Experience with other construction-related projects in a developing-world context has shown that there is a high possibility for construction workers to have the opportunity to interact with the local community in which significant risk is created for the development of social conditions and behaviours that contribute to the spread of HIV and AIDS.

In response to the threat the pandemic poses, MEFT has developed a policy on HIV and AIDS. This policy, which makes provision for a non-discriminatory work environment and for workplace programs managed by a Ministry-wide committee was developed with support from the United States Agency for International Development (USAID), Gesellschaft für Technische Zusammenarbeit (GTZ) and the German Development Fund.

1.12 Local Authority Act

The Local Authority Act (23 of 1992) makes provisions for municipalities, towns, and villages to make regulations and rules regarding the activities that may be conducted within the municipal, town or village jurisdiction. Incidents such as pollution, spillages or contamination may be investigated by the Health and Safety Officer at the Municipality, Town or Village Council and the offender may be fined an amount as per the rules and regulations of that Local Authority.

The Local Authorities at Swakopmund, Walvis Bay and Lüderitz are part of the Ad-hoc Committee for the Ministry of Fisheries and Marine Resources working on the mariculture development initiatives.

1.13 SOIL CONSERVATION ACT

To consolidate and amend the law relating to the combating and prevention of soil erosion, the conservation, improvement, and manner of use of the soil and vegetation and the protection of the water sources in the Republic and the territory of Namibia. Considering the proposed activity, care should be exercised to ensure that no contamination or pollution of soil through leakage or wind blowing of any marine products used during the operational stage. Specific measures regarding these possible impacts will be proposed further in generic EMP.

1.14 Town and Regional Planners Act 9 of 1996

The Town and Rehional Planners Act 9 of 1996 establishes a Council of Town and Regional planners and provides for the training and registration of individuals in this profession.It therefore stands to reason that the rezoning application should be dealt with by individuals which meet the requirement of this Act in order to ensure that it is done correctly.

1.15 Township and Division of Land Ordinance 11 of 1963

The Townships and Division of Land Ordinanace regulates subdivisions of portions of land falling within a proclaimed Local Authority area. In terms of Section 19 such applications are to be submitted to the Townships Board who will make a recommendation to the Minister of Regional and Local Government Housing and Rural Development for final approvals.

1.16 HAZARDOUS SUBSTANCE ORDINANCE (ORDINANCE NO. 14 OF 1974)

A substance is considered hazardous if it has one or more of the following hazardous properties i.e., explosive, flammable, oxidizes, corrosive or toxic to people. No hazardous material is anticipated during the construction and operational stage of the mariculture development. However, due to some potential health effects flagged, it is important to ensure that all activities during the setting up of the fish farms and during the operational stage are within the provisions of this Ordinance.

1.17 WATER ACT NO.54 OF 1956

This Act provides for Constitutional demands including pollution prevention, ecological and resource conservation and sustainable utilisation. In terms of this Act, all water resources are the property of the State and the EIA process is used as a fundamental management tool.

A water resource includes a watercourse, surface water, estuary or aquifer, and, where relevant, its bed and banks. A watercourse means a river or spring; a natural channel in which water flows regularly or intermittently; a wetland lake or dam, into which or from which water flows; and any collection of water that the Minister may declare to be a watercourse. Permits are required in terms of the Act for undertaking the following activity relevant to the proposed project:

Disposal of waste in a manner that may detrimentally impact on a water resource in terms of Section 21 (g).

1.18 ATMOSPHERIC POLLUTION PREVENTION ORDINANCE OF 1976

The Atmospheric Pollution Ordinance makes provision for the prevention of any activity that contributes to the pollution of the atmosphere. Provisions will be made in the generic EMP to direct staff responsible for setting up aquaculture parks to ensure that all activities do not cause atmospheric pollution.

1.19 WATER RESOURCES MANAGEMENT ACT OF 2004 (ACT NO. 24 OF 2004)

The Water Resources Management Act provides for the management, development, protection, conservation, and use of water resources throughout Namibia. Provisions have been made in the generic EMP to ensure that seawater is not contaminated with marine products during the operational stage of aquaculture.

1.20 POLLUTION CONTROL AND WASTE MANAGEMENT BILL (IN PREPARATION)

This Bill serves to regulate and prevent the discharge of pollutants to air and water as well as provide for general waste management. The Bill will repeal the

Atmospheric Pollution Prevention Ordinance (11 of 1976) (below) when it comes into force.

Only Parts 3 and 5 of the Bill apply to the proposed development of aquaculture (mariculture) activities in Lüderitz.

Part 3 of the Bill deals with the overall water quality monitoring, regulations that are applicable to pollution control and waste management, water quality action areas, discharge of waste to water or a watercourse, defence, licenses and registration aspects of water pollution-related matters.

Part 5 stipulates that no person may cause, permit or carry out any activity that gives rise to noise, dust or odour to the extent that, in the opinion of the competent authority, it creates or is likely to create a nuisance. It further provides for procedures to be followed in the event of noise and odour impacts in accordance with section 53 of the Abatement Notice.

The Bill also provides for noise, dust or odour control that may be considered a nuisance. The Bill advocates for duty of care with respect to waste management affecting humans and the environment and calls for a waste management licence for any activity relating to waste or hazardous waste management.

The proposed project would not entail the discharge to air and or water but might result in the generation of noise, odour and dust during the construction and operational phase. The potential risk of hazardous substance leakages does occur and should be managed accordingly.

1.21 PUBLIC HEALTH ACT 36 OF 1919 AND SUBSEQUENT AMENDMENTS

The Act, with emphasis to Section 119 prohibits the presence of nuisance on any land occupied. The term nuisance for the purpose of this EIA is specifically relevant specified, where relevant in Section 122 as follows:

> Any area of land kept or permitted to remain in such a state as to be offensive, or liable to cause any infectious, communicable or preventable disease or injury or danger to health; or
>
> Any other condition whatever which is offensive, injurious or dangerous to health.

Potential impacts associated with the development of the proposed project in Swakopmund are expected to include dust, noise and odour (nuisance) impacts.

1.22 NATIONAL HERITAGE ACT (NO.76 OF 1969)

The Act calls for the protection and conservation of heritage resources and artefacts. Should any archaeological material, e.g. old weapons, coins, bones found during the construction or operation, work should stop immediately and the National Heritage Council of Namibia must be informed as soon as possible. The Heritage Council will then advise clearing the area or deciding to conserve the site or material.

1.23 The Marine Resources Act No. 27 of 2000

The Act provides for the conservation of marine ecosystems, responsible utilisation, protection and promotion of marine resources on a sustainable basis. The Act is also aimed at enhancing opportunities for Namibian people, especially previously disadvantaged communities.

1.24 Namibian Ports Authority Act No. 2 of 1994

The Act gives Namibian Ports Authority (Namport) the responsibility of protecting the environment within the harbour areas. Namport has implemented a pollution tariff applicable to soil, water and air pollution. The pollution tariff was implemented with effect in 2003.

3 ENVIRONMENTAL BASELINE DESCRIPTION

3.1 Socio-Economic Context of the Region

//Karas Region is one of the fourteen (14) regions of Namibia and is located in the southern part of the country.
bordered by South Africa in the South, the Atlantic Ocean in the West, the Hardap Region in the North and with a section of Botswana and again South Africa in the East. Because of its geographical location and the fact that the region contains the harbour town of Lüderitz, it serves as a hub in terms of the movement of people and goods through the Lüderitz Namport harbour. Karas Region has experienced the largest influx of people due to the mining boom in recent times as well as green hydrogen inititives and oil discoveries by QatarEnergy and Shell offshore Namibia. There are a number of established mines such as Namibia Tantalite Mine, Namiba Diamond Corporation (Pty) Ltd, while a growing number of other mines are starting up in the region, and many more are in the exploratory stages. Tourism, agriculture and fishing are the other major contributors to the regional economy.

The region comprises of six constituencies: Berseba, Karasburg, Keetmanshoop Rural, Keetmanshoop Urban, Lüderitz and Oranjemund. According to the last census done 12 years ago, the region had a population of about 77 000 inhabitants of which about 38 000 were women and 39 000 were men and the population was growing at an annual rate of 0.1 percent.

The Lüderitz town is one of the biggest towns in //Kharas Region and has recently seen an influx of people due to the oil discoveries as well as green hydrogen project in the //Kharas Region.

3.1.1 Economic Setting

The main economic activities in the //Kharas Region are concentrated in the two coastal towns of Lüderitz and Oranjemund, as well as in Keetamsnhoop which is the admoisntation centre for //Kharas Region. The two coastal towns have recently seen an influx of people from other regions due to employment opportunities at the mines. Opportunities in agriculture, small-scale mining and tourism vary widely throughout the region.

3.1.2 Mining

Due to the scale of its influences across social, economic and environmental spheres, mining is a key activity within the //Kharas Region. There has been a noticeable decline in recent times in the contribution of the traditional powerhouses of mining in Namibia, such as gold and diamonds. But other minerals, particularly uranium, are benefitting from increased worldwide demand for clean nuclear energy. This has major repercussions for the //Kharas region as it is known to have potential for green hydrogen initiatives.

3.1.3 Fisheries

With Nambia having one of the richest fishing grounds in the world owing to the cold Benguela current which flows along the coast, the Namibian government sees commercial fishing as one of the main pillars of its economy (NPC 2001). Indeed the fisheries sector has been one of the major success stories of the post-independent government. There has been a steady growth of both stock levels and catches since 1990, and it is estimated that 600,000 metric tonnes of fish and shellfish are landed per annum. The bulk of this is processed at Lüderitz and exported, which provides much employment to the coastal towns. Exports of fish species have increased recently owed to the access to lucrative markets i.e. in the European market through the Economic Partnership Agreement (EPA) such that the fishing industry is now are among the key species exported.

3.1.4 Infrastructure

Given the importance of mining and the high volume of trade passing through Lüderitz harbour, //Kharas Region is served by an impressive infrastructure network. It is well connected both by tarred road and rail to Windhoek through Keetmanshoop and to South Africa.

The Karas Region has a set of very good road networks that connect the region to the Luderitz Harbour via the B4 national road and to Hardap Region via the B1 national road. There are also railway network connecting Luderitz to Windhoek and the rest of the country. Most towns in the regions are connected via either bitumen road or in some cases gravel but well maintained road. The electricity connection covers the entire region and water infrastructures are also available. There is also a railway that connect Luderitz to Rosh Pinah via Aus town.

3.1.5 Conservation and Tourism

There are a wide variety of tourist attractions in the //Kharas Region and this industry has much potential to drive development in the region. Lüderitz is a key attraction for Namibians and international visitors alike, from where activities as diverse as dolphin viewing, bird watching and dune-boarding can be practised. The //Kharas region is experiencing rapid growth in communal conservancies which is a clear sign that communities are seeking to benefit from the tourism opportunities in the region.

3.1.6 Agriculture

Although agriculture has been the backbone of Namibian society for the past century, it typically only contributes highly to the overall GDP. Interestingly in //Kharas Region, agriculture contributes particularly significantly towards both livelihoods and GDP. The potential of agriculture is limited by the extreme aridity of the region, particularly in the southern part. In the some part, ephemeral rivers are virtually the only areas where pastoralism and small-scale farming can be practised. The inhospitability of the land perhaps explains why 80% of the population resides in urban areas. This is an unusually high percentage when compared to other Namibian regions, with the exception of Khomas Region.

3.1.7 Social Setting

The social environment of Lüderitz and the wider //Kharas region has largely been shaped by the economic factors outlined above. The importance of mining in the region, as well as its relatively high level of industrialisation, and the recent increases in tourism, has attracted a large number of migrant labourers to the region. Similarly, //Kharas region differs from most other regions in Namibia in that its population is highly urbanised (80% of the people live in urban areas). The region also typically fares relatively better than other regions in terms of variables such as income, employment, health and education. However considerable social problems exist in the region.

3.1.8 Population and Migration

Migration is a key social factor at work in //Kharas, which continues to attract a large number of people in search of employment especially to the Namdeb Mine. Inherently, majoring of the people migrating into the region are mainly coming from other regions especially the four O regions in the northern part of Namibia mainly for employement purpose. This is further reflected in the fact that Oshiwambo is the most commonly spoken language at home in the region due to the migration from the northern regions.

3.1.9 HIV/AIDS

HIV/AIDS is having a strong negative social and economic impact in Namibia. The prevalence rate of HIV/AIDS was estimated at 19.9% in 2006 (NDP3). While child health, nutrition and other health areas are slowly improving, the increasing prevalence of AIDS among the population is having a detrimental impact on health with life expectancy falling, particularly in the poorer regions of Namibia (ERM, 2005). HIV/AIDS is also often associated with areas affected by high levels of migration.

While exact figures are difficult to come by, the //Kharas Regional Poverty Profile of 2005/2006 states that HIV/AIDS and orphanhood are steadily increasing throughout the region. However, it is generally considered a more serious problem in urban areas. Overall, the socio-economic impact of HIV/AIDS is significant, and includes reduced workforce productivity, premature loss of main bread-winners, cost of medicine and funerals, need for workforce replacement and training, and orphan care. The continuing rapid rate of HIV infection may be considered as one of

05).

3.1.10 Access to Services, Livelihoods and Income

The high urbanisation rate in //Kharas means that access to education, health services and other facilities is better than in most other regions in Namibia. According to the Population and Housing census (2001), 96% of households had access to safe water and 73% had access to electricity. The literacy rate stood at 92%, while //Kharas had an unemployment rate of 34%. These figures compare very favourably with other regions. This is supported by other figures from the NPC (2000) which showed that an average of 15.3% of the population in the //Kharas Region was living in poverty compared to 23.4% of the total population of Namibia. However, Mendelson *et al* (2002) note that the region is characterised by the highest level of inequality in Namibia, and significant differences are also found between urban and rural areas.

3.1.11 Marginalised groups

The Topnaar people are the most marginalised group in //Kharas. Since their ancestral land was declared a national park, they have essentially been squatters on their own land. They are no longer allowed to hunt and they subsist from smallscale goat herding along the ephemeral rivers. Their nutritional and medicinal needs are mainly met by the !nara melon, which is the main plant able to withstand the harsh conditions of the region. Other marginalised communities include retrenched mine workers who become stranded in the region without any other employment opportunities.

3.2 Archaeological and Heritage Context

An archaeological assessment for the mariculture sites at Lüderitz found that although all are located in areas with known archaeological sites the proposed development projects will not affect any known sites. No special mitigation measures are proposed except that the client should adopt the Archaeological Chance Finds Procedure in Appendix 1 (Archaeological Assessment Report).

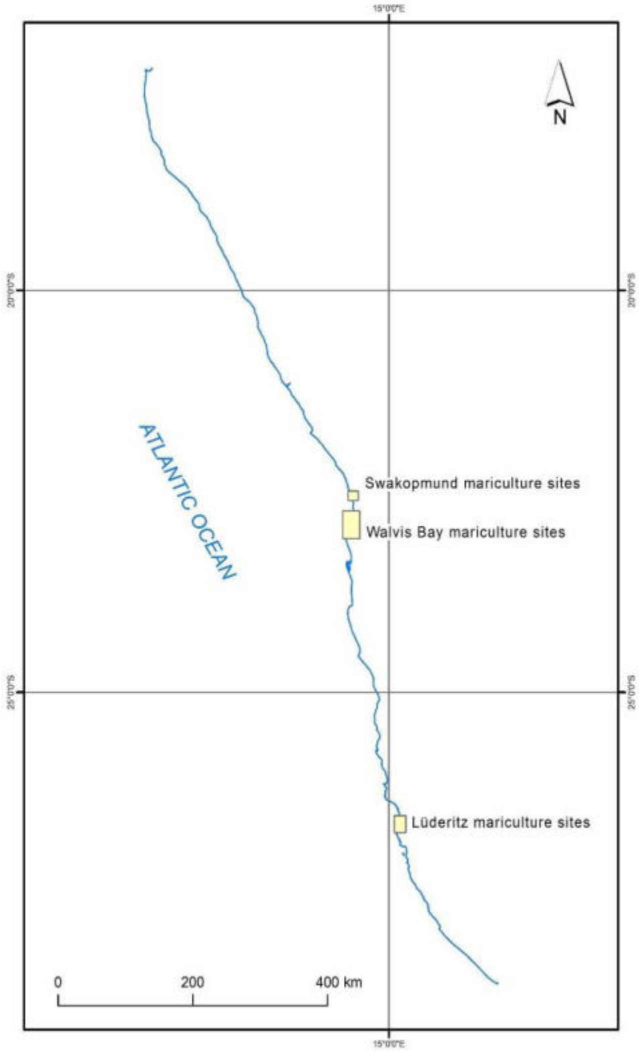


Figure 4: Map showing the location of the Lüderitz

Archaeological assessment relies on the indicative value of surface finds recorded in the course of field survey. Field survey results are augmented wherever possible by inference from the results of surveys and excavations carried out in the course of previous work in the same general area as the proposed project, as well as other sources such as historical documentation. Based on these data, it is possible to predict the likely occurrence of further archaeological sites with some accuracy, and to present a general statement (see Archaeological setting, below) of the local archaeological site distribution and its sensitivity. However, since the assessment is limited to surface observations and existing survey data, it is necessary to caution the proponent that hidden, or buried archaeological remains might be exposed as the project proceeds. Unexpected discoveries are subject to the Chance Finds Procedure.

Climatic fluctuations during the last few thousand years stimulated an increasing diversity of subsistence strategies, including an emphasis on marine resources. Coastal occupation, mainly represented by large shell midden sites was however limited to a small number of localities on the Namib coast where reliable water supplies existed. Shell midden sites on the Namib coast consist for the most part of large accumulations of *Donax serra* reflecting a heavy reliance on this food source during a period of climatic instability when the availability of food and water in the desert interior was particularly unpredictable.

The reliance on shellfish during this period on the Namib coast is matched by similar evidence from the west coast of South Africa where they are known as mega-middens due to their size.[1] However, some of the Namib coast middens are larger than the South African examples by several orders of magnitude. Although they are often larger than their South African counterparts, shell midden sites on the Namib coast are fewer in number and this is because sites with reliable water are less common.

On the Namib coast shell middens are subject to intense weathering and aeolian attrition, as illustrated by the example presented in Figure 3. As in most shell middens on this coast this example is an agglomeration of discrete shell heaps averaging around 0.2 m^2 each, with their margins obscured due to slippage. These accumulations are reduced through gradual removal of shell from the midden by the force of coastal winds reaching a velocity of up to 19 knots, in excess of 36 km/hr.[3] The wind repeatedly lifts and drops midden shell which fragments under attritional impacts until small enough (between 70 and 500 *μm*) to move by a process of aeolian saltation, leaving the site via a wellwind-transport course towards the north.

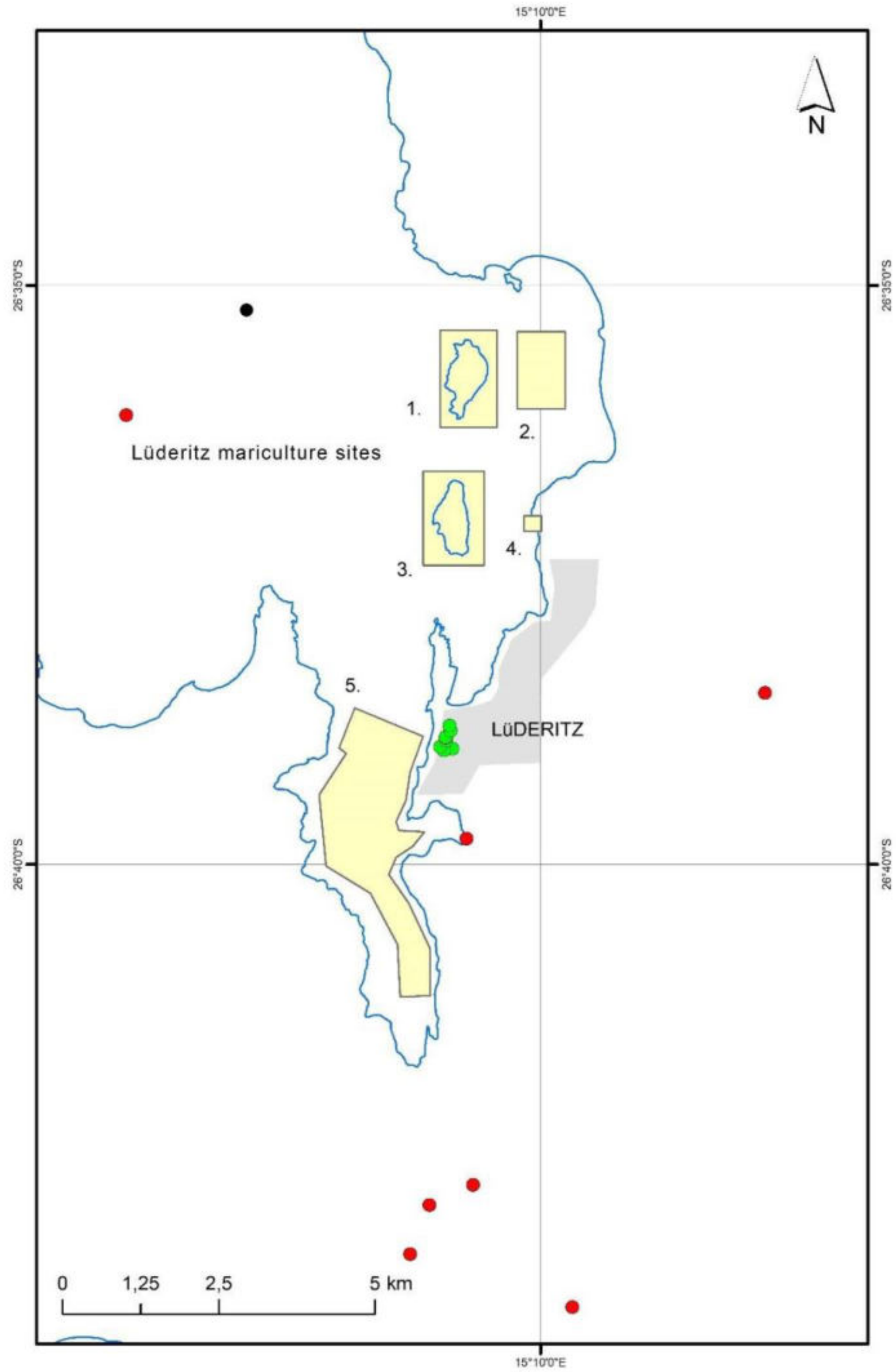


Figure 5: Map showing the Lüderitz Mariculture sites

Figure 10: The location of the Lüderitz mariculture sites (numbered 1 - 5) in relation to the town area, indicating one known shipwreck (black dot), proclaimed National Monuments (green dots), and archaeological sites (red dots).

The Lüderitz mariculture sites shown in Figure 10 comprise the waters surrounding two offshore islands, namely Seal Island and Penguin Island (1 & 3); an area between Seal Island and the edge of Lüderitz Bay (2); a small onshore site immediately north of the harbour (4), and an extensive collection of small sites in the northern part of Second Lagoon, combined for the purposes of this assessment as a single site (5). There are no known archaeological sites in any of the five proposed mariculture sites at Lüderitz.

For purposes of assessment archaeological sites are rated on two parallel 0 5 scales which allow independent assessment of Significance and of Vulnerability. These scales are set out in Table 1. Essentially, Significance reflects the known or potential importance of an archaeological site for the understanding of Namibian precolonial human history. The highest ranking would be given to a site of unique value both to national heritage and to scholarship. Vulnerability reflects the degree to which a site may be affected by the specific development project under consideration. In other words, high Significance does not automatically equate with high Vulnerability. The highest Vulnerability ranking would be given to a site that is certain to be destroyed or seriously degraded if the development proceeds. Thus, a highly Significant site can have a low Vulnerability, and vice versa.

In light of these observations the project should be approved as having a low risk of damage to archaeological sites that are protected in terms of the National Heritage Act (27 of 2004). No special mitigation measures are proposed. However, in view of the possibility that previously unknown underwater or buried archaeological sites may be found in the course of development, it is strongly recommended that the client should adopt the Archaeological Chance Finds Procedure in Appendix 1 as part of the project Environmental Management Plan.

3.3 Bio-Physical Environment

3.1.1 Climate

Lüderitz is characterized by a desert climate and is classified as BWh by the Köppen-Geiger system. The average maximum temperature as indicated in figure 3 below varies between 20 and 24°C with the average minimum temperature between 14 and 19°C.

Climate data for Lüderitz													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	23 (73)	22 (72)	22 (72)	21 (70)	20 (68)	19 (66)	19 (66)	18 (64)	18 (64)	19 (66)	20 (68)	22 (72)	20.3 (68.4)
Average low °C (°F)	14 (57)	14 (57)	14 (57)	13 (55)	11 (52)	11 (52)	10 (50)	10 (50)	10 (50)	11 (52)	12 (54)	13 (55)	11.9 (53.4)
Average precipitation mm (inches)	2 (0.08)	2 (0.08)	4 (0.16)	3 (0.12)	2 (0.08)	3 (0.12)	2 (0.08)	2 (0.08)	1 (0.04)	1 (0.04)	0 (0)	1 (0.04)	23 (0.92)
Source: World Climate Guide.													

Figure 6: *Average monthly temperature for Lüderitz (WorldWeatheronline®, 2022)*

There is not much rainfall recorded throughout the year in Lüderitz. Rainfall in Lüderitz is ordinarily expected during the summer months as indicated in figure 4 below and on average 80% of this rainfall is experienced from November to May. Lüderitz receives an annual precipitation of 29 mm. No rain of any significance falls from June to August, while the chance of rain increases gradually from November until February, which is the month with the highest total on average, and then decreases again until May.

3.1.2 Topography, Geology, Hydrogeology

<u>Topography:</u>

The Luderitz Harbour has a very shallow rock bottom, making it unusable for modern ships; this led to Walvis Bay becoming the centre of the Namibian shipping industry. Recently, however, the addition of a new quay has allowed larger fishing vessels to dock at Lüderitz. The town has also re-styled itself in an attempt to lure tourists to the area, which includes a new waterfront area for shops and offices.

Lüderitz surroundings, including the Peninsula and the coastal areas north and south of the town; the inland area; and the Lüderitz town area itself. With regard to the

hing some 500 m inland from the high water mark within the built-up area of the town and its surroundings, there is a strong emphasis on access to the coast for residents and tourists and the provision of public space.

The topography of Aus and Rosh Pinah can be described as generally flat with numerous ranges and small mountain ranges, and torra formations seen occasionally. The areas vegetation can be describe as a composition of bushes and shrubs with grasses evident almost everywhere. Amongst the important wildlife species found within the area are springbok, Chacma Baboon, Kudu, Cape Fox, Steenbok, and Aardwolf etc. The area also teemed with many species of birds and reptiles.

Geology:

The geological formation of the Karas Region varies from one area to another. The region is well known as having abundance of minerals and vast natural resources and

diamonds are mined, Luderitz with its fishing industry and Rosh Pinah where S

The Luderitz area is mainly made up of the Bogenfels which stretch along the coastal Namib Desert of Namibia. Bogenfels is noted for its natural rock formation which in most cases could be up to 55 metre high rock arc close to the cost. Some high rocks near Luderitz are not accessible due to the terrain and some location on the south eastern part are restricted area and only accessible with official guided tours.

The national road from Luderitz to Rosh Pinah passes through Aus town and it is about 294 km long. The route is mainly flat with some mountain between Aus and Rosh Pinah town. The Rosh Pinah area is dominated by the Karas mountain range mostly on the south eastern part.

Figure 7: Shows some mountains in the southern part of Rosh Pinah south east of Lüderitz

3.1.3 Terrestrial Ecology

Vegetation in the //Kharas Region is important for its uniqueness (high degree of endemicity), and its resource potential, including medicinal. Inselbergs, in particular, harbour many unusual and valuable plants with the Brandberg being outstanding in this respect. The role of inselberg vegetation as food source and habitat for wildlife, its function as a seed pool for re-colonising degraded areas and its tourism potential, strengthens the need for appropriate protection and management of inselberg habitats.

The riparian forests of ephemeral rivers are a resource for browsing livestock and game, and a source of wood for residents. The lichen fields, Welwitschias, and Naras are famous for their unusual and aesthetic characteristics, which are, for instance, valuable for promoting the tourism potential of the area. Fog plants, such as the pencilbush Arthraerua leubnitziae, the dune succulent shrub Trianthema hereroensis, and the spiny dune grass Stipagrostis sabulicola, illustrate important principles of this living desert.

Terrestrial Fauna

Major habitats of importance for the terrestrial fauna are the plains, river beds, washes, sand dunes, inselbergs, and beaches (see flora). The availability of water, food, and shelter differ between these habitats, as well as from west to east. Some animals, particularly many of terrestrial mammals and birds, are dependent on the regular availability of free water, and this affects their distribution and seasonal movements. There is no comprehensive list of the fauna to be found within the project area.

The Site:

The project area is free of any significant vegetation (endangered flora species) as well as tress to be considered and/or conserved as they are all water based a few kilometers offshore Namibia.

4 PROJECT DESCRIPTION

The proposed activity has the potential to improve the livelihood of the coastal communities through direct and indirect benefits to the operators. Marine Aquaculture has the potential to generate a wide range of benefits as a viable, sustainable and scalable climate change adaptation option. The Marine Aquaculture development initiative holds the unexplorable potential to improve food and livelihood security for the Lüderitz residents to contribute to the social and economic well-being of the coastal communities.

The project seeks to enable prospective operators who are interested in Marine Aquaculture to acquire permits and authorisations to operate mariculture at designated areas allocated by the Lüderitz Municipality.

The project will create employment opportunities for those interested in working on fish farms, especially the many unemployed youths who were retrenched as a result of the changes in legislation that left many companies lost out on their quotas.

4.1 Project Components

The proposed mariculture development includes designs, construction, operational and decommissioning stages of the aquaculture farms. Specific activities at each stage of mariculture development is outlined in the marine assessment report. The marine specialist assessment reports have outlined various designs that can be used for offshore and onshore mariculture's systems. Construction methods also various between aquaculture farms on land and one offshore.

Below area the proposed six (6) species to be part of the study as well as those that were identified during the consultations with the Interested & Affected Parties.

<u>Proposed species as per the Terms of Reference of References:</u>

Pacific Oyster (*Crassostrea gigas)*
Black Mussels *(Choromytilus meridionalis)*
Scallops *(Argopecten purpuratus)*

Abalone *(Hariotis midae)*
Kelp/seaweed *(Laminaria and Ecklonia)*
West Coast Rock Lobster *(Jasus lalandii)*

Proposed species from the consultations:

Sea Cucumber *(Holothuroidea)*
Tilapia *(Oreochromis niloticus)*
Yellowtail Kingfish *(seriola lalandi)*
Dusky Kob
Silver Kob
Atlantic Salmon
Galjoen
Steenbra
Dassie/Kolstert

5 PROJECT ALTERNATIVES

3.1 Alternative Assessment

The need for the mariculture development in Lüderitz derives from the need for providing alternative access to the marine species for farming at small scale in line with Vision 2030, National Development Plan 5 and 6 and the Harambee Prosperity Plan II. This initiative have the potential to ensure food security and improve livelihood of the coastal community.

According to the Environmental Management Act No. 7 of 2007 and its Regulations (2012), alternatives must be considered during the EIA process. According to the

3.2 No-Go Alternative

The no-go option is ruled out due to the economic prospects for mariculture development due to its potential to create employment opportunities for the Swakopmund residents while providing access to the much-needed fish species to the communities.

5.1 Site Alternative

An assessment of project alternatives was carried out to fulfil the requirements of the terms of reference (ToR) and EIA guidelines. The alternatives were suggested through professional experience and consultation with stakeholders, the public and local communities. The screening process used considered poterntial environmental effects, social acceptability, engineering feasibility and cost. This EIA Report includes but it is not limited to the acceptable alternatoves carried forward. Alternatives further identified during the development of the Project can also be assessed and if viable can also be considered.

An assessment of any possible alternatives to the proposed mariculture development for Lüderitz was carried out. The The alternatives were selected through professional experience and consultation with project stakeholders, the public and local communities. The screening criteria considered potential environmental effects, social acceptability, engineering feasibility, and cost. This EIA Report includes but is not limited to, the acceptable alternatives carried forward. Alternatives further identified during the development of the Project are also assessed. However, the study found the site identified by the Municipality to be appropriate for the proposed development due to its unique position, proximity to water sources and away from residential areas.

5.2 Proceed with the Project

From the impact assessment persepective, it would be ideal to proceeding with the proposed mariculture development will contribute
Vision 2030, National Development Plan 5 & 6 (NDP5 & 6) and its Harambee Prosperity Plan II (HPP 2016-
its NDP 5 (2017-2022) focus on improving the quality of life of the people of Namibia to the level of their counterparts in the developed world.

The proposed initiative would enable prospective operators to have access to fish species for farming at commercial purposes. This would enhance the livelihood of the local community by gaining longterm employment while contributing to food security in the region and beyond.

The design of the mariculture farms and assessment of altrnatives are focused on ensuring that all significant adverse effects of the mariculture operations are reduced or can be avoided entirely through good design, mitigation measures and implementations of the proposed mitigation measures.

5.3 Advantages of the Mariculture Development

The Project would have substantial economic benefits to the Lüderitz community and Karas Region in general in generating economic activity through the the mariculture development. The Project would be expected to make a substantial contribution to the development of Lüderitz by creating employment opportunities for local residents. Finally, the initiative would also encourage a level of general optimism and growth in communities facing significant development challenges.

6 PUBLIC PARTICIPATION PROCESS

6.1 PUBLIC PARTICIPATION REQUIREMENTS

In terms of Section 21 of the EIA Regulations, a call for open consultation with all I&APs at defined stages of the EIA process is mandatory. This entails participatory consultation with members of the public by according them an opportunity to comment on the proposed project. Public participation in this project has been undertaken to meet the specific requirements in accordance with the Environmental Regulations as well as the international best practice.

6.2 PROPOSED APPROACH

The public participation process (PPP) undertaken for this project can be divided into the following phase:

Project initiation;

Environmental Assessment Phase; and

EIA Phase (if required) by the Ministry of Environment, Forestry and Tourism.

6.2.1 Commencement of the Public Participation Process

The approach adopted for the initiation of the EIA and associated PPP was to identify and contact potential I&APs as possible through a number of activities which included:

Placement of site notices/ posters in Lüderitz namely; Municipality of Lüderitz notice board, and other public notice boards;

Placing advertisements in three newspapers namely, The Namibian and Namib Time and The Republikein;

Distribution of the Background Information Document to Interested & Affected Parties in Lüderitz area during the consultation period;

Giving written notice of the proposed project to potentially affected stakeholders via email during the consultation period.

Hosting a Public Meeting in Lüderitz.

The public consultation process was formally initiated with the advertisement of the EIA process in the newspapers (The Namibian, Namib Times and The Republikein) on **27th July 2022, 03rd August 2022 and 29th July 2022 and 05th August 2022**. As part of the notification period, all of the identified potential I&APs were invited to participate in the EIA process via email. I&APs were given more than 14 days within which to submit comments or register from **27th July 2022 to 29th August 2022**.

Public Meeting

At the public meeting that was held on 16th August 2022, the information was provided in English. The facilitated discussions, attendance register as well as presentation from the public meeting are documented. The public meeting was held at the Lüderitz Nest Hotel and it was attended by 61 people (see attendenace register). Comments and concerns raised by I&APs regarding the proposed project have been recorded in the Comments and Response Report (CRR) which is included as annexture. The table below highlights some of the comments raised at the meeting as well as those from the distribution of the background information document.

Table 2: Main issues received during initial PPP

Impact Group	Potential impacts / issues identified during public consultation
I&AP	Will the oysters and scallops will be kept in separate farm areas?
I&AP	Is it possible if mussel farming could be considered as an alternative for the industry?
I&AP	Were there any studies conducted related to the food chain dynamics of the area. Specifically, in terms of volume and diversity and how these parameters are being impacted on by the mariculture industry?
I&AP	How long it will take for the project to reach its maximum, and what exact areas have been identified?
I&AP	What are the factors affecting development of aquaculture and their use in forecasting production?
I&AP	Were the operators invited for the meeting?

The initial database formed the basis of the current I&AP Register, which comprises directly affected landowners, relevant authorities as well as other organs of state, who are automatically included in the I&AP register. The current I&AP register includes all I&APs who were identified in the initial database as well as additional I&APs who registered during the comments period. It should be noted that the I&AP database will be updated throughout the project as new I&APs register.

6.2.2 Environmental Assessment phase 2

The second phase of the PPP entails availing the Draft Environmental Assessment Report (DEAR) to all registered I&APs for comment and review. All registered as well as potential I&APs are informed of the DEAR for public comment via an email dated. An Executive Summary of the draft EA report is similarly included in the emails to the registered I&APs. I&APs will have until **November 2022** to submit comments or raise any issues or concerns they may have regarding the proposed project.

6.3 WAY FORWARD

Comments and input raised by the I&APs during the public consultation process will be integrated into the Final Environmental Assessment Report (FEAR) and will then be submitted to MEFT: DEA for consideration and decision making. If MEFT: DEA approves or requests additional information / studies all registered I&APs and stakeholders will be kept informed of the progress throughout the assessment process.

7 ASSESSMENT METHODOLOGY

This chapter describes the assessment methodology employed in determining the significance of the construction and operational impacts of the proposed project.

The Assessment of the anticipated significance of impacts for a proposed development is by its nature, inherently uncertain environmental assessment is thus an imprecise science. To deal with such uncertainty in a comparable manner, a standardised and internationally recognised methodology has been developed. This study's accepted methodology is applied to assess the significance of the potential environmental impacts of the proposed development, outlined as follows in **Table 3**.

Table 3: Impact Assessment Criteria

CRITERIA	CATEGORY
Impact	**Description of the expected impact**
Nature Describe type of effect	**Positive**: The activity will have a social / economical / environmental benefit. **Neutral**: The activity will have no effect **Negative**: The activity will have a social / economical / environmental harmful
Extent Describe the scale of the impact	**Site Specific:** Expanding only as far as the activity itself (onsite) **Small:** [illegible] km of the site (limited) **Medium:** Within 5 km of the site (local) **Large:** Beyond 5 km of the site (regional)
Duration Predicts the lifetime of the impact.	**Temporary:** < 1 year (not including construction) **Short-term:** 1 □ 5 years **Medium term:** 5 □ 15 years **Long-term:** >15 years (Impact will stop after the operational or running life of the activity, either due to natural course or by human interference) **Permanent:** Impact will be where mitigation or moderation by natural course or by human interference will not occur in a particular means or in a particular time period that the impact can be considered temporary

CRITERIA	CATEGORY
Intensity Describe the magnitude (scale/size) of the Impact	**Zero:** Social and/or natural functions and/ or processes remain unaltered **Very low:** Affects the environment in such a way that natural and/or social functions/processes are not affected **Low:** Natural and/or social functions/processes are slightly altered **Medium:** Natural and/or social functions/processes are notably altered in a modified way **High:** Natural and/or social functions/processes are severely altered and may temporarily or permanently cease
Probability of occurrence Describe the probability of the Impact actually occurring	**Improbable:** Not at all likely **Probable:** Distinctive possibility **Highly probable:** Most likely to happen **Definite:** Impact will occur regardless of any prevention measures.
Degree of Confidence in predictions State the degree of confidence in predictions based on availability of information and specialist knowledge	**Unsure/Low:** Little confidence regarding information available (<40%) **Probable/Med:** Moderate confidence regarding information available (40-80%) **Definite/High:** Great confidence regarding information available (>80%)
Significance Rating The impact on each component is determined by a combination of the above criteria.	**Neutral:** A potential concern which was found to have no impact when evaluated **Very low:** Impacts will be site specific and temporary with no mitigation necessary. **Low:** The impacts will have a minor influence on the proposed development and/or environment. These impacts require some thought to adjustment of the project design where achievable, or alternative mitigation measures **Medium:** Impacts will be experienced in the local and surrounding areas for the life span of the development and may result in long term changes. The impact can be lessened or improved by an amendment in the project design or implementation of effective mitigation measures. **High:** Impacts have a high magnitude and will be experienced regionally for at least the life span of the development, or will be irreversible. The impacts could have the no-go

CRITERIA	CATEGORY
	proposition on portions of the development in spite of any mitigation measures that could be implemented.

*NOTE: Where applicable, the magnitude of the impact has to be related to the relevant standard (threshold value specified and source referenced). The magnitude of impact is based on specialist knowledge of that particular field.

For every impact, the Extent, Magnitude and Duration are described. These criteria are used to determine the significance of the impact - in the case of no mitigation and then with the most effective mitigation measure(s) put in place. The decision as to which combination of alternatives and mitigation measures to apply lies with the Ministry of Fisheries and Marine Resources as the proponent, and their acceptance and approval ultimately with the relevant environmental authority.

The Significance of an impact is a result of considering the temporal and spatial scales as well as the magnitude. Such significance is also informed by the context of the impact, i.e. the character and identity of the receptor of the impact. The means of arriving at the different significance ratings is explained in **Table 3** above.

7.1 MITIGATION MEASURES

There is a hierarchy of actions which is usually undertaken to respond to any proposed project or activity. These includes avoidance, minimization and compensation. It is possible and considered sought after to enhance the environment by ensuring that positive gains are included in the proposed project. If negative impacts occur then the hierarchy indicates the steps below.

Impact avoidance: This step is most effective when applied at an early stage of project planning. It can be achieved by:

- not undertaking certain projects or elements that could result in adverse impacts;
- avoiding areas that are environmentally sensitive; and
- Putting in place preventative measures to stop adverse impacts from occurring.

Impact minimization: This step is usually taken during impact identification and prediction to limit or reduce the degree, extent, magnitude, or duration of adverse impacts. It can be achieved by:

- scaling down or relocating the proposal;
- redesigning elements of the project; and
- taking supplementary measures to manage the impacts

Impact compensation: This step is usually applied to remedy unavoidable residual adverse impacts. It can be achieved by:

- rehabilitation of the affected site or environment, for example, by habitat enhancement;
- restoration of the affected site or environment to its previous state or better; and
- Replacement of the same resource values at another location (off-set), for example, by wetland engineering to provide an equivalent area to that lost to drainage or infill.

8 Assessment of potential impacts and possible mitigation measures

The potential impacts that could arise as a result of the development of marine aquaculture in Lüderitz have been identified based on the existing sources of information and knowledge of the proposed area. Impacts related to the construction and operational stage of the mariculture farms have been identified and grouped into phases on when they are anticipated to occur and mitigation measures indicated on the adjacent impact. However, detailed mitigation measures have been proposed in the Environmental Management Plan.

8.1 Planning and Design Phase Impact

To ensure that the proposed marine aquaculture does not negatively impact the environment in which the project is being implemented, it is imperative to ensure that associated impacts are identified at an earlier stage of the project. The following are some of the identified issues to consider at the planning and designing stage of the proposed mariculture development.

8.1.1 Siting of the Land-based Mariculture Farms

Siting of the land-based Mariculture farms needs to be carefully considered as some areas proposed for mariculture activities might need to be levelled and earthworks may need to be done to ensure that the excavation works can be undertaken without causing any damage to existing municipal pipes and cables.

Any identified municipal pipes or cables should be re-routed to avoid disturbances during the construction stage. Authorisation should be sought from the Lüderitz Municipality before any re-routing work is done.

8.1.2 Land use

Existing land use of the areas allocated for mariculture activities should be considered during the planning and design stage to ensure that no conflicting land use activities are lumped together. Consent should be obtained from existing adjacent land users before aquaculture activities commenced to avoid conflict between various land users. All necessary land use Permits from the Municipality should be obtained before the commencement of the proposed activity.

8.1.3 Electricity availability

The electricity consumption for the proposed mariculture farms is not yet determined. However, more prospective operators should apply for the appropriate electricity requirements from the Municipality or relevant service provider.

8.1.4 Traffic flow

Traffic is expected to increase once the construction phase commences due to construction vehicles driving in and out of the site. Mitigation measures proposed in the EMP need to be followed to ensure that there is minimal impact on the traffic flow in Lüderitz and the specific suburbs where the mariculture farms will be constructed.

8.1.5 Aesthetic view

The construction of the mariculture farms is likely to bring in a new look due to the obstruction of the mariculture farming infrastructures. The planning and design team should consider the aesthetic view of the existing user to avoid conflict and competing interests. Mitigation measures to inform the planning and design team are included in the EMP.

8.2 Construction Phase Impact

The construction phase is mostly concerned with the impacts on the biophysical and socio-economic environment that is likely to occur during the construction phase of the mariculture development. These impacts are likely to be short-term lived, however, they may have long-term implications on the affected environment and therefore, needs to be mitigated.

8.2.1 Impact on Biodiversity

Construction activity such as site clearance might have an impact on biological diversity and might cause some. Site clearance may only occur in farms allocated for mariculture development once the areas have been allocated to prospective operators and once operators have met all legal requirements such as environmental clearance from the Ministry of Environment, Forestry and Tourism (MEFT) and other requirements from the local authority. Site clearance might also be required for a water pipeline from the shore to supply water to the selected site for mariculture purposes. As indicated in the Environmental Management Plan, the prospective operators are only expected to clear the land allocated to them for mariculture purposes. The areas allocated for mariculture development by the Lüderitz Municipality are not rich in biological diversity as not many faunas and floras are endemic to the area.

The impact on biodiversity in the areas allocated for mariculture development in Lüderitz town was assessed and was found to be average and manageable through proper implementation of the mitigation measures in the EMP. Below are some of the measures proposed in the EMP to ameliorate the biological disturbance and loss:

- Where applicable, vegetation should only be cleared where it is absolutely necessary. Where possible, efforts should be made to ensure that the plant species removed should be replaced with similar species.
- Indigenous trees and plant species should not be removed without the necessary Permit for the Directorate of Forestry at the Ministry of Environment, Forestry and Tourism.
- If unsure about a cetain plant species that may need to be removed, the contractor should consult the regional Directorate of Forestry or the Municipality.

8.2.2 Potential Pollution on Natural Environment

Lüderitz is considered a holiday destination for many Namibian and international tourists. Visitors have praised the coastal town for its serenity is considered one of the cleanest towns in Namibia. It is, therefore, important that the prospective operators and their contractors ensure that they have designated waste areas to curb the land, air and water pollution from their activities during the construction phase. All waste generated during the construction phase should be disposed of at an appropriate dumping site.

The impact of pollution is considered moderate and should be controlled through effective mitigation measures as follows:

- There should be a designated waste area for the construction site where all waste should be contained and regularly transported to an appropriate dumping area.
- For dust and air pollution, the contractor should use any dust suppression method to ensure that working areas do not produce more dust in the air.
- All employees should be inducted on a regular basis to remind them of the site rules relating to hygiene practices.
- Use well-maintained machinery and vehicles that meet acceptable emission standards to minimise emissions.

8.2.3 Impact on Heritage Sites and Archaeological sites

Heritage and Archaeological sites could be disturbed through construction works. An archaeological assessment was carried out by an independent archaeological specialist. The Archaeological Assessment Report did not indicate a potential archaeological site that could be disturbed during the construction phase of the mariculture development stage.

The archaeological assessment report advised that even though nothing of archaeological importance was reported. However, should the contractor find anything of archaeological importance, these should be reported to the National Heritage Council as per the steps identified in the EMP.

8.2.4 Health and Safety of Employees

The Health and Safety of all employees is should be the priority of an organisation. If employees are not provided with the necessary Personal Protective Equipment (PPE) they may be exposed to injuries and other risks that might impact their overall. Construction sector is considered as one of the risky working environment in which workers need to be provided with PPE.

In addition, employees, also needs to be inducted on the overall operations of the site and machinery to avoid cauotic sitions where anybody can just operate any machineries without training and authorisation. This risk is assessed and regarded as moderate risks. Hoever, it is important that mitigation measures are implemented to minimise risks.

8.2.5 Noise Pollution

Noise pollution could be a nuisance to neighbouring residents especially since noise from the construction site may impact nearby schools, offices and households who might be enjoying their quite time. Construction vehicles and machineries are some of the contributing factors to noise pollution from the construction site. It therefore important for the contractor to ensure that most of the work that requires heavy machinery that may excess too much noise is conducted at an appropriate time when schools are done and if excess noise is expected that neighbours are notified of such so that they are prepared.

Noise pollution is regarded as a moderate impact and can be minimised by ensuring that activities that may generate excessive noise are carried out at an appropriate time preferably between 07h00 to 17h00.

8.2.6 Dust Generation

Dust emissions from construction sites could be a nuisance to local residents. Activities such as excavation, and usage of some construction machinery and vehicles may contribute to dust emissions coming from the construction site. These emissions cause negative impacts on humans as well as on the environment. This impact is rated as moderate and can be managed by implementing dust suppression methods such as spraying of the road with water before road usage by trucks, and provisions of dust musks to workers exposed to dust. The contractor should also ensure that community members are informed about the planned activities. Construction vehicles should be driven at an appropriate speed and within the speed limit.

8.2.7 Waste Generation

Construction sites usually generate various types of waste ranging from general waste such as cement bags to construction debris. This waste needs to be managed, collected and transported away from the site to an appropriate dumping site. Waste can also be categorised into two groups; solid waste and wastewater. Both can be a nuisance if not handled carefully and disposed of at an appropriate dumping site.

Waste can also be rated as having a moderate impact as it can be controlled and managed easily provided there is willingness from the project owners. Some of the mitigation measures to control waste are as follows:

- Construction workers should be inducted on where to dump their waste.
- No Waste should be left unattended after the work has been completed.
- No Waste should be burned or buried on site.
- Was should be sorted at an appropriate bin/site.

8.2.8 Employment Creation

Temporary to long-term employment could be secured during the construction stage. Even though most companies would have their own long-term employees to work on the project, it is imperative that the contractor employ some people from outside the region. One of the mitigation measures is to ensure that local people are employed on the construction project.

8.3 Operational Phase Impacts

The operational phase impacts look at the impact that migh occur duing the implementation phase of the Lüderitz Mariculture development. These would need the operator or management to ensure that these action are implemented during the operational stage. Some of identified issues that might concern Lüderitz residents are issues such as aesthetic view of the infrsutructures, noise, smell, preditors/prey, health and safety and theft.

The operational activities should be conducted in a manner that does not pose risks to groundwater nor does it cause any problems towards the local residents. The operational issues identified that may come up during operational stage can be managed by implementing the proposed mitigation measures as follows:

- Ensure that there is an emergyency oil spill kits on site to contain any possible oil leakages.
- All hazardous sustances shall be stored and kept away from the general reach by unauthorised personnel.
- Noise levels should be kept at minimal where possible and should be kept within the allowable standard for urban areas.
- Noisy equipment and machinery should be shut down when not in use and stored ay.

8.3.1 Impact Assessment of Noise

Noise from machinery and equipment used at the mariculture farm might be a concern to the local residents. However, these maybe controlled by onlu using the noise equipment when necessary.

8.3.2 Impact Assessment of Solid and Liquid Waste

Solidwaste and Wastewater produced at the centre would be minimal. However, it is important for the for the operator to ensure that all waste are collected and disposed of at an appropriate registered municipal dumping site.

8.3.3 Impact Assessment of Health and Safety

The health and safety of all employees is a priority. Employees working and at the aquaculture farms should be provided with appropriate personal protective. It is also important that new employees are inducted on the overall operations of the fish farm, and machinery usage around the fish farm.

8.3.4 Impact Assessment of Hazardous

Hazardous materials to be used can be harmful to the fish species and to people working at the mariculture facility. Therefore, harzardous matrials should be handled with care and only by an authorised personnel. Appropriate personal protective equipment should be used when handling harzadous matrrials and empty containers or harzadous waste should be discarded at an appropriate waste area.

9 Conclusion & Recommendations

The Environmental Impact Scoping Report was conducted for the Mariculture Development for Lüderitz. Impact assessment was carried out in line with the Environmental Management Plan and Regulations. Aesthetic, noice and water pollution are identified as some of the issues raised by the stakeholders that needs to be addressed in the management plan.

The impact identified are moderate and can be mitigated through various mitigation measures identified in the management plan. It is important to highlight that the positive impact of mariculture development in Lüderitz far outweight the negative impaccts as the initiative will lead to the improvement of the livelihood of the Lüderitz residents.

It is recommenend that the Impact Assessment Scoping Report be updated once the input by the Marine Specialist has been finalised to strengthen the impact analysis, rating and for the generic Environmental Management Plan to propose mitigation measures relevant to the impact identified.

10 Reference

MET (2007). Environmental Management Act (No.7 of 2007) , Ministry of Environment and Tourism, Namibia. Available at: http://extwprlegs1.fao.org/docs/pdf/nam82643.pdf

MET (2012). Environmental Impact Assessment Regulations (No.30 of 2012). Available at: http://extwprlegs1.fao.org/docs/pdf/nam137363.pdf

Archaeological Assessment of Mariculture Projects in Swakopmund, Walvis Bay and Lüderitz, Dr. J. Kinahan (Archaeologist)

11 Appendices

MARINE AQUACULTURE (MARICULTURE) DEVELOPMENTS IN NAMIBIA (LUDERITZ, WALVIS BAY AND SWAKOPMUND)

SPECIALIST REPORT

November 2023

APP NUMBER – 221127000495

Prepared for:
Ministry of Fisheries and Marine Resources
Private Bag 13355
Windhoek
Namibia
Tel: +264 61 205 3911

Prepared by:
KPM Environmental Consulting
P.O. Box 26328
Windhoek, Namibia
Tel: +264 85 747 2222
Email: kpm.consulting@iway.na

ACRONOMYMS

BCLME:	Benguela Large Marine Ecosystem
BOD:	Biological Oxygen Demand
CO:	Carbon dioxide
DoA:	Directorate of Aquaculture
DO:	Dissolved Oxygen
HAB:	Harmful Algal Blooms
IMTA:	Integrated multi-trophic aquaculture
MAWRD:	Ministry of Agriculture, Water and Rural Development
MFMR:	Ministry of Fisheries and Marine Resources
MEFT:	Ministry of Environment, Forestry and Tourism
NDP:	National Development Plans
OIE:	Office International des Épizooties
PE:	Polyethylene
PVC:	Polyvinyl chlorine
RAS:	Recirculating aquaculture system
WOAH:	World Organization for Animal Health
WTO:	World Trade Organization
YTK:	Yellowtail Kingfish

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION AND BACKGROUND

1.1. Overview of the Mariculture Sector

Namibia boasts of being among the major fisheries countries in the world, ranked the 35th on the list of the world main fishing nations, fourth in Africa by production and among the top 10 fish exporting nations in the world. The fishing sector represents Namibia's second largest foreign currency export earner, (after mining) with over 90% of the national fisheries output being exported. The country has developed excellent fisheries markets with well-developed infrastructure for seafood processing that are accredited for export to the lucrative European, Asian, and American markets.

The country's total catches hovered between 500 000 and 600 000 tons for the last couple of decades and there is no expected increase in the Total Allowable Catch (TAC) or allocated quota as the fishery is strongly regulated, the fisheries stock recruitment is impacted by climatic variability and all major fish stocks are being fully exploited. It is within this context that the Namibian government has in recent years identified aquaculture, especially marine aquaculture, as an important potential growth area within the fisheries sector.

The aquaculture industry in the country is still in an infant stage, dating to the early 1800 with the introduction of carp, seabass and other exotic freshwater finfish species in state and private dams. Namibian aquaculture is consisting of the freshwater (inland aquaculture) and the marine aquaculture (mariculture). The growth and development of aquaculture in Namibia is favourable compared to other countries due to several conditions such as the vast unpopulated coastline, pristine and unpolluted waters, a large pool of potential aquaculture species and political support.

The Namibian government has embarked on an aquaculture development drive in early 2000, spearheaded by the Ministry of Trade and Industry, that cumulated in the construction of several community fish farms in the Oshana, Okavango, and Zambezi Regions. When the Directorate of Aquaculture of the Ministry of Fisheries and Marine Resources, was established, it took over the mandate and task of developing the aquaculture sector.

While the freshwater aquaculture sector is a government-driven initiative that is concentrating on low-value species on a semi-intensive level, being low cost and aimed at providing the necessary protein and food self-sustainability, the mariculture sector is capital-intensive and purely a private-sector operation that target high-value species geared towards the export market.

Namibia, in keeping with the Sustainable Development Goals (especially 1, 2, 3, 8, 12 and 14 that deals, respectively, with no poverty, zero hunger, decent work and economic growth, responsible consumption and production, and life below water) has ensure that aquaculture is high on the country's developmental agenda, featuring both in the Government's Vision 2030 and the National Development Plan (NDP5) priority list (NPC, 2017).

1.2. Legislative Framework

Besides the natural resources attribute, the aquaculture development in Namibia is enhanced by the conducive legislative framework. The Government of the Republic of Namibia (GRN), through the Ministry of Fisheries and Marine Resources (MFMR) established the Directorate of Aquaculture (DoA) that is mandated to regulate and control aquaculture and inland fisheries activities and provide sustainable development of aquaculture as well as the conservation and protection of inland aquatic ecosystems and their sustainable management. The DoA has been actively involved with the development of and advocacy for the aquaculture industry. The MFMR put together certain guiding documents such as the aquaculture policy, legislation, and a deployment strategy to provide for an enabling environment and sustainable development of the aquaculture sector. The Aquaculture Policy (MFMR, 2001) was pathway prepare towards responsible development of aquaculture and the adherence to sustainable and best aquaculture practices that included the establishment of the legislative and administrative framework, culminating in the Aquaculture Act (No.18 of 2002). The Aquaculture Act included the provisions in respect rights for aquaculture licenses, establishment of aquaculture zones, emergency preparedness, the allowable and prohibited species in order to maintain genetic diversity and integrity of aquatic ecosystems. This was followed up by the first Aquaculture Strategic Plan (MFMR,2004) which was followed by other strategic plans with last the 2017 – 2022 Strategic Plan, both that assessed the business climate, public acceptability, and strategies to ensure training, research, marketing and infrastructure development during the critical initial plan of the aquaculture development. Aquaculture Master Plan (2012) examined the viability of developing aquaculture (both marine and freshwater) into a vibrant and profitable sector within country. There are also a number of regulations that provide the protocol for some aspects of the legislative documents such as the policy on Aquaculture Regulation on Licensing. Aquatic animal health is regulated through the Regulation relating to Import and Export of Aquatic Organisms and Aquaculture Product.

1.3. Status of the Namibian Mariculture Sector

Namibia is bordering the Atlantic Ocean, having a coastline of approximately 1,572 km that constitutes a wealth of natural resources which is shaped by one of the most productive ocean systems in the world, the Benguela Current Upwelling System. The Benguela Upwelling System is one of five wind-driven coastal upwelling systems in the global oceans and forms an important center of marine biodiversity and is one of the most productive ocean areas in the world due to its distinctive bathymetry, hydrography, chemistry and trophodynamics (Hutchings et al., 2009). The available productivity and abundant biodiversity provide an ample opportunity for the development of the mariculture sector.

The possibility of mariculture sector development is, however, restricted to the few coastal towns of Swakopmund, Walvis Bay, Lüderitz and Henties Bay where suitable infrastructure exists to support the sector as well as established market routes for the fisheries products.

The mariculture industry in Namibia is characterized by extensive and semi-intensive culture systems, most that require significant start-up capital and technical expertise. This is because some aquaculture facilities are pump-ashore systems while others are in the few available bays, and this requires boats to reach the long-lines and drum-suspended baskets. Private investors are involved in the marine aquaculture and only high value species are considered. The mariculture industry is dominated by shellfish as at present the species being farmed are Pacific oyster (*Crassostrea gigas*) and European oyster (*Ostrea edulis*), abalone (*Haliotis midae*), that are not native to Namibia. New developments are being investigated for other exotic species of commercial value such as scallops (*Argopecten purpuratus*), Giant kelp (*Macrocystis pyrifera*).

There are, furthermore, plans of moving towards diversification into marine finfish, which can be viewed positively to ease the pressure and reliance on capture fisheries and to enable robustness of the mariculture industry. New finfish species under consideration for which aquaculture licenses had been submitted include the native Kob species, the Silver and Dusky Kob, (*Argyrosomus inodorus* and *Argyrosomus coronus*), the Yellowtail kingfish (*Seriola lalandi*), and exotic Atlantic salmon (*Salmo salar*).

The mariculture form in Namibia varies from extensive to semi-intensive levels of production. The extensive level of production entails the use of the natural ecosystem (natural environment) such as the ocean and bays for the rearing of the aquatic species with minimal intervention (less effort) in the husbandry process. Limited intervention in the husbandry process that include size grading, cleaning and removal of mortalities constitutes the semi-intensive mariculture level of production.

The prevalent mariculture system employs the using long-lines, racks, and baskets for the rearing of shellfish and aquatic plants. Materials used for the systems ranges from locally available plastic containers, synthetic plastic, polyvinyl chlorine (or PVC), polyethylene, and nylon. The introduction of finfish culture will bring along the introduction of cage culture and tank culture systems for the rearing, for either the sea based or land-based mariculture operation.

Current indications are that the mariculture industry is experiencing good growth after the slump experienced in 2008 due to the unfavourable environmental conditions (harmful algal blooms, sulphur eruption, hypoxia). Noticeable increase in the number of applications for aquaculture licenses have been reported, which is a clear indication of the private sector appetite in venturing into the mariculture industry as an alternative to the traditional capture fisheries.

Mariculture has been classified as sea-based (offshore) and land-based (onshore). This has been mainly oysters and abalone production, practiced at Walvis Bay, Swakopmund and Lüderitz. In Walvis Bay sea-based oyster operations has been practiced at areas that have been designated by NamPort as aquaculture parks (Aquaparks) and land-based operations were restricted to the utilization of the salt works ponds. Swakopmund is currently the site for the only oyster hatchery in the country that is situated at the guano and salt production facility. Experimental work in determining the growth and survive rates of scallops are also being undertaken at the hatchery. Sea-based and land-based operations are practiced for oysters and abalone production, respectively in Lüderitz.

The main mariculture export markets are South Africa, China (Beijing and Hong Kong), Russia with the local market confined to several restaurants and supermarkets. There are currently 3 oyster farms in operation in Walvis Bay, 1 oyster hatchery in Swakopmund, 3 oyster farms in Lüderitz and 2 abalone farms that are also engaged in abalone ranching. A seaweed, the Giant Kelp (*M. pyrifera*) pilot project has been initiated in Lüderitz and is expected to be fully operational once satisfactory results are obtained from the baseline monitoring. An aquaculture license was recently granted for scallops with new aquaculture license under consideration for finfish (Atlantic salmon, Kob and Yellowtail kingfish).

Mariculture production for the mayor economic important species has seen a considerable decline since 2016 to 2021 with accompanying 25% decline in the employment rate in the sector (Table 1). There may be several factors contributing to that, with obvious one being the unpredictable and variable environment conditions along the Atlantic coast.

Table 1. Mariculture production 2019 - 2021 (as reported by MFMR, Namibia)

Year	**Oysters sold (MT)**	**Abalone sold (MT)**	**Mussels sold (MT)**	**Employment (n)**
2016	607.48	0	14.18	213
2017	475.03	0	17.01	213
2018	336.07	0.03	2.72	185
2019	216.97	0	0	182
2020	149.47	0.0048	0	168
2021	261.37	0.57	0	159

2. PROBLEM STATEMENT

2.1. Planned Aquaculture Development.

Aquaculture has been touted as the fastest growing food producing sector, recording growth rates of more than 5% since the early 1980's. For most of the developing countries, aquaculture production is the main source of fish for human consumption, being a solution in relation to the deterioration of fishing reserves and the excessive capture of fish in their natural habitat. Predictions are that the aquaculture industry will be one of the main sources of food produced in the sea, surpassing traditional fishing. In fact, records of 2020, indicates that production from aquaculture has equal that of capture fisheries. The exponential growth of the aquaculture industry, especially when not properly planned is responsible in bringing forth some challenges such as habitat destruction, pollution, biodiversity loss, disease outbreak and contamination of freshwater resources. For example, recently there is mounting evidence of the environmental impacts of plastics and marine litter, which are a growing public, political and academic concern. The aquaculture sector is having to cope with production and management of plastic waste, in addition to the implications that plastic pollution may have on wild stocks and potential health risks from harvested products. Coupled with that, aquaculture is also competing for space and resources with other economic sectors such as agriculture, sea-transport, housing and tourism.

The opposite of the planned mariculture development is an over-crowded and dysfunctional marine space with serious environmental impacts and costly socio-economic conflicts. There is, therefore, a need for planning that considers the accompanying environmental issues that is aimed at striking a fine balance between the site location, type of species and aquaculture system, and accommodation of other users, across the land and marine space. Namibia is in its early stages of mariculture development and stand a good chance in ensuring that environmental, social and conflicting demands are addressed through a well-planned and multi-sectoral decision-making approach.

The need for EIA in the Namibian aquaculture development is aimed at assisting with evaluating the possible environmental, ecological, and social impact and to suggest a framework for sound environmental management in this sector. The culminating results of the stakeholder engagement and input as well as the facts emanating from the observations will be incorporated to better managing potential aquaculture impacts and to ensure that aquaculture development takes place within the environmental legal framework.

2.2. A Scenario analysis of the Namibia Mariculture Sector.

Scenarios planning is a tool used to predict future possibilities based on past trends. This section attempts to predict the future of the Namibian mariculture sector from 2022 to 2030 using the 2000 to 2021 as a past trend. It is shown that since the year 2000, the sector was booming (*Scenario 1*); however, growth slowed down significantly around 2008/9 and switched to *Scenario 2*. *Scenario 2* was being characterized by a stagnant growth and it dominated until 2020/21 (figure 1). From 2022, the mariculture sector was predicted to be growing slowly until 2023 where it is expected to enter a rapid growth phase until 2030.

Scenario 1

In the early 2000's, mariculture was booming as a result of GRN's incentives to invest in the sector such as establishment of various "Aquaculture Parks". This boom phase was followed by a stagnant face due to sulphur eruptions and low DO. These climatic factors which were superimposed on concentration of the sector on shellfish farming only forced closure of many farms between 2008 and 2009. Unfortunately, this forced the sector to switch into Scenario 2, instead of continuing to grow.

Scenario 2

Apart from risks of sulphur eruptions and low dissolved oxygen (DO) levels the lack of diversification also hampered growth of the mariculture sector. Dependence only on shellfish species as well as limited production systems are some of the main factors limiting development of the mariculture sector in Namibia. Shellfish species farmed included pacific oysters (*Crassostrea gigas*), European oyster (*Ostrea edulis*), surf clam (*Donax serra*) and others.

Critically, a window of opportunity exists in the mariculture sector. This window coincides with development of the blue economy in Namibia and many other social changes like the impacts of COVID-19. If these opportunities are seized, this will likely to slowly increase growth of the sector until 2023. Further investments are likely to boost growth of the sector until it reaches a peak in 2030.

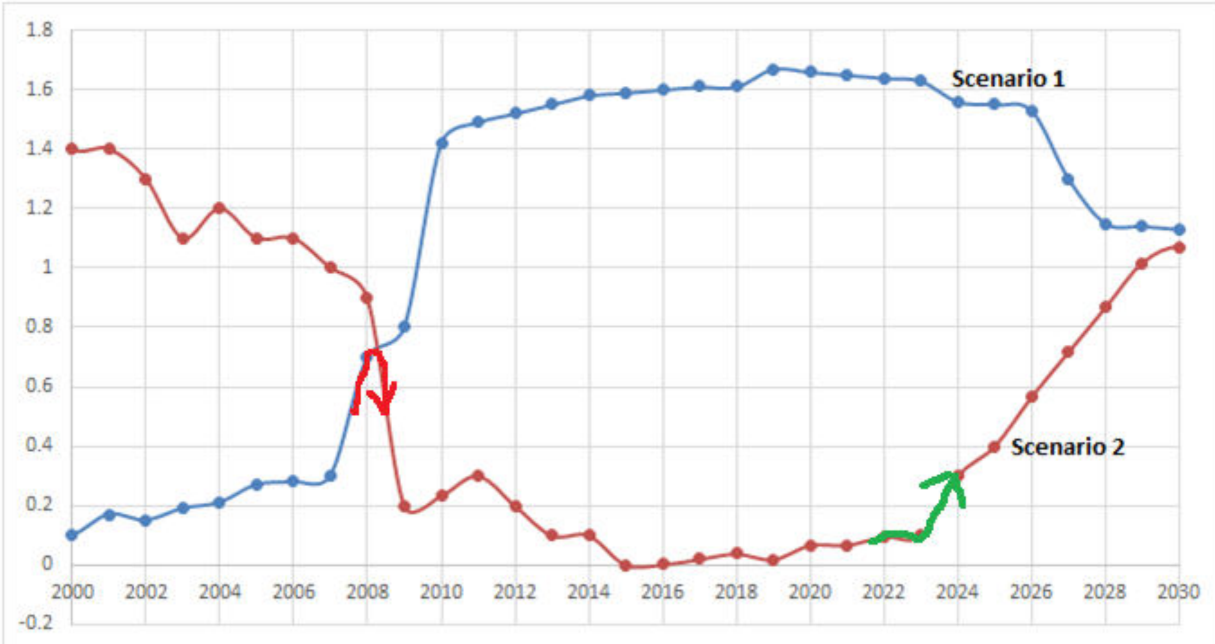


Figure 1. Scenario analysis of the Mariculture Sector.

The selection of a site and species for mariculture development should conform to certain criteria that will improve the chance of success:

- Conducive environmental attributes of the site (water quantity and quality, absence of pollution sources and diseases, water flow velocity)
- No or limited possibility of conflict with other resources users (social acceptance)
- Carefully defined objectives for species selection (e.g., increasing protein supplies to the poor, export for foreign exchange, or restocking),
- Reliable provision of seed within the technological grasp of users, whether through sustainable wild capture or hatchery production,
- Exhibition of fast growth and ability to attain table or market size in minimum time,
- Ability of species to derive its nutritional requirements from materials available from the pond and/or inexpensive artificial feeds,
- Flavour, taste, and texture that is acceptable to the potential consumers,
- Existence of a known market capable of absorbing the planned level of production,
- Ease of handling and harvest,
- Previously tested production systems

- Preference for native species to avoid environmental risks posed by introducing exotic species.

3. THE MARINE ENVIRONMENT

3.1. Sensitivity of the Marine Environment

The south-western Atlantic Ocean along the coast of South Africa, Namibia, and Angola forms part of the Benguela Upwelling System that is one of the four (4) major upwelling systems in the world. The upwelling, the interaction between the wind movement and the rotation of the earth pushes surface water offshore causing deeper, cooler, nutrient-rich water to rise towards the surface to replace them (Fig. 2). This phenomenon is responsible for the high mean annual primary productivity in this region (estimated to be about 1.25 g C/m^2/year). The Benguela Current Large Marine Ecosystem (BCLME) supports a large biomass of fish, crustaceans, sea birds and marine mammals.

The sea surface temperature in the region fluctuates between 11 – 14 °C to a maximum of 18 °C and 22 °C further north. The salinity is in the range 35.8 – 35.2 ‰.

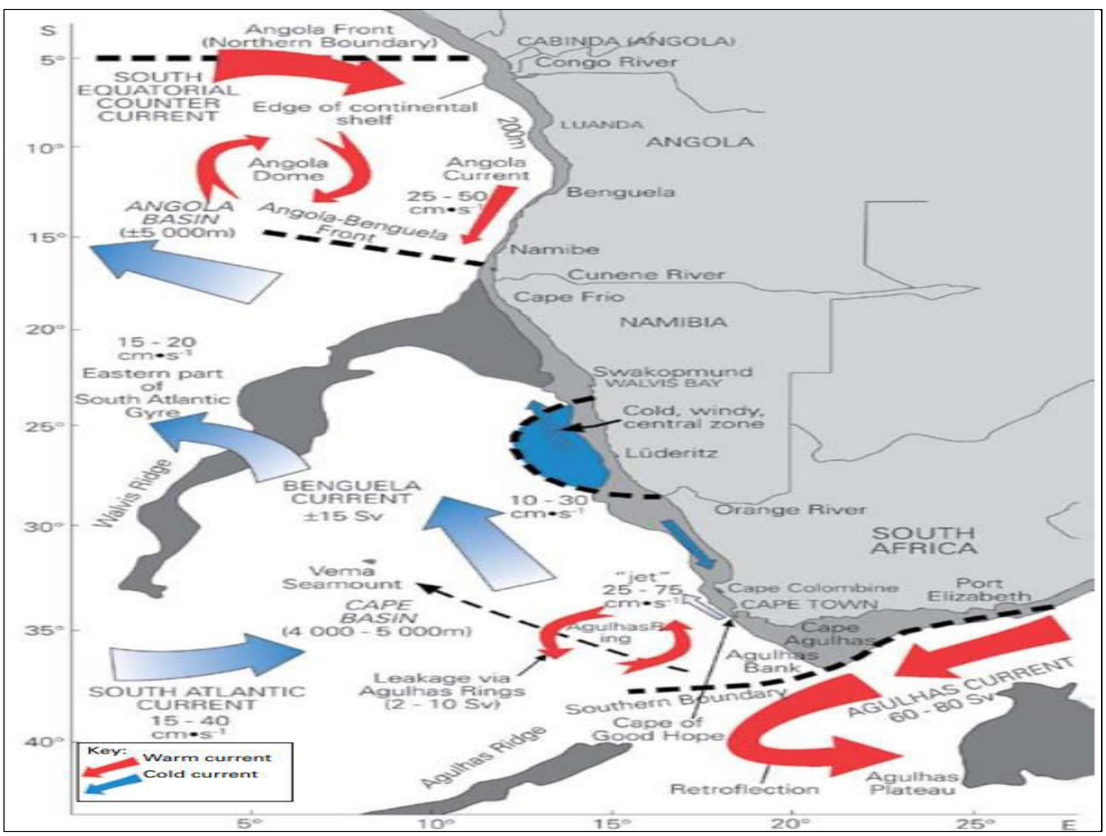


Figure 2. Oceanographic and Surface circulation along the west coast of southern Africa (source: BCLME).

There exists a complex interrelationship between the biotic component (animals and plants) and the abiotic component (physical environment). Any harm to the physical environment automatically leads to harm of animals and plants. This harm is often can be concentrated to a single species and consequently cause damage for other species further up the chain.

Pelagic species in open marine environment can escape away from the harm by going deeper in the deeper or further out to sea, reducing the likelihood that they will be harmed by any harm or unfavourable water quality.

Sedentary organisms and organisms living closely to the shore are at greater risk as the possibility of escape is limited.

3.2. Physical, Chemical Factors

3.2.1. Temperature

Temperature affects all chemical and biological processes. The metabolic rate of fish doubles for every rise of 10°C. Therefore, temperature has a direct effect on important factors such as growth, oxygen demand, food requirements and food conversion efficiency. The higher the temperature, the greater the requirement for oxygen and food and the faster the growth rate. Temperature partly determines the concentration of oxygen in water. The solubility of oxygen decreases with increasing temperature, and so concentrations are usually lower in summer. Temperature also has a crucial role in stimulating fish gonad maturation and spawning activity.

3.2.2. Turbidity

Total solids (TS) are the total amount (measured in mg/L) of solids in water that is either due to physical (e.g., rock weathering), chemical or biological (e.g. decay of phytoplankton biomass) activities and anthropogenic activities such as mariculture, mining or fish processing. Sediment loading of non-organic origin results from physical and chemical activities which usually leads to total dissolved solids (TDS) (e.g. salts, trace elements, etc) and total suspended solids as well as total volatile solids (TVS). Together, they are used to indicate water clarity, which is usually referred to as turbidity.

Mariculture operations can be responsible for turbidity, especially when the cleaning of nets and other equipment takes place at sea. Additionally, the wastes from fish and the feed particulates can also be classified as two major sources of turbidity in cage culture. Increase in turbidity of water results in decrease in light penetration, which in turn affects the phytoplankton production and may further affect photosynthesis of benthic vegetation, and this leads to an increase in microbial loads and in ammonia levels at the cage culture site. Plumes due to the movement and placement of ankers and hooks on the ocean sediment are also sources of turbidity.

3.2.3. Dissolved Oxygen

Oxygen is the most critical and limiting factor in intensive aquaculture. Oxygen enters water through photosynthesis by aquatic plants, principally phytoplankton, and by diffusion at the air-water interface. Diffusion occurs when waters are below saturation, and the greater the deficit between the oxygen concentration in the water and the saturation concentration, the greater the rate of diffusion. In ponds, diffusion is promoted by wind and wave action and by artificial aeration. Oxygen is lost from water through respiration by fish, plankton and other organisms, and by aerobic decay of organic matter. There are distinct diurnal fluctuations of oxygen, with concentrations lowest just after dawn, increasing during daylight hours. This is because of the photosynthetic production of oxygen, (there is also usually more wind during the day) to a maximum in late afternoon, before decreasing again during the night. Oxygen consumption by fish and microbial activity can lower oxygen concentrations in the water column. Consumption is variable and relates to fish biomass, the season and the physical characteristics of the site.

Cage aquaculture systems has been reported to lead to several water quality problems (Nastiti *et al*, 2001), chief among which is depletion of oxygen in the surrounding areas of cage system. This is due to the eutrophic conditions being created by the high levels of dissolved nutrients that emanates from feed and other waste from the operations. Oxygen reductions can be increased by the settlement of algae, hydrozoans, bryozoans and tunicates on the nets.

The nutrients induce algal blooms that, when they die and settles on the benthic environment, are consumed by micro-organisms. There exists valid concern that marine cage culture may significantly decrease dissolved oxygen concentrations capable of causing local short-term impacts, such as the biofouling of the cages, oyster bags and baskets by organic waste, the impact of sulphur eruptions, especially around the Walvis Bay area. Low oxygen water or hypoxic conditions have been observed, especially in the Walvis Bay are. This low oxygen period is during the summer period (February – May) and is preceded by high temperatures, rapid algal blooms and little or no wind or wave action. It is then followed by decay (die-off) of phytoplankton and harmful algal blooms. Mass mortalities of inshore benthic communities follows after this period that results in commercial loss due to rock lobster walkouts and considerable oyster and fish mortalities.

3.2.4. Ammonia

Ammonia is the major waste product of protein or nitrogenous metabolism in fish and other aquatic organisms. The major source of nitrogen compounds in aquaculture production is the protein contained in the feed. Therefore, the rate of ammonia production of fish is proportional to the feeding rate. It is excreted primarily across the gills, and in urine and faeces. Ammonia is also produced during the aerobic decomposition of organic matter by bacteria. In water, the total ammonia-nitrogen (TAN) occurs in two forms, un-ionized ammonia (NH_3) which is toxic to fish, and the ammonium ion (NH_4^+) which is relatively non-toxic, except at extremely high concentrations. Ammonia can change from one form to the other creating a balance between the two forms. Water pH and temperature influence the proportion of total ammonia occurring as the toxic (NH_3) form. Consequently, water samples are taken for TAN levels in the afternoon when pH and temperature are at the daily maxima. Ammonia levels then decrease during the night.

3.2.5. Recommendations for better Water Quality Management practice in Cage culture

- Selection of a suitable site with sufficient depth (10 – 20 m) is recommended to have better water exchange and to avoid the deposition of suspended wastes at the bottom. It also helps to avoid the contact of cage bottom to the sea floor which eliminates the bacterial interactions and benthic foulers.
- Cages should be installed at a place where there is a continuous water current for good exchange of bottom fish wastes and suspended materials.
- The water current velocity should be between 0.05 m/s to 1 m/s with a tidal amplitude of < 1 m. 3.
- Development of nutrient and water quality threshold values.
- Development of feeding strategies to improve the FCR and reduce the nutrient influx into the waters.
- Regular Monitoring of water quality parameters, at weekly intervals, is essential to understand the health status of the cage environment.

- Regular net exchange, at monthly intervals, also improves the water exchange in the cages and improves the environmental health. The nets which are with biofoulers are to be brought to the shore and should be thoroughly cleaned and can be reused.
- Measures should be taken while using the farm vessel, and properly operated with minimum spill and leaks, which may cause pollution in the farm site, that may further lead to fish mortalities.
- Rotation of cages should be implemented to decrease the waste deposition.
- Fish wasters, dead organisms. debris and other suspended materials must be transported to the shore and properly disposed.

3.3. Biological Factors

3.3.1. Effect on the Plankton Communities

Plankton are primary producers in aquatic ecosystems. Changes in species composition, community structure, and abundance of plankton directly impact water quality, energy flow, matter cycling, and biological resources (Bartozek et al., 2014). In addition, most of the plankton species is often used as an important indicator to detect changes in environmental factors and water quality of aquatic ecosystems due to their high sensitivity and rapid response to environmental changes. The temporal and spatial variability in phytoplankton abundance and composition is controlled by various biotic and abiotic factors, such as water temperature, nutrients availability, pH, light conditions, and predation by zooplankton and fish. Any change of environmental factors will lead to the change of phytoplankton community.

The release of nutrients from aquaculture farms can stimulate an increase of pelagic primary production. Higher phytoplankton and zooplankton count, and biodiversity has been observed when nutrients from uneaten feed, organic waste and fish tissue is directly utilized which could induce algal growth (Yongli Gao, et al., 2014). In addition, assemblages in planktonic communities are highly dynamic that changes rapidly in response to circulation and fertilization patterns and with other favorable physical and environmental factors. Planktonic assemblages might fluctuate at short-time scales with different assemblages characterizing the various phases of an upwelling cycle as evident in coastal upwelling systems (Marañón, 2015).

Mariculture operations can change the plankton compositions, in terms of dislocation of previous inhabiting community, aggregation and hierarchy and dominance structures.

3.3.2. Marine Birds, Mammals and other Aquatic Organisms

The mariculture activities can have potential impacts on marine ecosystems, including seabirds, turtles, and cetaceans. Marine mammals and birds are attracted by the high density of available food associated with fish farms. This section presents an Environmental Impact Assessment (EIA) of mariculture operations in the Lüderitz, Walvis Bay, and Swakopmund areas, focusing on the impacts on these three important marine species and proposed mitigations to minimize adverse effects.

3.3.2.1. Marine Birds (Sea Birds)

Seabirds are top predators in the marine environment that play a pivotal role as health indicators of the ecosystem. There are about 82 seabird species found in the Benguela Current Large Marine Ecosystem (BCLME) and 7 species are endemic to the region (MFMR, 2009). Namibia is home to 14 breeding seabird species. The highly productive Benguela Current Ecosystem attracts large populations of seabirds. Seabirds breed mostly on islands, islets, rocks, and platforms in Namibia. However, seabirds also breed on mainland cliffs, salt pans, estuaries, and dune fields as well as on shipwrecks. In Namibia, the offshore islands provide breeding and roosting grounds for different species of high economic and conservation importance. Most of the seabirds are threatened by direct competition with commercial fisheries, overfishing, mortality of seabirds in the fishing industry, oil pollution, predation, disease outbreaks, natural disasters, and direct harvesting of seabirds for food and their products.

The most threatened seabirds in Namibia are the African penguin (*Spheniscus demersus),* Cape gannet (*Morus capensis*), Bank Cormorants (*Phalacrocorax neglectus*) and Cape Cormorants (*Phalacrocorax capensis*). All these species are classified as Endangered in Namibia under the IUCN. They are endangered due to the rapid decline of their populations attributed mainly to the lack of sufficient quality prey and mortality from longline and trawl fisheries as bycatch (MFMR, 2009). This lack of quality prey was caused by the overexploitation of sardines and anchovies in the 1960s. Another contributor to the declining number of seabird populations is the removal of the accumulation of guano deposits on offshore islands which results in habitat loss and altering of habitats of seabirds. Most of these seabird species are endemic to Southern Africa or the BCLME. Most of these species are classified as '*Least concern*" as their conservation status because their populations do not show a decrease. However, the Damara tern and Caspian tern is listed as “Near Threatened” due to habitat loss caused by mining, off-road driving, and coastal development.

Table 2. Seabirds of Namibia that are in the Mariculture Operations Area.

Scientific Name	English Name	Seasonality	Relative Abundance	Foraging range	IUCN Conservation Status
Spheniscus demersus	African Penguin	All year	Common	Coastal waters & offshore	Endangered
Morus capensis	Cape Gannet	Breeding (summer)	Uncommon	Offshore	Endangered
Phalacrocorax capensis	Cape Cormorant	All year	Common	Coastal waters & offshore	Endangered
Phalacrocorax neglectus	Bank Cormorant	All year	Common	Coastal waters	Endangered
Phalacrocorax coronatus	Crowned Cormorant	All year	Common	inshore	Least concern
Phalacrocorax lucidus	White-breasted Cormorant	All year	Common	Coastal waters & inshore	Least concern
Pelecanus onocrotalus	Great white pelican	All year	Common	Coastal waters	Vulnerable
Phoenicopterus ruber	Greater flamingo	All year	Common	Coastal waters	Vulnerable
Phoeniconaias minor	Lesser flamingo	All year	Common	Coastal waters	Vulnerable
Larus Hartlaubii	Hartlaub’s Gull	All year	Common	Coastal waters & inshore	Least concern

Larus dominicanus	Kelp Gull	All year	Common	Coastal waters & inshore	Least concern
Larus cirrocephalus	Grey-headed Gull	Vagrant	Rare	Coastal waters & inshore	Least concern
Sterna balaenarum	Damara tern	All year	uncommon	Coastal waters & inshore	Near threatened
Hydroprogne caspia	Caspian tern	Breeding (summer)	Rare	Coastal waters & inshore	Near threatened
Sterna bergii bergii	Swift tern	Breeding (summer	Uncommon	Coastal waters & inshore	Least concern
Haematopus moquini	African black oystercatcher	All year	Common	Intertidal zone	Least concern
Sterna dougallii	Roseate tern	Vagrant	Rare in Namibia	Coastal waters & inshore	Least concern
Procellaria aequinoctialis	White-chinned petrel	Vagrant	Uncommon	Offshore	Vulnerable
Podiceps nigricollis	Blacked-necked Grebe	All year	Uncommon	Coastal waters & inshore	Least concern

Potential Impacts

Mariculture operations can lead to several impacts on seabird populations, including:

- Entanglement: Nets and other structures used in mariculture may pose entanglement risks to diving seabirds, affecting their foraging and survival. Plunge-diving seabirds such as swift terns, Caspian terns and Cape gannets are at higher risks of entanglement with mariculture farm structures.
- Competitive Interactions: Increased fish farming can lead to competition for food resources between farmed fish and seabirds, potentially leading to reduced prey availability for seabirds.
- Mariculture feeding activities will attract small fish and a high density of small fish will attract seabirds and other marine organisms creating intra-specific competition as well as inter-specific competition.
- Attractants: Mariculture operations can attract large populations of seabirds, mostly scavenging seabirds due to high assemblages of prey species. Mariculture activities can release organic matter and uneaten feed into the water, attracting seabirds that may become entangled or face ingestion risks.
- Artificial lighting: Introduction of artificial lighting to a natural marine environment. Artificial lighting at the establishments can cause disorientation in seabirds, which will cause further entanglement and mortality in seabirds.

Mitigation Measures

To mitigate impacts on seabirds, the following measures are recommended:

- Net Design and Placement: Employ bird-friendly net designs that minimize the risk of entanglement while allowing fish farming to continue.
- Exclusion Devices: Install exclusion devices or deterrents to prevent seabirds from accessing mariculture structures.
- Feed Management: Implement efficient feeding practices to reduce the release of organic matter and uneaten feed, which can attract seabirds.
- Spatial Planning: Consider seabird foraging areas during site selection to minimize competition for food resources.

- Monitoring and Adaptive Management: Regularly monitor seabird populations and behaviours to assess the effectiveness of mitigation measures and make necessary adjustments.

3.3.2.2. Seabird Entanglement in d\Disintegrating Rope strands/Twine

Aquaculture ropes, commonly used in fish farming operations, can have several impacts on seabirds and their habitats. Here are some of the potential impacts:

- Entanglement: Seabirds can become entangled in aquaculture ropes, leading to injury or death. Birds might get caught while diving for fish or when flying low over the water.
- Ingestion: Seabirds may mistakenly ingest aquaculture rope fragments, mistaking them for food. Ingesting foreign objects can lead to digestive issues and, in severe cases, can be fatal.
- Disturbance: The presence of aquaculture infrastructure, including ropes, can disturb seabirds in their natural habitats. This disturbance can disrupt their nesting, feeding, and breeding behaviors, potentially leading to decreased reproductive success.
- Altered Behavior: Seabirds might change their behavior in response to the presence of aquaculture ropes. For instance, they could avoid certain areas, impacting their foraging patterns and potentially leading them to less suitable feeding grounds.
- Habitat Alteration: Aquaculture facilities can lead to changes in the seabed and water quality due to waste and uneaten feed. These changes can affect the availability of prey for seabirds, indirectly impacting their food sources.
- Predator Attraction: Aquaculture operations can attract seabird predators, such as gulls and crows, which are drawn to the easy availability of fish near the surface. This increased predation pressure can affect seabird populations.
- Chemical Contamination: Chemicals used in aquaculture, such as antifoulants and disinfectants, can leach into the surrounding waters and contaminate the food of seabirds. These chemicals can have toxic effects on both the birds and their prey.
- Spread of Diseases: Concentrated populations of farmed fish near aquaculture ropes can facilitate the spread of diseases. Seabirds that come into contact with infected fish or contaminated water are at risk of contracting these diseases. Seabirds can also become the secondary hosts of some of the parasites with indirect life cycles.

- Climate Change Impact: Aquaculture contributes to climate change through greenhouse gas emissions. Climate change, in turn, can affect seabird populations by altering their habitats, food availability, and migration patterns.

To mitigate these impacts, aquaculture operators can implement measures such as using bird-friendly netting, proper waste management practices, and strategic placement of aquaculture facilities to minimize disturbance to seabird habitats. Additionally, ongoing research and monitoring are essential to understanding the long-term effects of aquaculture ropes and implementing effective conservation strategies.

3.3.2.3. Turtles

Sea turtles are long-lived species (k-selected) and due to juvenile high mortalities, they have low reproductive capacity (Petersen et al., 2007). There are 7 sea turtle species worldwide. Today sea turtles come from two subgroups namely the *Dermochelyidae* family (leathery turtles) and the *Cheloniidae* family (hard-shelled turtles). The *Dermochelyidae* family consist of only one species, the Leatherback turtles (*Dermochelys coriacea*) and the *Cheloniidae* consist of the other six species of turtles, namely the green sea turtle (Chelonia mydas), Hawksbill Sea turtle, Flatback sea turtle, loggerhead sea turtle (*Caretta carreta)*, Kemp's Ridley Sea turtle and the Olive Ridley Sea turtle (*Lepidochelys olivacea*). Only 5 species are found within the BCLME excluding the flatback and Kemp's Ridley (Petersen et al. 2007). According to the IUCN Red-List Data Book, three species are critically endangered (Hawksbill, Kemp's Ridley, and the leatherback), three species are endangered (Green, Loggerhead and Olive Ridley) and one species, the Flatback sea turtle conservation status is unknown as there is not enough data on the species collected and is the least studied species with the smallest geographical range. Fishing and mariculture activities globally are affecting sea turtle populations especially long liners, trawlers, and gill nets.

Only three species of sea turtles are found in Namibian waters. However, only a few green turtles nesting have been recorded along the Skeleton coast, especially around the Kunene River mouth area (Cunningham & van Rooyen, 2020). Most of the green turtles found in Namibia are from populations in southern Angola. The cold temperature along the Namibian coastline affects the breeding success of turtles compared to warmer temperatures north of the Kunene River mouth in Angola (Cunningham & van Rooyen). The green turtles are protected under the Marine Resource Act No: 27 of 2000 and its conservation status is *Endangered* in Namibia. On 01 June 2022, 24 individuals of green turtles were spotted in the Kunene River estuary by D. Tom (personal communication, 2023Mik). The Kunene River mouth/estuary is an important conservation area for green turtles and migratory seabirds and shore birds. The green and leatherback turtles are more frequent compared to the loggerheads and the hawksbill. The northern BCLME is characterised by a high biomass of jellyfish due to the overfishing of small pelagic fish like sardines (Roux et al., 2013). The high biomass of jellyfish in the northern Benguela region attracts sea turtles as they feed on jellyfish. Several tagging studies indicated that the BCLME is an important foraging area for sea turtles, and this can be due to the high biomass characteristics of the jellyfish, which is a potential food source for sea turtles (Elwen & Braby, 2015). However, all the species found in the BCLME region are not endemic to the region. The leatherback breeds in both South Africa and Angola, while the loggerhead's breeding range is confined to South Africa and both the green turtle, and the Olive Ridley breeding is confined to Angola.

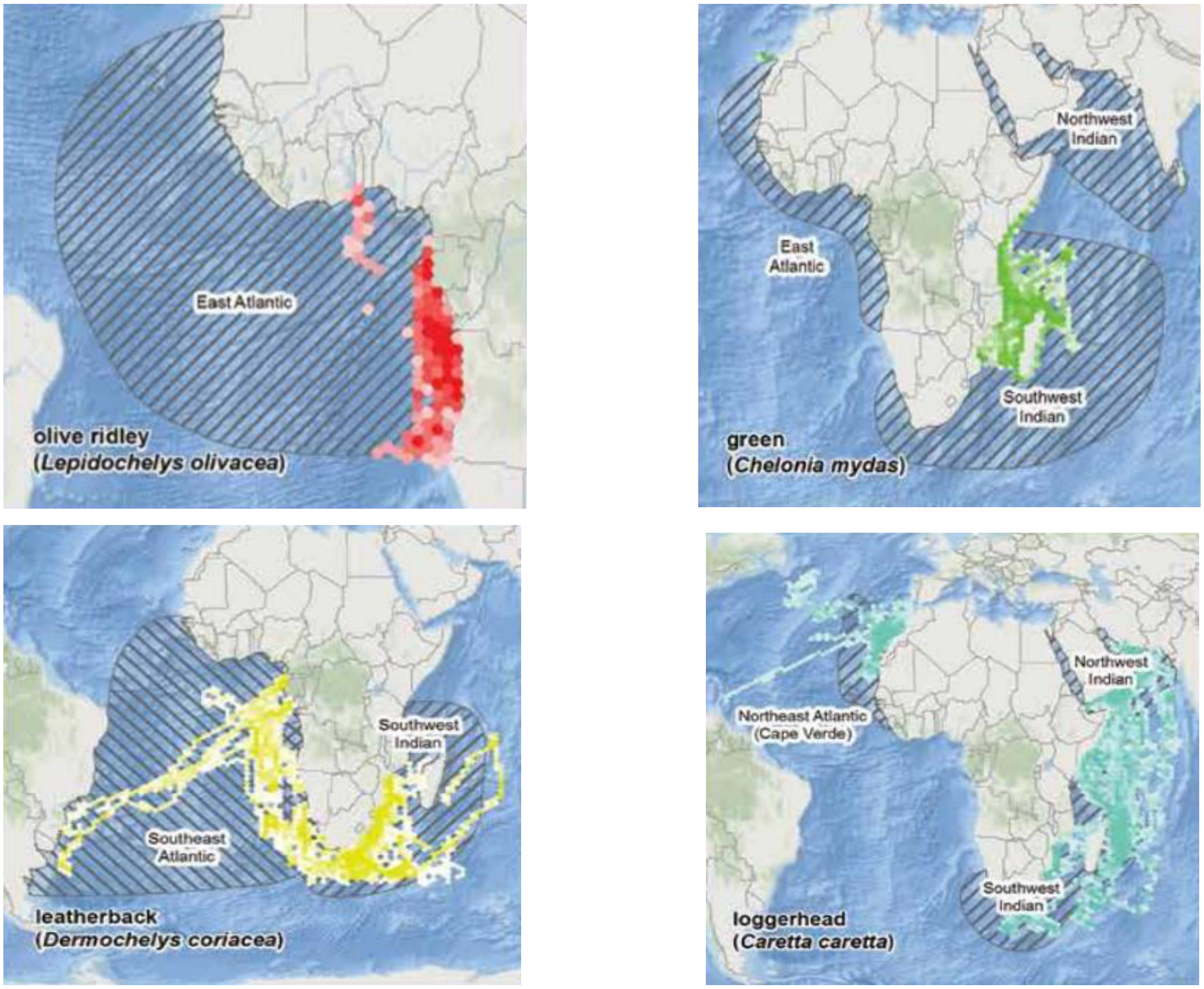


Figure 3. Sea turtle satellite telemetry data of Africa and their range in which different individuals occur. (SWOT report, 2006). Different colour codes show the different species and the grey (shaded areas) indicates the distribution range of sea turtles.

There are transatlantic movements of Leatherbacks from Brazil to the south-eastern Atlantic Ocean from satellite telemetry tagging studies (Almeida et al. 2014). All these turtles were found stranded along the Namibian coast. Most turtles found in Namibia are either from nestings in West Africa (Gabon) or South America (Brazil) based on tags recovered from dead animals found (Elwen & Leeney, 2011). However, no breeding or nesting of Leatherback turtles in Namibia is recorded. Most of the leatherbacks found in Namibian waters are either migrating from South America or the Indian Ocean coast of South Africa around the Cape of Good Hope. From Tagging studies, it is shown that leatherbacks can tolerate colder waters. Generally, sea turtles are mostly spotted when the sea conditions are very calm (flat calm waters) between February and March when the sea surface temperatures are above 15 °C.

Table 3. Turtles in Namibia in the Mariculture Operations Areas.

Scientific Name	English Name	Seasonality	Relative Abundance	Foraging range	IUCN Conservation Status
Dermochelys coriacea	**Leatherback turtle**	All year	Uncommon	Coastal Waters & Offshore	Critically endangered
Chelonia mydas	Green turtle	Summer	Uncommon	Offshore	Endangered
Caretta Caretta	Loggerhead turtle	All year	Common	Coastal Waters & Offshore	Endangered

Potential Impacts

Mariculture activities can also affect turtle species through:

Habitat Alteration: Mariculture structures may alter coastal and nearshore habitats that turtles use for nesting and foraging.

Entanglement and Ingestion: Similar to seabirds, turtles can become entangled in mariculture equipment or ingest debris associated with mariculture operations.

Light Pollution: Artificial lighting used in mariculture facilities can disorient hatchling turtles, leading them away from the ocean.

Entanglement: Mariculture structures may pose threats by entanglement with cage nets, mooring lines, and collision with floating structures.

Mitigation Measures

To minimize impacts on turtles, the following mitigation measures are suggested:

- Light Management: Implement lighting protocols that minimize disorientation of hatchlings and avoid light pollution along nesting beaches.

- Beach Protection: Establish buffer zones around nesting sites to prevent habitat alteration and disturbance from mariculture activities.
- Debris Management: Implement debris control measures to prevent entanglement and ingestion risks for turtles.
- Animal handling: A minimum bycatch or entanglement mitigation measure is to train the Mariculture farmers/operators to be trained on how to catch and release sea turtles caught in their structures. Therefore, the operators or farmers should carry a line cutter and a de-hooker when going out on the site to cut and remove lines, ropes and nets.
- Reduce attraction: To reduce sea turtle attraction, fishermen/farmers should rather use fish as bait rather than squid bait and use circle hooks instead of J-shaped hooks (Petersen et al., 2007).
- Monitoring and reporting: There is a need to collect data and data assessment of sea turtle interactions with mariculture activities and the lack of data on sea turtle should be addressed. In addition, sea turtle interactions with fish farming operations should be reported. FAO sea turtle bycatch guidelines or NPOA-sea turtles should be implemented.

3.3.2.4. Cetaceans and Seals

Of about 86 species of cetaceans globally, 10 species are classified as endangered under the IUCN Red List data book, and some are to become extinct soon. Since the whaling moratorium of 1986, the killing/harvesting of whales has decreased greatly but some countries still hunt whales for products such as oil and meat. Marine mammals are quite abundant in Namibian waters compared to sea turtles. There are about 31 species of cetaceans that are found in Namibian waters. Two of these species namely, the southern right whale and the Heaviside's make use of the coastal waters for breeding while the Humpback whale uses it as a migratory route. The southern right whale uses coastal waters between South Africa and Namibia for calving in winter and then migrates to the sub-Antarctic in summer. Historically, the species used to breed in Namibian bays (Walvis Bay down to Sperrgebiet. However, the species was overexploited in the 19th century. About 3700 whales were harvested in Walvis Bay between 1788 and 1803 (JP et al., 2001). Aerial surveys contacted recently indicate that most of the calving sites of the southern right whale since 1996 are within the Namibian Island Marine Protected Area (NIMPA). Like the southern right whales, the humpback whale was also exploited globally. Both species are listed in the Convention on Migratory Species as endangered migratory species in 2005. The populations of the humpback whales in Africa are shared by three Large Marine Ecosystems namely, the Antarctic Large Marine Ecosystem, BCLME and the Guinea Current Large Marine Ecosystem in different countries.

Killer whales are observed in Namibian coastal waters but not frequently throughout the year by different marine tour operators as well as observers on fishing and research vessels. In the harbour town of Walvis Bay, they are mostly observed between August and March from 2003 to 2010 (Elwen & Leeney 2011). However, porpoises and dolphins favour shallow waters and are most likely to interact with Mariculture operations. Most of the cetaceans occurring in Namibia are found offshore and less likely to interact with mariculture operations that are mostly inshore.

Table 4. Marine Mammals in Namibia in Mariculture Operations Areas.

Scientific Name	**English Name**	**Seasonality**	**Relative Abundance**	**Foraging range**	**IUCN Conservation Status Globally**
Arctocephalus pusilus pusilus	Cape fur seal	All year	Common	Coastal waters & offshore	Least Concern
Eubalaena uastralis	Southern right whales	July-September	Common	Offshore	Vulnerable
Megaptera novaeangliae	Humpback whale	All year	Common	Coastal waters & offshore	Vulnerable
Balaenoptera physalus	Fin whale	winter	rare	Coastal waters	Endangered
Caperea marginata	Pygmy right whale	winter	Uncommon	inshore	Least concern
Balaenopters acutorostrata	Minke whale	winter	uncommon	Coastal waters	Least concern
Physeter macrocephalus	Sperm whale	vagrant	rare	offshore	Endangered

Orcinus orca	Killer whale	All year	Common	Coastal waters & offshore	Endangered
Cephalorhychus heavisidii	Heaviside's dolphin	All year	Common	Coastal waters	Vulnerable
Lagenorhynchus obscurus	Dusky dolphin	All year	Common	Coastal waters	Least concern
Tursiops truncatus	Common dolphin	All year	Common	Coastal waters	Least concern
Lissodelphis peronii	Southern right whales dolphins	Winter	Common	Coastal waters	Least concern

Potential Impacts

Mariculture operations may impact cetaceans in the following ways:

- Underwater Noise: Construction and operation of mariculture facilities can introduce underwater noise, which can disturb and disrupt cetacean behaviours such as communication and navigation.
- Collision Risks: Vessels associated with mariculture may increase collision risks with cetaceans, especially in high-traffic areas. Structures can obstruct the movement of larger marine mammals like whales, and they can damage infrastructure as well as injuring themselves.
- Entanglement Risks: Mariculture structures such as mooring lines, cage nets pose a threat to entanglement with cetaceans and seals. Cetaceans like Heaviside's dolphins and seals are also threatened by drift nets.

Mitigation Measures

To mitigate impacts on cetaceans, consider the following measures:

- Noise Mitigation: Use noise-reducing technologies during construction and operation, and schedule activities to minimize disturbance during critical cetacean periods.
- Vessel Traffic Management: Implement vessel traffic management strategies to reduce collision risks and establish speed limits in areas frequented by cetaceans.

- Monitoring and Reporting: Establish protocols for cetacean monitoring and reporting of any interactions or strandings.

3.3.3. Feed and Waste

The contribution of feed to the aquatic environmental deterioration has received increased attention with the rapid growth of aquaculture. The intensification of aquaculture requires that aquaculture production heavily depends on the external aquafeeds or nutrients supply to the aquaculture system. Management of aquaculture feed is important to prevent feed wastage, leading to poor water quality.

Since the 1980s, there has been increasing concern about the environmental impacts of marine aquaculture, especially the wastes from its operation and production processes. Wastes from cage systems primarily consist of uneaten food, metabolic waste (faeces and urine) and chemical wastes (Beveridge, 1996). The bulk of the wastes are solids and are thus subjected to sedimentation.

The sedimentation of the solids is dependent upon on their settling velocity which in turn is dependent upon pellet shape and density, current velocity, turbulence, depth of the sites and salinity (Chen et ai., 1999). In general, the impacts occur on several space and time scales, which can be classified as internal, local, and regional.

The nutrient models are mainly based on calculating phosphorus (Dillon and Rigler, 1974; Beveridge, 1984; Foy, 1992; Ackefors and Enell, 1994; Kelly, 1995; Hakanson et al., 1998) and nitrogen (Turrell and Munro, 1988; Gowen et al., 1992; Ackefors and. Enell, 1994; Troell and Norberg, 1998) losses to the environment.

The diet made by the traditional methods of steam pelleting followed by compression, result in a dense pellet that sink rapidly in water. Modern diets made via extrusion, a process, through which the feed material is moistened, pre-cooked, expanded, extruded, and dried, produces low density feed particles that sink slowly or float in water. The sinking rate of the later diet has in several tests and literature estimated to be between 5.2 – 6.5 cm/s. Many finfish species such as salmonids (*Salmo salar*), Kob (*Argyrosomus sp.*) and Yellowtail Kingfish (*S. lalandi*) respond quickly to a diet that is of suitable pellet size and palatability given that such pellets can retain their physical stability in water for only a few minutes.

In this report attempts will be made to evaluate the effect of feeding on the environment of some of the species in fed aquaculture.

Organic enrichment can result from intensive aquaculture activities. Due to high settling velocities of uneaten pellets, much of this material settles out in the immediate vicinity of fish cages. The area of the seabed over which the material will be dispersed will depend on the surface area of the farm, the settling velocity of the uneaten food and faeces, current speeds and the depth of water beneath the cage.

Namibian has a very exposed coastline, with few exceptions of the bays (not closed-off) in Lüderitz and Walvis Bay, and the water current is estimated to be between 3 – 6 cm/s and deemed as sufficient to carry the feed and other waste from the site.

Potential Impacts

Water quality changes (turbidity; changes in biological oxygen demand; increase in nutrients such as nitrogen, phosphorus, etc.) have effect on aquatic biota. Turbidity due to the suspended uneaten feed and waste of aquaculture origin, algal blooms as an effect of nutrient release in the aquatic environment and changes in the pelagic and benthic community structure due to scavenging are all impacts that can be attributed to feed and waste.

Mitigation Measures

Several mitigation measures can be proposed such as:

- Good, well-flushed sites in deep water; improved feed and efficiency in feed management.
- Fallowing (relocating or not restocking cages to allow the sediment below to undergo natural recovery);
- Implementation of multi-trophic aquaculture system (culturing species from different trophic level where the waste of one species can serve as a nutrient to another species);
- Regular data collection and monitoring of the water quality parameters, community structure around the aquaculture site in order to assist in decision making.

3.3.4. Diseases

There is an ever-present risk posed by aquatic animal and plant diseases. Disease outbreak in aquaculture is common and causes serious damages to the aquaculture development and people that consume aquaculture products in cases of zoonotic pathogens. Costs of production are increased because of the investment lost in dead fish, the cost of treatment, and decreased growth during convalescence. Namibia, as a developing country that is striving for successful aquaculture, has an important duty to consider the potential impact of diseases. It is a fact that disease-causing organisms are present in natural environment and can be in a dynamic equilibrium with their host. This equilibrium can be, however, disturbed when such hosts are subjected to stress factors such as high stocking densities, husbandry practices. The intensity of aquaculture (high stocking densities in small volumes of water) is also responsible for the proliferation of the disease-causing organisms, shortening the infestation pathways.

The Namibian aquaculture industry have not experience major disease outbreaks, partly due to its finite size and low density. Attention to the monitoring and reporting of aquatic animal diseases is non-existent.

There are vast volumes of research literature on diseases and anomalies of species currently under investigation for aquaculture in Namibia. Table 5 provides the diseases caused by viruses, bacteria, fungi (mycosis) and parasites for the identified species. The records for some species found in Namibia are scant or not available. In such cases the data of closely related family or genus will be used as an indication. In this case, for instance, for the Silver and Dusky Kob, the closely related cousins (red drum, *Sciaenops ocelatus*; Grouper, *Epinephelus coioides*) will be used (Mmanda et al., 2014; Eldar et al., 1999; Maeno et al., 2002; Yongjia et al., 1996). It must be noted, however, that immunity to certain diseases is species-specific.

Table 5. Diseases of the Proposed species.

Aquaculture Species	Disease type				
	Virus	**Bacteria**	**Fungi**	**Parasites**	**OIE Notifiable Disease**
Finfish					
Silver and Duky Kob (*A. coronus and inodorus*)	Largemouth bass virus (family Iridoviridae); Lymphocystis virus; Viral nervous necrosis	*Vibrio anguillarum*; *Photobacterium damselae*: *Streptococcus* sp.; *Flexibacter maritimus*	*Ichthyophonus* sp.	*Diplectanum* sp. *Corynosoma austral*; *Calceostoma glandulosum*	*Vibrio anguillarum*; *Photobacterium damselae*: *Streptococcus* sp.; *Flexibacter maritimus*
Yellowtail Kingfish (*S. lalandi*)	Lymphocystis virus; Viral nervous necrosis; Epizootic haematopoietic necrosis (EHN	*Vibrio anguillarum*;		Caligus asp. (sea lice)	Vibrio sp.
Atlantic Salmon (*S. salar*)	Infectious salmon anemia; Infectious pancreatic necrosis (IPN); Viral	*Aeromonas salmonicida*: *Vibrio salmonicida*; *Reinobacterium salmonicida*;	*Saprolegnia parasitica* *Ichthyophonus* sp.	*Gyrodactylus salaris*; *Henneguya salmonicola*	*Vibrio salmonicida*; *Reinobacterium salmonicida*;

	haemorrhagic septicaemia (VHS)			Caligus asp. (sea lice)	
Galjoen (*D. capensis*)	Viral haemorrhagic septicaemia			Isopoda; Caligus asp.	
Steenbras (*L. aureti*)	(VHS); (EHN)			Isopoda; Caligus asp.	Red seabream iridovirus
Blacktail (*D. s. capensis*)	(VHS); (EHN)			Isopoda	
Tilapia (*O. niloticus*)	Tilapia Lake virus (TiLV); Viral encephalopathy and retinopathy			*Cichlidogyrus* sp.	*Aphanomyces invadans* (EUS), TiLV,
Shellfish					
Pacific oyster (*Crassostrea gigas)*				*Bonamia ostreae*	*Bonamia ostreae*
Black Mussels *(Choromytilus meridionalis*)			Chaetothyriomycete (genus *Capronia*)		

Abalone *(Haliotis midae)*	Abalone Viral Ganglioneuritis (AVG)	*Candidatus Xenohaliotis californiensis*		*Terebrasabella heterouncinata*	Abalone Viral Ganglioneuritis (AVG)
Scallops *(Argopecten purpuratus)*	Acute viral nicrosis				
West Coast Rock Lobster *(Jasus lalandii)*	*Panulirus argus*	*Aerococcus viridans*; *Vibrio harveyi*	*Aphanomyces astaci*: Peritrich ciliates	*Carcinonemertes* sp.	White spot syndrome virus
Seaweed					
Giant kelp (*Macrocystis purifera*)					
Brown (*Laminaria* sp.)	Green spot rot		Olidiopsis, Pythium		
Ecklonia sp.					

Namibia is a signatory to the World Trade Organization (WTO) as well as the World Organization for Animal Health (also referred to as Office International des Épizooties, OIE). Under the treaties signed, the country has obligations to report certain disease outbreaks for notice purpose. This is done by the Focal Point person, in this case either in the MAWRD or MFMR. The Office International des Épizooties (OIE - World Organization for Animal Health) lists 29 diseases of finfish, molluscs and crustaceans which fit the criteria of the OIE as being of significant economic importance and thus reportable to the (OIE, 2000a). The criteria used for this list are as follows:

i) Diseases notifiable to the OIE: this includes the list of transmissible diseases that are of socio-economic and/or public health importance within countries and that are significant in the international trade of aquatic animals and aquatic animal products. Reports are normally submitted once a year, although more frequent reporting may be necessary in some cases to comply with Articles 1.2.0.2. and 1.2.0.3. The diseases notifiable to the OIE are set out in Part 2, Section 2.1. and 2.2. of this Code. ('Diseases notifiable to the OIE', as used in this Code, were previously known as 'List B diseases.)" (OIE, 2000a).

ii) Other significant diseases: include diseases that are of current or potential international significance in aquaculture but that have not been included in the list of diseases notifiable to the OIE because they are less important than the notifiable diseases; or because their geographical distribution is limited, or it is too wide for notification to be meaningful, or it is not yet sufficiently defined; or because the aetiology of the diseases is not well enough understood; or approved diagnostic methods are not available." (OIE, 2000a).

Potential Impact

There are many pathways for disease transfer between cultured organisms and the wild organisms inhabiting the environment surrounding the aquaculture sites. These may include pathways such as inter-and intra-specific spillover (co-introduction), inter- and intra-specific spillback (disease from wild), transmission interference. In terms of inter-specific spillover, a species may be taken from its environment and transported to a new one, with the effect of a possibility of transporting diseases along with them. When a disease is co-introduced with a host species to an environment which is inhabited by other naive potential host species, there is a possibility of the infectious agent switching hosts. On the other hand, in terms of intra-specific spillover, many cultured species, such as Yellowtail Kingfish, are not bred in captivity, but larvae or juveniles are caught from the wild and transported to aquaculture facilities for grow-out (Boyd & McNevin, 2005). If these larvae or juveniles are infected, parasites are co-introduced to the farm environment, potentially leading to disease outbreaks within the farmed stock.

In terms of the inter- and intra-specific spillback, a wild species acquiring disease from cultured species, parasites from wild species in the proximity of aquaculture farms may also spillover into cultured species, a phenomenon like the 'reverse spill-over' of disease from wild populations to susceptible domesticated animals.

Some of the diseases are zoonotic, meaning that it can be transferred from animal to human.

Mitigating Measures

The impact of disease can be mitigated by applying several biosecurity measures, that is the application of practices that minimize the risk of introducing an infectious disease and spreading it to the animals at a facility and the risk that diseased animals or infectious agents will leave a facility and spread to other sites and to other susceptible species.

- Apply the established internal- (preventing the spread of disease-causing organisms onto and off an aquaculture farm or hatchery) and external barriers (preventing the spread of disease-causing organisms within an aquaculture farm or hatchery).
- Inspecting all imported aquatic organisms, vessels, fomites and media for any disease and/or presence of disease-causing organisms
- Ensuring that the seeding stock (broodstock, fingerling, larvae, egg, spat, inoculant) is from disease-free sources.
- Quarantine of imported aquatic organisms (especially when the origin is not known and where there is reasonable suspicion)
- Regular monitoring and screening for diseases.
- Application of scientifically proven disinfection and sanitation measures.
- Application of appropriate (best) aquaculture management practices.
- Development of a national disease list

3.3.5. Introduction of Alien species

The Namibian mariculture is, entirely, reliant on non-native species (Pacific oyster, *Crassostrea gigas*, European oyster, *Ostrea edulis*, Abalone, *Haliotis midae*). Some concerns are being raised (rightfully so) about the impacts of introduced species on marine ecosystems. The introduction of new proposed alien finfish species (Atlantic salmon, *Salmo salar*) is adding onto the list of such concerns. The reasons of introducing exotic species are due to the fact the indigenous species' biology is still being studied and husbandry protocol are yet to be developed for the endemic species, and it is likely that new alien species will continue to be introduced to supply the needs of the growing aquatic food market. The concerns are that if allowed to escape, these species may establish breeding populations and dislodge native species from established niches. Non-reproducing alien species may also interact with native species and affect predation and competition for food. Mixing of exotic genes through hybridisation, habitat modification and the introduction of diseases and parasites are other areas of concern. It is therefore important to have procedures in place to assess the risks and benefits associated with the introduction of alien species into an ecosystem and, if appropriate, to develop and implement a plan for their introduction and responsible use (FAO, 2005). In Namibia several non-native marine organisms have become established after being accidentally introduced such as the bivalve mussel *Mytilus galloprovincialis*. Increasing sea temperatures due to climate change may mean that it will become possible that those species that cannot spawn in the Benguela Current (such as the Pacific oyster) due to low temperature will be able to reproduce and proliferate. Concern of the introduction of the proposed finfish, Atlantic salmon (*S. salar*), an anadromous fish that begin their lives in fresh water, where the young grow to several inches in length, and then migrate to the sea, where they grow more rapidly and become sexually mature after 1, 2, or 3 years is valid. Atlantic salmon spawn in freshwater streams. Spawning occurs in autumn, and the eggs develop in gravel nests that are dug by the female. Incubation is temperature-dependent and can last for 90 days at 6°C. The pattern of homing to their natal streams leads to a variety of local adaptations, including the timing of spawning runs, growth rates, and other life-history features. Namibia has two rivers (Orange and Kunene River) that washes into the Atlantic Ocean. Monitoring of the impact of the introduced finfish is necessary to provide information on the acceptable levels of introduction that will not be detrimental.

Potential Impact

Impacts of introduced species can vary depending on the capacity of such species to adapt to the new environment and can be include the following:

- When escape can establish niche if conditions are favourable to reproduce in new habitat.
- Ecological risks of environmental degradation, outperforming the wild population.
- Genetic pollution when escaped farmed fish spawn with wild conspecifics. potentially resulting in loss of fitness in the mixed population.
- Disease transmission to the native population.

Mitigation Measures

- Ensure that stocking fish (broodstock, eggs or fingerling) is from certified, disease-free origin.
- Control escape.
- Harvesting prior to sexual maturation.
- Dietary manipulation or maintaining environmental conditions to delay, reduce or prevent sexual maturation.
- Using sterile or monosex fish.

3.3.6. Escapees

The escape from aquaculture holding facilities is a serious concern that present several risks, namely the impact on the wild stock that may be genetic and ecological. This includes the competition for food and/or habitat, disease transfer and reproductive mixing (genetic pollution). Mariculture operations (as opposed to closed circulation or land based aquaculture) have the potential to provide an almost continuous supply of escapees into the natural environment. These escapes occur during the day-to-day operations of an aquaculture farm which include stocking, grading, and disease treatment, as well as occasional mass releases caused by storm or predator damage of the cage equipment or by construction failure. Impacts of escaped farmed animals on wild populations may include transfer of diseases and parasites, competition for wild food resources, competition for spawning habitat and the destruction of habitat for the native species. The severity of some of these impacts could be worse when the species is exotic. In the case of this report, the exotic species proposed are the finfish species, the Atlantic salmon, *Salmo salar*, shellfish such as Pacific oyster, *Crassostrea giggas* and abalone, *Haliotis midae*.

Potential Impact

The following are possible impacts:

- Ecological risks of environmental degradation, outperforming the wild population.
- Genetic pollution when escaped farmed fish spawn with wild conspecifics. potentially resulting in loss of fitness in the mixed population.
- Disease transmission to the wild population.

Mitigation Measures

Some of the preventative measures in place that can be implemented in part or as complement to envisaged escape mitigation are as follows:

- Develop and regularly update an escapes reduction and mitigation plan for each farm,
- Use cage designs which minimize the possibility of escape,
- Routinely monitor cages for escapement and properly maintain cage equipment,
- Take measures to avoid unintended releases of cultured gametes, eggs, and larvae,
- Culture local (native or naturalized) species and discourage or prohibit the culture of non-native species,
- Require risk assessment for non-local species,
- Develop a broodstock program that conserves genetic diversity (integrated approach) or selects for low wild fitness (segregated approach), and,
- Consider stocking sterile fish.

4. TECHNICAL DETAILS OF MARICULTURE

4.1. Mariculture Production Systems and Technologies

A certain fact that everyone involved in aquaculture unanimously agree upon is that a body of water is required to raise aquatic organisms and plants, but what is open to considerate debate is how this body of water should be contained. In Namibia the current mariculture production technologies involve enclosed, semi-enclosed and open production units.

Closed (or close containment) aquaculture systems are farming methods use a barrier that control the exchange between farms and the natural environment. This include ponds (could be earthen or concrete) and the recirculating aquaculture systems (RAS). Some of the cage culture systems consisting of plastic net are also classified as a closed aquaculture system.

The semi-closed production units are mostly land-based production in which water is exchanged between the farm and a natural waterway (water body). In terms of the mariculture production in Namibia, this may include the oyster ponds in the salt production systems.

The open aquaculture systems are the type of culture system that is connected with natural water bodies and include open cage aquaculture systems, oyster baskets and seaweed ropes.

The choice of production system for the specific aquatic organism or plant depends on the species biology, objective for culture, specific site characteristic and intensity of culture. Table 4 provides a sample of culture technologies for the different proposed aquatic species (organisms and plants) for Namibia.

Table 6. Mariculture Technologies for different Proposed Marine Aquatic Species.

Species	Cages	Ponds	Baskets	Ropes	Raceway	RAS
Finfish						
Yellowtail Kingfish (*Seriola lalandi*)	X				X	X
Dusky and Silver Kob (*Argyrosomus japonicus*)	X	X			X	X
Atlantic salmon (*Salmo salar*)	X	X			X	X
Galjoen (*Dicihistius capensis*)	X					X
Steenbras (*Lithignathus aureti*)	X					X
Blacktail (Dassie/Kolstert) (*Diplodus sargus capensis*)	X	X				X
Tilapia (*Oreochromis niloticus*)	X	X				X
Shellfish						
Pacific oyster (*Crassostera gigas*)		X	X	X		
Black Mussel (*Choromytilus meridionalis*)		X	X	X		
Scallops (*Argopecten purpuratus*)		X				X
Abalone (*Haliotis midae*)					X	X
West Coast Rock Lobster (*Jasus lalandi*)		X				X
Seaweed						
Laminaria species (*Macrocystis purifera*)				X	X	X
Ecklonia species (*Ecklonia maxima*)				X	X	X

4.2. Impact of Systems on the Aquatic Environment

Several reports, academic journals and books have documented the effects of cage systems on the marine environment. Cage culture systems have impacts ranging from affecting water quality, biodiversity (pelagic and benthic organisms) and the physical environment. Turbidity is because of particles or dust from feed and fish waste, while scraping of biofouling may also result in decrease of water clarity. When cages are sited in areas with decrease current flow, feed and waste suspended in the water column may increase turbidity. Increased turbidity may result in lower light penetration affecting phytoplankton production (Harrison et al. 2005) and may affect photosynthesis of benthic aquatic vegetation. The water movement in the three areas is however such that turbidity is a lesser a concern.

Finfish feed is a source of nitrogenous discharge released both in the form of particulate matter (uneaten food and faeces containing undigested food that passes through fish digestive tracts) and dissolved metabolic wastes including ammonia and urea. Organic matters and nutrients derived from fish-farm wastes deposited on the sea bottom may cause an increase in sediment oxygen demand, anoxic conditions, and production of toxic gases (e.g., methane and sulphur, H_2S) in bottom sediments, thereby adversely affecting benthic organisms. Feed waste can also lead to changes in benthic community when sediments become enriched with organic farm waste nutrients.

Oxygen concentrations in the water column near farm operations are lowered primarily through fish respiration, but also due to microbial metabolism. Although most reported instances of effects on dissolved oxygen by marine fish cage culture are localized or insignificant, the concern remains that under certain conditions marine cage culture may significantly decrease dissolved oxygen concentrations sufficiently to cause local short-term negative effects.

Many studies have been unable to detect a phytoplankton response tied to nutrient loading from fish farm effluent in open marine environment, however, the possibility that marine fish farm effluent could induce HABs in coastal waters has been raised (Bouwman et al. 2013). When these occur near fish farms, fish may die as a direct result of poisoning, gill damage or decreased growth and vigour (Beveridge 2004, Davidson et al. 2009, Borg et al. 2011). Impact of the cage nets on birds, mammals and other aquatic organisms has been fully expounded in section 3.2.5.

4.3. Siting of the Mariculture Operation

4.3.1. Offshore Mariculture

The offshore operation is the most current system in Namibia for mariculture and is, in fact, viewed as a potential means of large-scale sustainable culture of fish and shellfish with minimal environmental impact. The exposed marine site, with high wave action and good current movement provides more stable sea temperatures, better water exchange, less pollution and potential for disease contamination, higher water exchange and better flushing of wastes and less user conflicts and less maintenance as the equipment is more robust so as to handle stormy ocean conditions. However, it is important that careful consideration be given to the potential environmental impacts and means of mitigation.

Concerns remain, though, over the measures to be taken to prevent fish escapes and proliferation of pathogens and invasive alien species. With the development of Artificial Intelligence, it would be most efficient to operate offshore farms remotely, and therefore, it is essential that monitoring systems are sensitive enough to detect damage to cages, fish escapes and mass mortality events as quickly as possible so that mitigation measures can be employed.

4.3.2. Shore-Based Mariculture

Coastal mariculture, or land-based mariculture systems, are the earliest system that previously employed pond systems for the rearing of aquatic organisms and plants. The adoption of flow-through systems and raceways as well as recirculating mariculture system provides new alternatives. The adoption of the one above the other depends on the objectives, the species, site, water resource and the financial ability. Shore-based aquaculture involves some measure of water pumping. This is having some measure of environmental impact. The proposed mariculture species for Namibia involves life stages that the culture organism will spend on the shore-based systems, especially the broodstock, egg, larval and fingerling stages.

The design of an intensive land-based farm depends on whether a flow-through system or a re-use system is used. Adoption of a flow-through system require huge volumes of water, while that of a re-use system reduce the amount of new inlet water necessary, but the need for equipment for water treatment increases.

Intake system should consider a number of issues: stability and durability, debris and unwanted species, fouling and self-cleaning ability. The coastal areas along the proposed town have rocky areas that can be better used for the anchoring of water intake system. To avoid fish and other large substances being dragged into the inlet pipe, a screen is used at the orifice. The water velocity through the screen must not be too large to prevent small fish and other objects getting sucked onto the surface of the screen and blocking the inlet. Water inlet velocities of less than 0.1m/s are recommended, while in the inlet pipe itself flows of 1–1.5m/s are used. Polyethylene (PE) has proved to be a suitable material for inlet pipelines, because it is both reasonably priced and to some extent will follow the contours of the terrain.

The effluent (or outlet) water discharge from aquaculture facility can present environmental problems which create an imbalance in the ecosystem of the recipient water body. Effluent discharge from a mariculture farm can contain three classes of pollutants: Nutrients and organic matter, Micro-organisms, and Escaped fish.

The quantity of nutrients and organic matter discharged depends on the amount of feed used and farm management practices. Discharge of nutrients to the recipient water body will result in increased algal growth leading to eutrophication and imbalance in the recipient ecosystem. The effluent water may therefore also contain a higher concentration of pathogenic microorganisms (parasites, bacteria, viruses and fungi) that can cause disease in the fish population. Escape of fish or other aquatic organisms from arm conditions may also present environmental problems.

4.4. Impact of Aquaculture Materials on Marine Environment

Consideration of material for use in marine culturing system will involve the evaluation of several impacts on the environment. One of the major considerations is the potential toxicity of material. This is due to the leaching or releasing of specific ions, chemicals or corrosion by-products from the surface when acting upon the water or due to tear and wear. The released substances may, in most cases, not be clearly identified, with the rate of release being time dependent. The toxicity of the released substances in the marine environment may have different effects on the marine organisms which will be species specific and dependent on the environmental conditions and the specifics of age, genetic strain, history and the current health of the target organism. In most cases these effects are most obvious in the form of mortalities, especially when the substance is at high concentrations. At lower concentrations the toxicity levels may result in reduced growth, lower reproductive fitness, susceptibility to diseases and decreased survival rates. The levels of toxicity of materials used in aquaculture can have different levels from being temporal to permanent.

It is a recommended practice to eliminate all metals from contact culture water. It is, however, difficult, if impossible to acquire high precision, high temperature and high-strength parts made of more biologically acceptable materials. Some metals, however, pose little or no danger of toxicity, such as titanium that is considered biologically inert and therefore biologically acceptable. Titanium is often used in heat exchangers. Titanium is, however, very expensive. Steel and cast iron is commonly used as they are much cheaper compared to titanium. Rusting is an issue, but used in moderate amounts, steel and cast iron have little direct toxicity and may often be biologically acceptable. Table 5 provide a general guide, as specific manufacturer and product formulation, prior treatment of materials and condition of use can alter the acceptability of materials.

Table 7. Effects on Algal Cultures of some readily Available Materials for Aquaculture use (Huguenin and Colt, 2002).

Material	Safe	Inhibitory	Toxic	References
Acrylic	X			Bernard et al., 1966; Dotty and Oguri, 1959
Aluminium alloy	X			
Charcoal		X		Dyer and Richarson, 1959
Copper alloy		X		Dyer and Richarson, 1959
Cotton	X	X		Ryther and Gilliard, 1962
Epoxy resin	X			
Iron		X		Dyer and Richarson, 1959
Nylon	X	X	X	Dotty and Oguri, 1959, Davis et al., 1953
Paraffin	X			Dotty and Oguri, 1959
Plywood		X		Dyer and Richarson, 1959
Polycarbonate	X			
Polyethylene (black)	X	X		Dyer and Richarson, 1959; Bernard et al., 1966
Polyethylene (white, clear)	X			
Polypropylene	X	X	X	Dyer and Richarson, 1959;
Polystyrene	X			

Polytetrafluoroethylene	X			
Polyurethane foam		X		Dyer and Richarson, 1959;
Polyvinyl chlorine	X	X	X	
Rubber (white, black, green)	X	X	X	
Silicone stoppers	X			Dyer and Richarson, 1959
Silicone (cement, sealant)	X	X	X	Dotty and Oguri, 1959, Davis et al., 1953
Solder (silver)				Dotty and Oguri, 1959
Solder (soft)	X			Dyer and Richarson, 1959
Stainless steel	X	X		
Titanium	X			

Tributyltin (TBT) is a chemical, commonly used in antifouling paints on the hulls of ships to prevent the attachment of molluscs, algae and other organisms. This chemical can leak into the seawater and can, unintentionally, kill sea life and pollute the environment, especially when consumed by filter-feeders and end up in the food chain.

5. BIOLOGICAL DETAILS OF MARICULTURE PRODUCTION

5.1. Proposed Species, Biology, Aquaculture

Several species were proposed for mariculture at the specified sites that include both finfish, shellfish, plant, and Echinodermata species (often included in the shellfish designation) and even freshwater finfish species. The proposed species ranges from both endemic and exotic ones. A summarized report (Table 3) is provided that considers but that will not be limited to the species description, feeding, growth and reproduction. Other considerations will include the aquaculture profile of each species (including certain historical, current, and future prospect), structures for cultivation, and sourcing of spat. The environmental issues of each species will deal, inter alia, with the impact of structures for cultivation, impact of feed, pollution (includes genetic) due to the aquaculture activities of the species (operational as well as harvesting), and diseases impact and biosecurity aspects.

An environmental impact risk score of 1 – 5 (1 = good; 2 = moderate; 3 = high; 4 = very high; and 5 = extreme) will be assigned to the factors. It must be noted that some of the areas discussed may be cross-cutting and reference will be made where such issues are dealt with in other sections. Examples will be made of similar or closely related species in cases where no reference of the specific species can be found or is non-existent. The species discussed here will be assumed to be applicable for the three sites (Lüderitz, Walvis Bay and Swakopmund), except when the issue of shore-based and offshore-based facilities are concerned.

The finfish consist of endemic species (Yellowtail kingfish, *S. lalandi*; Dusky and Silver Kob, *A. coronus* and *A. inodorus*; Galjoen, *D. capensis*; Steenbras, *L. auratus*) and exotic species (*S. salar*) as well as freshwater species (Tilapia, *O. niloticus*) that is exotic. Noteworthy to indicate that Dusky and Silver Kob are grouped into one section as these two species are closely related (Griffiths and Heemstra, 2000; Griffiths, 1997), have overlapping habitats (niche) (Kirchner and Holtzhausen, 2001) and consist of hybrids (Merimin et al., 2014; Pringle et al., 2023).

Proposed shellfish consist of only two endemic species (Black mussels, *Choromytilus meridionalis* , and West Coast Rock Lobster, *Jasus lalandi*), and exotic species (Pacific oyster, *Crassostrea gigas*; Abalone, *Haliotis midae*; Scallop, *Argopecten purpuratus*; Sea cucumber, Holothuroidea species)

The farming of finfish species will require an intensive culture system, requiring inputs in such as feed as it is fully dependent on feeding nutritionally balanced diets. Impact of such feed on the environment is a matter for consideration, in addition to biodiversity impact due to escape and disease transmission.

The shellfish aquaculture, particularly oyster and mussel cultivation, is a good example for extensive production and has become very attractive (Gibbs, 2004). These candidates do not require artificial feeding (Ferreira et al., 2009, Garen et al., 2004) and as essential bio-extractive organisms can even improve water quality in marine systems (Ferreira et al., 2009, Rose et al., 2010).

5.1.1. Finfish

The finfish species proposed are the Yellowtail Kingfish (*Seriola lalandi*), Silver (*Argyrosomus inodorus*) and Dusky Kob (*Argyrosomus coronus*), Galjoen (*Distichous capensis*),

None of the proposed finfish species are cultured in the Namibian marine environment, except for the included freshwater finfish, *Oreochromis niloticus*, but several finfish species and related cousins are cultured elsewhere. Information on the culture specifics of the species will be used to provide the needed information. Studies that have been done on some of the proposed species (Galjoen) indicated undesirable characteristics for aquaculture, while some (Nile tilapia) does not fit in the given marine environment and require high temperature than the environments that has been suggested (will require higher input cost due to the temperature regulation to meet the species requirement).

5.1.1.1. Yellowtail Kingfish (*Seriola lalandi*)

The Yellowtail Kingfish (YTK) is an established mariculture species in South Australia, South Africa and Japan. In Australia, especially in Fitzgeral Bay, a production of over 2000 ton per year has been recorded with a total of approximate 20 ha at water depths of 10 – 20 m. These farms are sited where the current speed is in the order of 15 cm/s and water temperatures in the range of 12 – 28 °C. The culturing of this species in South Africa is being conducted in recirculating aquaculture systems (RAS) and cages.

This situation is closely related to what is currently the state of the Aquaparks in both Lüderitz and Walvis Bay. The Aquapark in Lüderitz is having a water depth of ….m and the measured water currents are in the range of 3 – 5 cm/s.

Yellowtail Kingfish is harvest usually after two years at the size of 3 – 3.5 kg in which time they are grated two times. The fish are held at a density of 13 kg/m^3. The typical cage for the fish is 25 m in diameter and 6 m in depth. Sedimentation rates measured at such farm are in the range of 79 – 83 g/m^2/day. The species is also cultured in South Africa in recirculating aquaculture system (RAS) in East London. It is a closed production system (from broodstock, larval and marketable fish). The harvest target for SA YTK is around 2.5 kg in 12 months. Stocking densities of up to 60 kg/m^3 can be achieved in the RAS system.

In all the cases of YTK culture, the fingerlings are sourced from broodstock spawned in land-based hatcheries. This is bound to, inevitably, lead to transfer of infections from parent fish to offspring via the vertically disease transmission process. Several of the culture conditions such as increased stocking densities, suboptimal nutrition and reduced water quality contribute to increased prevalence and intensity of infectious diseases (caused by virus, bacteria, fungi, and parasites).

At present there is no data available of the pathogens of this species in Namibia, however, development of the mariculture will provide interest into the disease-causing agents for this species.

5.1.1.2. Silver and Dusky Kob (*Argyrosomus inodorus* and *Argyrosomus coronis*)

Farming is well established for the closely related species to the species found in Namibia, such as mulloway (*Argyrosomus japonicus*) in Australia, dusky kob (*A. japonicus*) in Japana and South Africa, and the red drum (*Sciaenops occelatus*) in the USA and the meagre (*Argyrosomus regius*) in the Mediterranean region (France). Studies are conducted in Namibia for the captive rearing of the Silver Kob (*Argyrosomus inodorus*). Successful spawning and early larval rearing until juvenile stage was achieved that entailed the live feed stage and onset of feeding artificial diet. This indicates that the species can be reared in closed production system. The ability of the species to be maintained and spawning in captivity, robustness, fast-growth, and adaptation to locally available diets make it a potential candidate for aquaculture.

The best temperatures for the optimal growth in captivity for this species is within the rage of 19 – 22 °C. It has been observed that feeding activity is substantially reduced when temperatures drop below 13-15 ºC. Dissolved oxygen (DO) levels of 7 mg/L for optimal growth and metabolic functioning. Intensive production of the species can be conducted both in land-based tanks, ponds, and cages. Proposed stocking densities for tanks is 50 kg/m^3, in cages it is established at 45 kg/m^3 and the fingerlings of 2 – 5 g are stocked 300 – 350 fish/m^3 in ponds.

There has been reports of diseases in culture conditions of the species most notably from viruses (viral nervous necrosis and Lymphocystis) and bacteria (Vibriosis and systemic bacterial infection caused by *Streptococcus iniaei*). In Namibia parasite studies were conducted (Amakali, et al., 2022) that enumerated several external and internal parasites organs in terms of monogeneans (*Diplectanum sciaenae*, Calceostoma sp.) and Acanthocephala (*Corynosoma austral*). Other parasites that is widely observed with the capture held finfish is the sea lice. This is indicative that the short pathway for infection created by high stocking density in intensive culture system could lead to serious disease outbreaks if correct husbandry practices are not carefully observed.

5.1.1.3. Blacktail (*Diplodus sargus capensis*) and Steenbras (*Lithognathus aureti*)

These two species are grouped together as they both belong to the Sparidae family. The tclosely related species that received attention as mariculture candidates are the Gilhead bream (*Sparus aurata*) that is cultured in France, Italy and

Gilthead seabream can be farmed in various ways such as in coastal ponds and lagoons, with extensive and semi-intensive methods; or in land-based installations and in sea cages, with intensive farming systems. These methods are very different, especially regarding fish farming density and food supply. Temperature for optimal growth ranges between 18 – 26 °C. Very high densities (15 – 45 kg/m^3) can be realised in tanks. The species can reach commercial size of 350 – 500 g in 20 months.

Diseases include viral diseases such Lymphocystis, bacterial diseases: Pasteurellosis (caused by *Photobacterium damsalae*), and Vibrio, as well as parasitic diseases (Parasitic interidis, caused by *Myxidium leei*).

5.1.1.4. Atlantic Salmon (*Salmo salar*)

This is a cold-water species that prefers water temperatures between 0 and 20 °C with preferences between 4 and 18 °C, a swimming optimum at 16-17 °C and a growth optimum at 14-19 °C. They reduce or stop feeding below 6-7 °C. Optimum dissolved oxygen levels range from 7 – 11 mg/L with pH 6 – 8.2 but have pH tolerance level range between 5.0-5.4. Artificial spawning of the species is usually accomplished in shore-based hatchery where eggs are incubated until they hatch. The fish spend their early life stage (larvae until the smolt stage) in freshwater. The fish is then transferred into seawater cages after smoltification for further ongrowing (for approximately 22 months) until they reach market size (500 – 1000 g). Maximum stocking densities ranges from 20 – 30 kg/m^3.

The introduction of the exotic Atlantic salmon is a concern in terms of ecological and biodiversity impact in the event of an escape. The Atlantic salmon is an anadromous fish species, with their lifecycle beginning with a freshwater phase, followed by smoltification (where young salmonid fish adapt from living in fresh water to living in seawater) and migration to the sea for feeding and growth, and a return to their native river for spawning (Norrgård, 2011). *S. salar*, in their native environment have a predisposition to strictly return and breed to rivers were they were bred, termed as "Homing" (Heggberget *et al,* 1988). In areas where salmon are non-native e.g., Tasmania, escaped Atlantic salmon have been shown to have poor colonization ability, lose condition rapidly after escaping from cages, and do not predate upon native fauna (Abrantes *et al.,* 2011). Experience in South Africa also shows that, even in the rarest possibility of escape, no colonies have been formed. In Namibia these impacts are likely to be similar and, therefore, possible impact could be negligible.

5.1.2. Shellfish

Species being cultured include the Pacific (*Crassostrea gigas*) and European (*Ostrea edulis*) oysters, respectively, and abaone, *Haliotis midae*. The culture of scallops (*Argopecten purpuratus*) was recently started on experimental basis. All the shellfish species are not native to Namibia. The culture methods for most of the shellfish consist of suspended bags, rafts and longlines.

5.1.2.1. Pacific Oyster (*Crassostrea gigas*)

The Pacific oyster, although non-native to Namibia, perform better than their natural habitat and reaching market size between 8 – 12 months, partly due to the nutrient-rich Benguela upwelling system.

The current source of oyster input is the only hatchery in Namibia, based in Swakopmund and operated by Beira Aquaculture. Broodstock are induced to spawn, and after the hatching of eggs and the metamorphosis, the spat are reared micro-algae cultures. At around 4 – 6 mm the spat is transferred to Lüderitz for ongrowing in small wooden baskets with mesh netting. The wooden baskets are attached to long lines and suspended in water. Grading takes place after the oysters are reared in the water for one month or more where the slightly bigger oysters are placed in baskets. This process takes places for several months until the desired sizes are met. Once they reach the desired size for final fattening (cocktail, medium or large), they are transported to Walvis Bay for final conditioning. Oysters are filter feeders and will exclusively rely on naturally occurring microscopic phytoplankton, generally referred to as plankton, for their diet. This diet consists mainly of algae and oysters filter approximately 50 litres of water per day to obtain enough food. No artificial food, antibiotics or chemicals are used at any stage of the rearing process. Long lines and grow-out baskets create additional habitat and refuges for local species including juvenile lobsters and fish. This can be regarded as a positive impact.

5.1.2.2. Black mussels (*Choromytilus meridionalis*)

Culture of the species is a low investment activity. About 500 to 750 g (from 15 to 25 mm) of seed is required for seeding on one-meter length of rope. Nylon is usually used and a cotton net, cotton mosquito net or cheap cotton cloth etc. is used for covering the seeds around the rope. Raft culture is the most popular method in which seeded ropes are suspended from a raft set in a desirable site and depth in the inshore area. Pond systems can also be used for the culture of mussels.

5.1.2.3. Scallops (*Argopecten purpuratus*)

Reared with the same technology as oysters. Spat was previously collected from the wild, but having a hatchery has its advantages. The culture methods is either the hanging culture and bottom culture, where the hanging culture relies on either a raft or longline system (with buoys and lines) that floats on the sea surface from which the cultured scallops are suspended, usually on ropes to which they are attached in some manner. Rafts are considerably more expensive than the equivalent distance of longline and are largely restricted to sheltered areas. However, raft systems require much less handling time. The added advantage of the hanging culture method is the exploitation of mid-water algal populations for this filter-feeder that cannot be fully utilized in other forms of culture. Disease of this species is not well-understood, but there has been reports of malacoherpesviridae.

Abalone (*Haliotis midae*)

Abalone, occurring in South Africa, is not native to Namibia. This is a high value species that is reared in both cages and flow-through tanks it takes 3 to 4 years for abalone to grow to commercial market size of about 7.6 to 8.9 cm. The current feeding approach of using beach-casted seaweed is not sustainable if there is any envisaged growth of the abalone industry. New artificial feed being developed with good results and received market acceptance.

5.1.3. Seaweeds

Marine seaweed is becoming an increasingly competitive biomass production candidate for food and related uses. The seaweed industry experienced exponential growth over recent decades.

5.1.3.1. Laminaria and Ecklonia species

The farming of seaweed on longlines have several ecological and environmental benefits:

- Low environmental impact
- Uptake of excess coastal nutrients or substitution of other products with higher carbon footprint.
- It is a form of regenerative aquaculture, and it can, therefore, be produced in the ocean using methods which may not require additional feed/nutrient inputs.
- Improvement of water quality and buffer the effects of ocean acidification in surrounding areas.
- Carbon sequestration
- Having the potential to produce a range of different products with broader environmental benefit, such as methane inhibiting feed additives for livestock.
- Integration in fed aquaculture as part of the multi-trophic aquaculture system.

Table 8. Summary of Proposed Species.

Category	Species	Biology, distribution	Aquaculture		Environmental Impact Risk Factor				
1. Finfish				**Native/Non-native[0]**	**Structure[1]**	**Water Quality[2]**	**Feed & Waste[3]**	**Genetics[4]**	**Diseases[5]**
	Silver and Duky Kob (*Argyrosomus coronus and Argyrosomus inodorus*)	- Both are large sciaenid (Sciaenidae family), attaining a maximum total length of about 130 cm and 200 cm, respectively. - highly palatable and constitutes about 70% of all recreational shore angling catches in Namibia. - Species have overlapping distribution and occur	- Closely related species are farmed (Dusky Kob, *Argyrosomus japonicus* in Japan and South Africa; Red drum (*Sciaenops*	Native	3	2	2	0	1

		between Meob Bay, north of Angra Fria, Lüderitz and Cape Frio	*ocellatus*) in America and Mulloway (*A. japonicus*) in Australia. - The species can be reared in cages, RAS, and ponds.						
	Yellowtail Kingfish (*Seriola lalandi*)	- Large marine pelagic fish from the family Carangidae. - Long bodies and slender heads, which are longer than their body depth.	- High commercial value and global demand - Cultured in Chile, Japan,	Native	3	2	2	0	1

		- Blue or blue green colour on their back, white silver below. - Yellow caudal fin. - Maximum length up to 180 cm and weights between 40 and 50 kg - Migratory species - Distributed in Pacific Ocean and South Atlantic Ocean.	Australia, New Zealand, USA, Mexico, the Netherlands, and South Africa. - Cultured in cages, RAS. - High stocking densities (in cages 150 kg/m^3; 40 kg/m^3 in RAS). - Limiting factor to stocking						

			density is oxygen and waste removal. - In RAS stocking densities can be increased through pure oxygen infusion and increased flow rates.						
	Atlantic Salmon (*Salmo salar*)	- Belongs to the family Salmonidae that naturally occurs in the Northern hemisphere. - Possesses adipose fin and have a silvery	- High value species with wee-developed and established	Non-native	3	2	2	3	4

		colouration during ocean life and turn brownish during maturation, - This is anadromous fish where the young migrate from the river to the sea for feeding and at sexual maturation return to their natal river to spawn as adults. - Requires a freshwater environment for spawning and the development of the early life stages.	rearing protocol. - Farmed in two stages: hatched from eggs and raised on land in freshwater tanks and when 12 to 18 months old, the smolt (juve nile salmon) are transferred to floating sea cages or net pens.							

	Galjoen (*Dichistius capensis*)	- This is an indigenous fish to the coasts of southern Africa, Namibia and Angol - It is generally found at shallow depths around. - Feeds on mussels, barnacles and seaweeds - Important angling species	- No culture of this is taking place. - Investigation to assess its potential was carried out. - The idea for its culture is primarily on economic grounds, due to the high price commanded by this species.	Native	3	2	2	1	2

			- Growth rate is very low and there is a need for research to optimize production of larvae and consequent mass rearing.						
	Steenbras (*Lithognathus aureti*)	- This is an endemic to southern Africa, - In Namibia occurring between the mouth of the Orange River and the mouth of the Kunene River.	- The species was investigated for aquaculture potential. - Steenbras showed efficient	Native	3	2	2	1	2

		- Important commercial and recreational fishery.	utilization of a commercial pellet diet. - Growth rate is very low and there is a need for research to optimize production of larvae and consequent mass rearing. - Other Sparidae are cultured with success in						

			the Mediterranean region (gillhead sea bream, *Sparus aurata*, and red sea bream, *Pagrus major*)						
	Blacktail (*Diplodus sargus capensis*)	- Important endemic species along the Namibian coastline - It is abundant inshore and form a part of the recreational and artisanal fisheries		Native	3	2	2	1	2
	Tilapia (*Oreochromis niloticus*)	- Cichlids endemic to Africa. - Consists of three aquaculturally	- A freshwater species with well-	Non-native	3	1	1	1	2

		important genera — *Oreochromis, Sarotherodon* and *Til apia* - Widely distributed in all temperate regions of the world.	established aquaculture potential. - Prefer temperature s from 20 - 27 °C. - Husbandry developed for culture in cages, hapas, ponds, raceways, and RAS. - Positive aquacultura l characterist ics of tilapia are their						

			tolerance to poor water quality and the fact that they eat a wide range of natural food organisms.						
2. Shellfish									
	Pacific oyster (*Crassostrea gigas*)	- This are estuarine, sedentary, and often attached to rocks, debris and shells from the lower intertidal zones. - Prefers firm bottom substrates but can also	- Established in all major coasts of the world, making it the most ubiquitous	Non-native	3	1	1	1	1

		be found on mud and sand-mud bottoms. - Filter-feeders, extracting micro-algae and other particles from water. - Its origin is Japan, where it has been cultivated for centuries, but the species is widely distributed elsewhere through introduction in aquaculture or accidental via shipping activity from the coasts of America to Africa. - Broad temperature tolerance from 2 – 35 °C.	oyster in the world. - Small pockets of the European oyster, *Ostrea edulis*, but the Pacific oyster, *C. gigas*, is the species that is mostly cultured in Namibia. - Cultured in bags, rags, buckets, suspended on ropes						

			along buoys to keep above the bottom sediment						
	Black Mussels *(Choromytilus meridionalis*)	- Filter-feeder molluscan bivalve that grow clustered on substrates (rocks, seaweeds) - Found in coastal, inner shelf, outer shelf, oceanic, brackish, seawater. - This species is found only around the southern African coast, from central Namibia to Port Elizabeth,	- Attaches naturally to the ropes suspended in the water. - Farming in Namibia is negligible, but the species is commercially farmed in Saldanha Bay, South Africa	Native	3	1	1	1	1

		- Particulate organic matter is the major food source	- Farming of it is extensive (being a filter feeder they obtain food from the nutrient rich water) - Other mussel species are produced in South America (Chile) and Europe (Spain, France and Italy)						

	Abalone *(Haliotis midae)*	- It's a marine vetigastropod molluscs, which are distributed along rocky shores and reefs of coastal temperate and tropical waters. - Species is endemic to South Africa abundant. - It is the largest and most of the abalone species in this country. - Found on rocky reefs between the intertidal and subtidal zones	- Farming in South Africa only started in the late 1950's - Poaching necessitated the culturing of abalone as a sustainable means. - Only one farm in Namibia, Lüderitz.	Non-native	3				
	Scallops *(Argopecten purpuratus)*	- Bivalved molluscs that can be found around the world.	- Successful hatchery technology developed	Non-native	3	1	1	1	2

		- Widely spread in the Atlantic Ocean - Unlike their relative the oyster, scallops are free-swimming mollusks that live inside a hinged shell.	for sea cucumber. - Investigation on the broodstock conditioning and rearing ongoing in South Africa						
	West Coast Rock Lobster *(Jasus lalandii)*	- Spiny lobster that is found off the coast of Southern Africa - occurs in shallow waters from Cape Cross, Namibia to Al goa Bay, South Africa, - of mussels, sea urchins, abalone, bar nacles	- Trails to determine the viability of the species for aquaculture were conducted in SA,	Native	3	1	1	1	2

		- Reach total length of 46 cm and carapace length of 18 cm. - Important fishery in Namibia and South Africa	- Complex life cycle, survival rate and slow growth is the limiting factors for closed loop culture, - Possibility of collected wild seed for ongrowing						
3. Kelp									
	Giant kelp (*Microcystis* Seaweed (Laminaria, Ecklonia)	- The giant kelp is one of the fastest growing. - Adapted to various climate conditions	- Seaweed farming is a carbon negative cr op, with a high	Non-native	1	1	1	1	1

			potential for climate change mitigation - One farm established pilot trials with						

Notes:
0. Impact of native and non-native (exotic) species on the natural population can be genetic and ecological. The notion of escaped fish that is not native is that they will adversely impact wild stocks, either through competition for food or habitat, disease, or through reproductive mixing. This depends on the reproductive capacity of the exotic species to thrive in the new environment, interbreed with native populations, establish niches.
1. This include the impact of the aquaculture structure (pond, cage/net pen, RAS, raceway, basket, ropes) for the specific species on the natural environment.
2. Any negative change of water quality due to the activity and operation of the aquaculture facility (stocking, size grading, harvest, disease treatment) for the specific species
3. Expected impact of feed (uneaten feed) on the physical and chemical water quality. The accumulation of waste during the aquaculture operation (faeces, scales, debris, etc.) during the aquaculture operation for the specific species.
4 & 5. Closely related to 0 and also include the development, spread and transfer of diseases to the natural population.

6. MARICULTURE DEVELOPMENT AT IDENTIFIED SITE

The mariculture development in Namibia had seen tremendous growth since the beginning of 198 and 1990 from single farmers cultivating oysters, mussels, and seaweed. In 2004 the Ministry of Fisheries and Marine Resources registered 50 license holders for various species ranging from seaweed, mussels, sea cucumbers, oyster and abalone (Table 9). From 2012 to date (2023) only 13 license holders were active, 6 and 7 in the Erongo Region and Karas Region, respectively.

Table 9. Registered Mariculture Operations in Namibia (records of MFMR).

Species	**License holders**
Seaweed	5
Mussels	12
Oyster	22
Abalone	16
Sea cucumber	2

6.1. Lüderitz.

6.1.1. Overview

Lüderitz, in the Karas Region, is the farthest harbour town of Namibia, that gained prominence with the discovery of diamonds in 1908. The town became a lucrative fishing base providing more than 80% of the employment and comprises commercial fishing as well as subsistence fishing. Fishing activities center on white fish (hake), tuna, crayfish and oyster farming. Other economic activities include the tourism industry, logistics and retail. The tourism industry specifically has seen reasonable growth over the last decade due to the establishment of the waterfront and various luxury accommodation facilities, the hosting of mayor annual events such as the Crayfish Festival and the occasional calls of passenger liners. The port of Lüderitz makes the town is the nearest port-of-call in southwestern Africa and an important logistics hub with the expected repair and upgrading of the railway envisaged to also attract increased exports of commodities through the port of Lüderitz that is focused on the export of mining minerals, grapes and fish and the import of heavy machinery, equipment, and chemicals. Servicing of ships for the diamond and oil and gas exploration activities also take place at the Lüderitz harbour. The envisaged plans to dredge and deepen the port is expected to attract larger vessels and will help to promote the port as attractive logistics import and export alternative for land-locked SADC countries such as Botswana.

6.1.2. Environment

Lüderitz has a rocky area with few sand spots. The currents in the Lüderitz area are rather strong owing to the Kelvin waves, which must propagate longer distances before they can arrest the coastal jet, with a typical surface flow speeds are 0.2 - 0.5 m/s and the annual amount of water transported estimated to about 20 million m^3/s (Fennel, 1999). The seawater quality in Lüderitz is considered good quality, owing to few activities, and no large upstream agricultural activity that could be responsible for the inflow from the terrestrial environment.

The primary productivity in Lüderitz is high due to the Benguela upwelling system. The sunlit waters of approximately the upper 50 m from the epipelagic zone. Phytoplankton abundance is high and variable. High concentrations of diatoms are associated with cold water upwelling activity, whilst micro flagellates and dinoflagellates tend to dominate when the upwelling is suppressed, and the water column is stratified. Copepods and euphausiids dominate the zooplankton community.

6.1.3. Mariculture Activities

Lüderitz is having sheltered bay and islands. Five oyster operations are active at Lüderitz, one abalone farm and one seaweed farm. The oyster spats are produced at a hatchery in the Swakopmund salt works, then reared in the nursery phase in the Lüderitz lagoon areas, before being transferred for final grow out to farms in Walvis Bay.

Despite recent improvements in productions systems, there remain in terms of development of the mariculture sector. Dependence on shellfish species alone as well as limited production systems are some of the main factors limiting development of the mariculture. Shellfish species farmed include pacific oysters (*Crassostrea gigas*), European oyster (*Ostrea edulis*), surf clam (*Donax serra*) and others on an experimental basis. Most of the operations are land-based.

Table 10. Shellfish farming facilities in Lüderitz, //Karas Region.

Institution/Facility	Status	Location	Species	System
Lüderitz Research Center/MFMR	Regulation/research	National	N/A	N/A
Lüderitz Abalone Company	Hatchery/on-growing	Lüderitz	*H. midae*	Land-based
Elonga	On-growing	-	*C. gigas*	Off-shore longlines
Lüderitz MC	-	-	*C. gigas*	-
Ocean Grown	-	-	*C. gigas*	-
Five Roses Aquaculture	On-growing	Lüderitz	*C. gigas*	Off-shore longlines
Lagoon Aquaculture	On-growing	Lüderitz	*C. gigas*	Off-shore longlines

Expansion can include the introduction of finfish in cage culture systems. Cage culture systems for finfish can be accomplished in areas where water depths are more than 10 – 20 meters to allows for dispersion of waste (distance of 1 – 2 meters between the cage bottom and sediment). Ongrowing of Yellowtail Kingfish, Kob and Atlantic salmon in sea cages of different formats has great potential. Estimated production of 100 tonnes per year is feasible without causing ecological disturbance.

The allocated sites in the aquapark are presently not used to full capacity (Fig. 4).

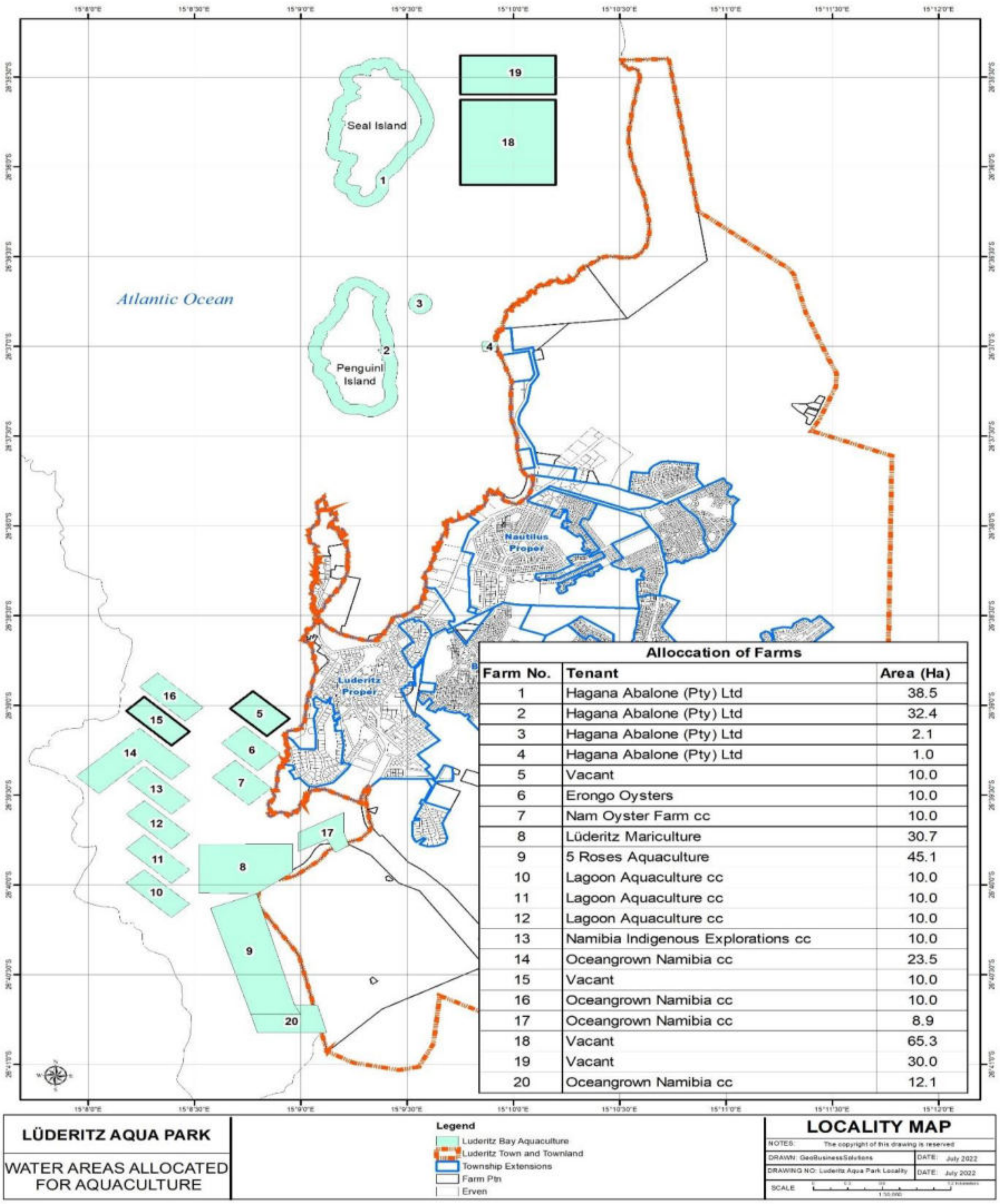


Figure 3. Allocated Aquaculture Parks in the Port jurisdiction of Lüderitz

6.1.4. Marine Space Users

The mariculture activities may impact marine space users in Lüderitz in terms of access to the resource.

6.1.4.1. Fishing

The economy of Lüderitz is heavily depended on the local fishing industry. Fishing consists of commercial fishing vessels catching white fish (hake), tuna, crayfish, and the artisanal fishery that is catching nearshore species such as Kob, Steenbras, Mullet, and crayfish. The route to fishing grounds for commercial fishing boats and vessels is matter for consideration. Access to traditional fishing grounds (beach site) for artisanal fisheries also need to be considered when developing mariculture sites.

6.1.4.2. Mining

Diamond mining activities are not in the vicinity of the envisaged aquaculture sites. There are, however, possibilities of the aquaculture activities infringing on sites that can have prospects for mineral (such as phosphate), gas and oil mining activities.

6.1.4.3. Tourism

Tourism is an important economic activity as Lüderitz is known for its German colonial buildings, historic monuments, water activities and other attractions. The self and guided tours to historic monuments such as the Diaz point, the sight-seeing ventures to the seal and penguin colonies with the catamaran are activities that will be affected or affect the mariculture development.

6.1.4.4. Construction/Housing Development

Coastal town of Lüderitz is project to grow, putting pressure on the availability land, water, and other amenities. The development of mariculture, especially when such is shore-based, will compete with the housing development needs. The aquaculture systems may also be construed to affect the value of adjacent properties. Other concerns will be that activities at the aquaculture site may pollute the air.

6.2. Walvis Bay

6.2.1. Overview

Walvis Bay is an important economic hub of Namibia and due to its geographical location between the Namib Desert and the Atlantic Ocean, Walvis Bay is a strategic gateway for exports and imports between landlocked countries in Africa and the rest of the world. Walvis Bay links the Trans-Kalahari, Walvis Bay-Ndola-Lubumbashi Development, and Trans-Zambezi corridors. It is the second largest city in Namibia and contains the country's only deep-sea harbour with wellequipped infrastructure and port facilities. Fisheries, mining, tourism, manufacturing, and construction are the key economic activities.

6.2.2. Environment

Walvis Bay lies north of the main upwelling centre (off Lüderitz) and water here is dominated by decomposition and respiration where oxygen saturation is generally below 100 %. Usually, the surface of bottom sediments and at times deep waters are anoxic, and occasionally the entire water column turns anoxic and high concentrations of toxic hydrogen sulphide are found even in the surface, releasing the “rotten egg” odour. At the same time the water turns milky due to the production of fine sulphur particles during oxidation of hydrogen sulphide.The phenomenon is termed “sulphur eruptions”. This led to the collapse of the oyster culture during 2008 and 2009.

6.2.3. Mariculture Activities

There are, currently, only 3 active farms in Walvis Bay. Shellfish are the main culture species. Production is estimated at 3.6 million units per year, consisting mainly of the European oyster, *C. gigas*. Few scallops are rearing, mainly on experimental basis and no market exist at the moment. Rearing is carried out at sea and the sea pans. Recirculating aquaculture systems are usually employed for depuration or to maintain the shellfish when environmental conditions at sea becomes unfavourable.

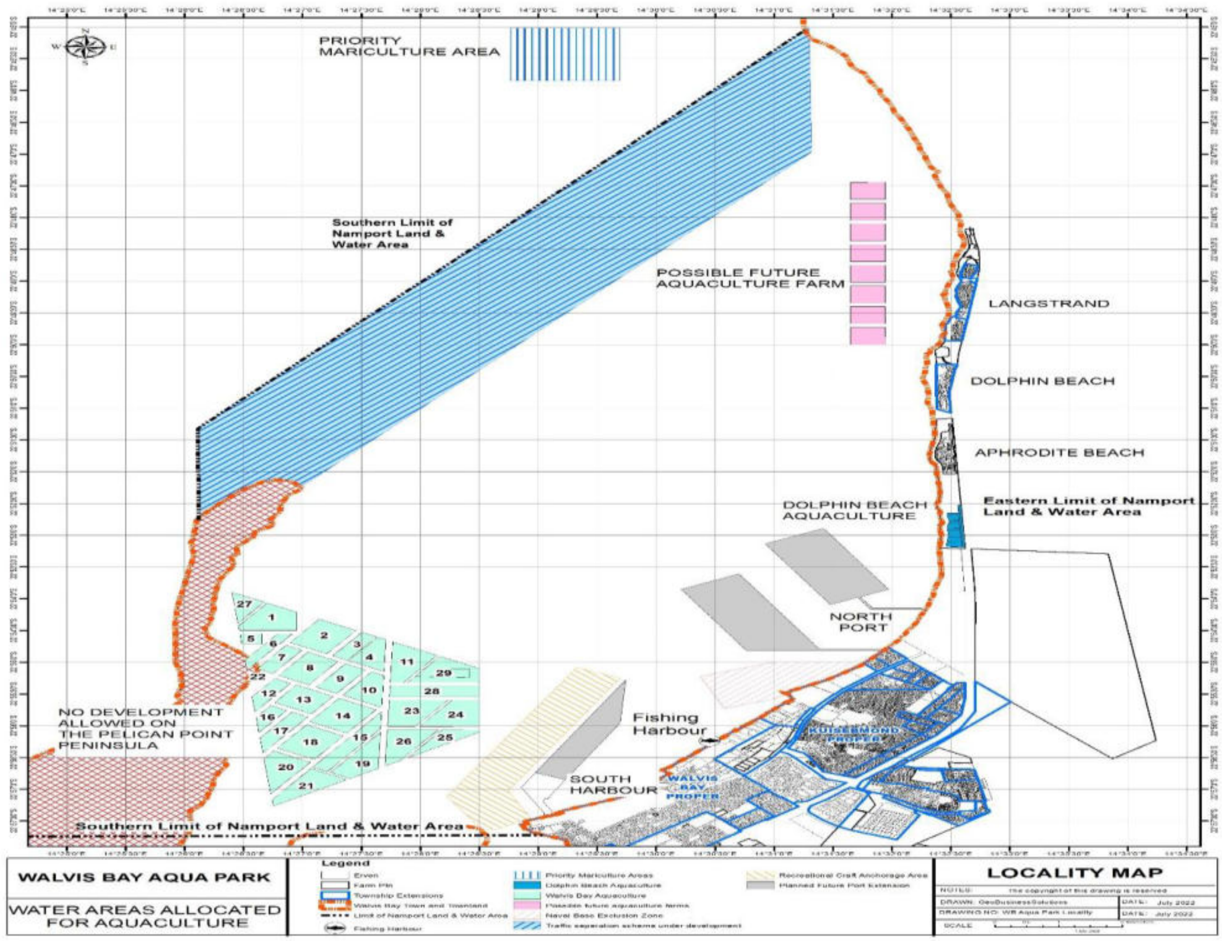


Figure 4. Allocated Aquaculture Parks in Walvis Bay

6.2.4. Marine Space Users

Walvis Bay is the second biggest city in Namibia and an important commercial and industrial hub, being the deepest port. Although good care was taken in the demarcation of the aquaculture parks (Aquapark) there is strong possibility of mariculture activities impacting on or being impacted by marine space users in terms of access to the resource.

6.2.4.1. Fishing

The fishing industry, with more than 50 years existence, is the cornerstone of the Walvis Bay economy with well-established factories and has developed into a leading force in the world's fish supply market. High value fish (hake, tuna, crayfish, monk) and related products are caught and processed for export purposes to niche markets in Europe, Australia, the United States and Hong Kong. Other fish species caught commercially include pilchards, anchovy, tuna, monk, sole, horsemackerel and other demersal species. The artisanal fishery is confined to small boats (not more than 2 meters) fishing Mullet and Snoek and nearshore angling with hook-and-line for Kob, Steenbras, Blacktail and Mullet, and crayfish. The route to fishing grounds for commercial fishing boats and vessels is far from the mariculture sites, thereby not posing any conflict. The artisanal fishers launch their boats via the Walvis Bay Lagoon and the path out to sea is closer to the Aquapark 1.

6.2.4.2. Mining

Salt mining activities are in the Kuiseb river delta at the southern end of the Walvis Bay lagoon, which is a proclaimed Ramsar wetland and an important bird sanctuary. The salt mine is also closely located near to the designated Aquapark 1, along the Pelican Point peninsula where no further development is allowed. A company is making use of the salt mining company intake ponds for the rearing of oysters.

6.2.4.3. Tourism

Tourism is an important economic activity as it is located by the Pelican Point sand spit, and the Walvis Bay Lagoon is home to abundant birdlife including flamingos, pelicans and Damara terns. The dolphins, whales and Cape fur seals inhabit the Atlantic waters around the Pelican Point Lighthouse are major tourism attractions, while east of the bay, the coastal sand dunes, like Dune 7, that marks start of the Namib Desert is frequently visited by tourists, both local and foreign.

6.2.4.4. Construction/Housing Development

The growth of Walvis Bay is to grow, putting pressure on the availability land, water, and other amenities. The development of mariculture, especially when such is shore-based, will compete with the housing development needs. The aquaculture systems may also be construed to affect the value of adjacent properties. Other concerns will be that activities at the aquaculture site may pollute the air.

6.3. Swakopmund

6.3.1. Overview

Swakopmund has been marketed as a tourist and holiday home destination. This town with a rich German architecture provides an ideal location close to a strategic port hub and serves as a link to the inland.

6.3.2. Environment

The marine environment along Swakopmund is relatively clean with very few activities in terms of fishing and passenger vessel operations. There is strong wave action (south-northerly) with swells of up to over 2.5 m often reported. The beach is sandy with rock patches.

6.3.3. Mariculture Activities

Aquaculture development in Swakopmund is not well established as in other coastal towns such as Walvis Bay and Lüderitz. There is only one oyster hatchery operating from the salt processing and guano manufacturing plants. Species being cultured include the Pacific (*Crassostrea gigas*) and European (*Ostrea edulis*) oysters. The culture of scallops (*Argopecten purpuratus*) was recently started on experimental basis. The oyster hatchery is a land-based (onshore) facility with flow-through system and the water supplied to the hatchery facility is being obtained from the existing intake for the salt production operation. Freshwater use is minimal and restricted to cleaning and dilution of seawater to obtain specific salinity levels.

There is currently no demarcated aquaculture zone or aquaculture park for the municipal area of Swakopmund. Offshore aquaculture development at Swakopmund is not possible due to the straight coastline with only a few capes and bays. The most viable aquaculture development option remains pump-ashore facility that can include lined ponds or an inhouse recirculating aquaculture system (RAS). The partial rocky bathymetry provides ideal anchoring sites of the pumping system and few traffic operations along the coastline and few angling spots providing less disturbance and conflict of resource use. Several culture methods are possible within the given site such as mono- and polyculture as well as the integrated multi-trophic aquaculture systems.

Kob (both the silver and dusky), oysters, abalone, seaweed can be cultured in tanks in a monoculture, however, it is beneficial to apply the polyculture system in order to better utilize the full potential of the water niche. For example, Kob, that is a high value species, could be reared with a low value species such Mullet (*Cheron richardsonni*) at a stocking rate of 1:3. The abalone system will require a flow-through system, but require optimal water quality (pH and DO levels). The filter-feeding species (oysters, scallops and mussels) and abstractive species (seaweed) can make use of a flow-through system, but at very flow rates. The possible flow-through or RAS systems are ideal for the culture of finfish (max. 10 tonnes/annum), oysters (15 million/year) as well as other downstream species in an integrated multi-trophic aquaculture (IMTA) set-up.

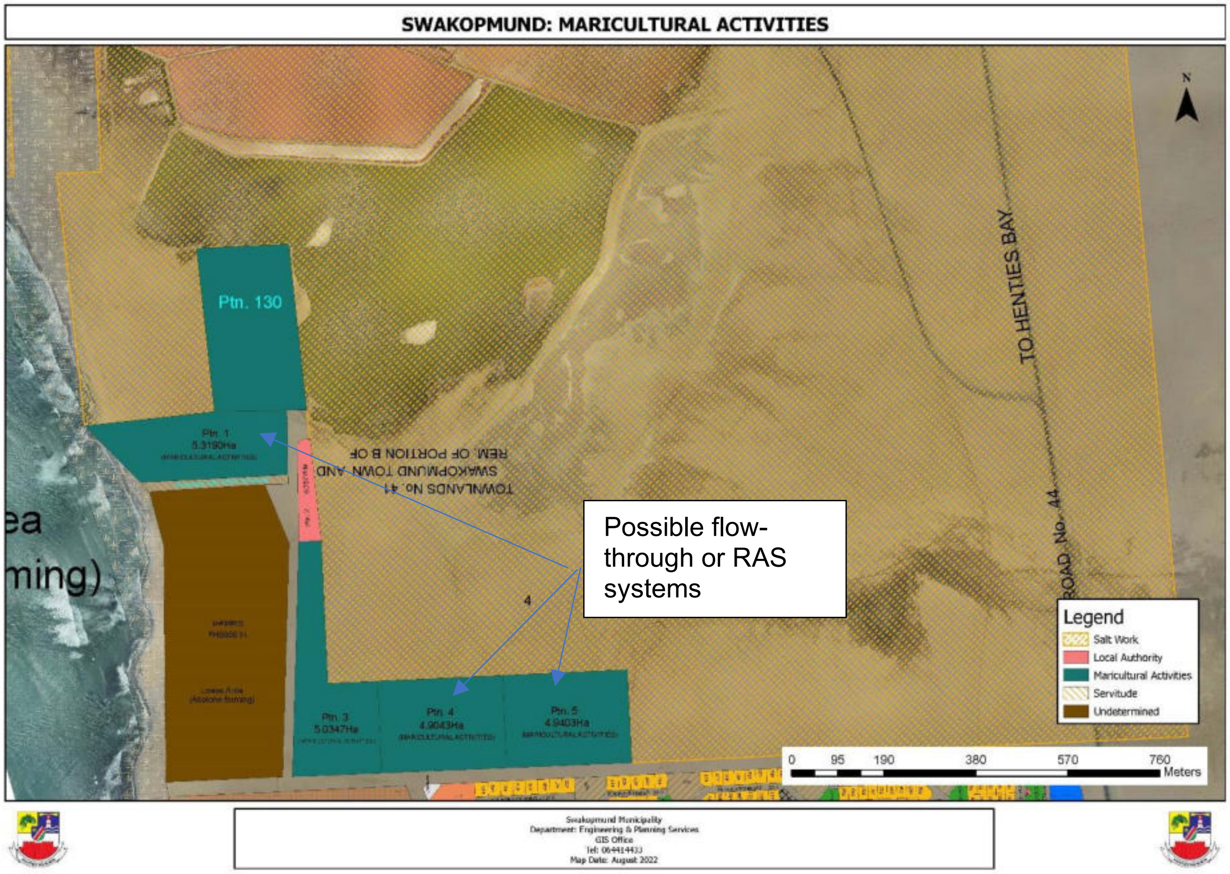


Figure 5. Possible Mariculture Sites along Swakopmund (Mile 4 on the way to Henties Bay)

6.3.4. Marine Space Users

Swakopmund does not have the possibility for any offshore aquaculture set-up due to the straight coastline. The area has good sites that are suitable for shore-based (or setting of pump-ashore) mariculture systems.

6.3.4.1. Fishing

Fishing activities are only limited to recreational and artisanal. Fishing is conducted along the coastline (areas of Mile 4 and along the rod of Walvis Bay-Swakopmund) as well as using ski-boat. Most ski boat owners have apparently found the tourist trade to be more profitable than commercial fishing, and now offer recreational fishing, dolphin or seal watching and trips round the bay.

6.3.4.2. Mining

Salt mining activities is at Mile 4. A guano mining activity. An oyster hatchery is making use of the salt and guano mining premises (water intake and evaporation ponds for ongrowing).

6.3.4.3. Tourism

Swakopmund is a preferred tourism destination and serves as a gateway to the harbour town of Walvis Bay, the Skeleton Coast Recreation area.

6.3.4.4. Construction/Housing Development

Swakopmund is one of the fastest growing towns, due to the influx of work immigrants to the mines. This is putting pressure on the availability land, water, and other amenities. The development of mariculture, which is shore-based, will compete with the housing development needs. The preferred locations for housing development is along the seaside and this is the identified area for aquaculture development (Mile 4 area). The aquaculture systems may also be construed to affect the value of adjacent properties. Other concerns will be that activities at the aquaculture site may pollute the air.

6.4. Carrying Capacity

The determination of the carrying capacity of the selected sites needs to follow the established ecosystem-based management approach to aquaculture as part of the FAO Code of Conduct for Responsible Fisheries (FAO, 1995). This entails inter alia, that the aquaculture development should not threaten but consider the full range of ecosystem functions and services, improve human well-being and equity for all stakeholders and develop in the context of other sectors, policies, and objectives.

The determination of carrying capacity will involve the assessment of the physical carrying capacity (of the selected site that will look at evaluate the natural condition of the site, the needs of the species and the culture system), production carrying capacity (based on the assessment of the scenario between no production and maximum production), ecological carrying capacity and the social carrying capacity (production that does not lead to significant changes to ecological processes, services, species, populations or communities in the environment or have adverse social impact).

The purpose of determining the carrying capacity of each site (Lüderitz, Swakopmund and Walvis Bay) is to ascertain the production level (production size or density of the cultured aquatic organism or plant) that does not cause adverse effect on the environment.

As is the case, even though the respective towns demarcated the aquaculture zoned sites the occupancy is not even 2% of the capacity provided.

In this report the determination for carrying capacity was not established for the following reasons:

i. There is no threshold established as no data on the monitoring is available.
ii. The exposed site of the Namibian coast – this reduces the potential for eutrophication (except for no wind days in the summer period)
iii. Absence of models (predictive) that will be developed from the monitoring data and stakeholder consultation for the estimation of carrying capacity.

There is a need to:

- Monitoring data on the environment performance of the current aquaculture farms that can be able to provide data for determining the carrying capacity.

7. ENVIRONMENTAL MANAGEMENT PLAN

A summary of the identified impacts of the mariculture development and also the impact on the receiving environment are provided in table 11 and table 12, respectively. The tables, below, apply to all the sites identified as some difference in magnitude were not considered to be significant for any of the potential impacts.

Table 11. Impacts, Mitigation Measures and Entities that are Responsible and/or having Mandate.

Possible Environmental Impact and their Sources		**Mitigating Measures**	**Entity Responsible for Implementation**
Water Quality	Release of waste from fish feed and faeces into seawater contributes to organic matter content. Organic matter will: • Increase turbidity and reduce water clarity. • Reduce water clarity decreases light penetration which could in turn decrease photosynthesis and primary productivity.	• Biomass/production limits • Management of feed quality and quantity • Appropriate site selection to maximize dilution and dispersal of any waste discharges • Monitoring should be designed to address water quality risks (nutrient status, dissolved oxygen (DO), algal abundance); Benthic sediment enrichment (redox,	➢ Ministry of Fisheries and Marine Resources ➢ Ministry of Environment, Forestry and Tourism ➢ Ministry of Agriculture, Water and Rural Development ➢ NamPort

	• Increase in dissolved nutrients which could lead to eutrophication and subsequent increase in abundance of harmful algal blooms (HABs). • Increase in BOD	nutrient loads, organic content, particle size distribution, benthic macroinvertebrates, surface appearance; Disease risks (disease surveillance of domestic and wild fish populations). • Pre site establishment monitoring • Routine surveillance monitoring • Establish nutrient and water quality thresholds. • Timely removal of and disposal of fish mortalities • Institute proper harvesting methods and off-site processing • Implement measures to prevent discharge of contaminants from farm and	

		develop chemical and oil spill response plan. • Provide employees with approved marine sanitation devices aboard vessels or working platforms.	
Diseases	Disease transfer to aquaculture species and wild marine species. The high stocking, intensive farming systems may lead to: • Introduction of diseases to wild species. • Introduction of diseases to captive held species and increase in established diseases. • Introduction of diseases of unknown aetiology. • Proliferation of zoonotic disease.	• Screening of imported seeding stock (broodstock, fingerlings) • Importing seeding stock only from sources with • Regular disease exposure and pathway assessments are needed to consider the probability of a disease occurring at the envisaged cage culture site and the origin of such disease. There are currently no baseline data on aquatic animal diseases in Namibia.	➢ Ministry of Fisheries and Marine Resources ➢ Ministry of Agriculture, Water and Land Reform ➢ Ministry of Environment, Tourism and Forestry

	• Release of antimicrobial and other chemicals in aquatic environment during treatment	• Develop health monitoring plans and protocols in additional to employing biosecurity practices and protocols. • The usage of appropriate stocking densities and employing techniques to minimize physiological stress to cultured fish. • Minimize the usage of antimicrobials and only use approved vaccines. • Close collaborations and coordination with veterinary, husbandry and fish pathology agencies and researchers for updated and best management practices	
Birds, mammals, and other	• Entanglement in aquaculture nets	• Employ bird-friendly net designs that minimize the risk of entanglement while	➢ Ministry of Fisheries and Marine Resources

aquatic organisms	• Ingestion of debris origination from aquaculture operation • Predation on culture organisms	allowing fish farming to continue. • Install exclusion devices or deterrents to prevent seabirds from accessing mariculture structures. • Implement efficient feeding practices to reduce the release of organic matter and uneaten feed, which can attract seabirds	➢ Ministry of Environment, Tourism and Forestry
Spillage	• Spillage of debris during operation (size grading, harvesting, cleaning, etc.)	• Size grading and harvesting to be conducted in such a way that debris are captured and discharge responsibly. • Ensuring that the material lifespan is maintain at optimum. • Cleaning and other disinfection to be done on and waste to be disposed of in a responsible manner	➢ Ministry of Mines and Energy ➢ Ministry of Fisheries and Marine Resources ➢ NamPort Company

Habitat modification	• Degradation of nearshore habitats through physical installation (cages, pens) • Degradation of landscapes through aquaculture systems (ponds) construction	• Apply good site selection. • Good construction and operation principles • Usage of robust aquaculture structures	➢ Ministry of Mines and Energy ➢ Ministry of Fisheries and Marine Resources ➢ Ministry of Environment, Tourism and Forestry
Wastewater pollution	• Discharge of wastewater without treatment can lead to a series of negative ecological impacts: - serious oxygen deficit caused by the decomposing of organic substances. - eutrophication or algae bloom caused by the	• Best aquaculture management practices • Most basic operations (size grading, cleaning, etc.) to be shore-based. • Effluent from ponds to be treated before released in the sea	➢ Ministry of Fisheries and Marine Resources ➢ Ministry of Agriculture, Water and Land Reform ➢ Ministry of Environment, Tourism and Forestry ➢ Local Authority

	accumulation of organic nutrients like N and P - Water deterioration will bring about low productivity. - Diseases may break out.		
Noise pollution	• Pollution due to operation on the aquaculture platforms - Noise due to operation of boats - Pneumatic feeding systems sounds and vibration	• Noise reduction on service boats and other mechanical devise	➢ Ministry of Fisheries and Marine Resources ➢ Ministry of Environment, Tourism and Forestry
Accessibility	• Aquacultures include a component of ownership (both in site of operation and production) - Loss of access to previous fishing grounds, tour operation routes, natural	• Select sites that do not exclude resource user access	➢ Ministry of Fisheries and Marine Resources

Table 12. Receiving Environment Sensitivity.

IMPACTS	PHYSIO-CHEMICAL COMPONENT					BIOLOGICAL COMPONENT						HUMAN COMPONENT					
SENSITVITY RATING 1 Negligible 2 Low 3 Medium 4 High 5 Very high	Air Quality	Seawater Quality	Seabed & topography	Sediment Quality	Organic matter & nutrient content	Phytoplankton & zooplanktons	Benthic Communities	Fishes	Turtles	Seabirds	Cetaceans	Fishing Industry	Mineral exploitation & mining	Other mariculture users	Tourism & Recreation	Maritime Transport	Public health and sustainability
1. Use of higher rich carbon oil and release of GHGs	1	2	1	1	1	2	1	1	1	1	1	1	1	1	1	2	1
2. Ocean acidification due to increased	1	2	1	1	1	2	1	1	1	1	1	1	1	1	1	2	1

atmospheric Carbon Dioxide.																	
3. Release of dust and metals particles into the air during grit blasting	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1
4. Release of waste from fish feed and faeces into seawater	1	4	4	4	4	4	4	2	2	2	2	2	1	1	1	1	1
5. Increased dissolved nutrients	1	4	4	4	4	4	4										
6. Settling or deposition of organic waste	1	4	4	4	4	4	4	1	1	1	1	1	1	1	1	1	1

and increase in sediment thickness.																	
7. Effects of artificial lights on ‘free-floating’ plankton communities.	1	1	1	1	1	2		1	1	1	1	1	1	1	1	2	1
8. Release of viable adult, juvenile and larval stages of exotic species.	1	1	1	1	1	1	1	2	2	2	2	2	1	1	1	1	1
9. Entanglement of seabirds and cetaceans in cages	1	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1

10. Accidental striking of seabirds and cetaceans by propellers	1	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1
11. Exclusion of other users from the area	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2
12. Dumping of marine litter such as plastics	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1	2	2
13. Risks of diving including decompression sickness (DCS), arterial air	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2

embolism and drowning.																	
14.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
15. Release of pharmaceutical or any medication during disease treatment.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
16. Fire, drowning, risks of ships grounding or sinking.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
17. Accidental oil and chemical spills.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
18. Tripping over loose objects	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2

on floors, stairs and platforms.																	

REFERENCES AND PEOPLE CONSULTED.

1. Almeida, A. P., Filgueiras, H., Braby, R., & Tiwari, M. (2014). Increasing evidence of leatherback migrations from Brazilian beaches to the West African coastline. *African Sea Turtle Newsl*, *1*, 9-14.
2. Amakali, A.M., Halajian, A., Wilhelm, M.R., Tjipute, M., Heckmann, R., Luus-Powell, W. (2022). Selected parasites of silver kob (*Argyrosomus inodorus*) (Actinopterygii: Sciaenidae) from northern Namibia. *South African Journal of Science*, 118 (1/2)
3. Beveridge, M.C.M.(1984). Cage and pen fish farming. Carrying capacity models and environmental impact. FAO Doc. Tech. Peches. No. 255. FAO, Rome, 126 pp.
4. Beveridge, M. (2004) *Cage aquaculture*. Blackwell Publishing, Oxford Black KD, Cook E
5. Bouwman L, Beusen A, Glibert PM, Overbeek C and others (2013) Mariculture:significant and expanding cause of coastal nutrient enrichment. Environ Res Lett 8: 044026 Braaten B (2007) Cage culture and environmental impacts. In:Bergheim A (ed) Aquacultural engineering and environment. Research Signpost, Kerala, p 49−91
6. Borg JA, Crosetti D, Massa F (eds) (2011) Site selection and carrying capacity in Mediterranean marine aquaculture: key issues. Draft Report GFCM: XXXV/2011/Dma.9. General Fisheries Commission for the Mediterranean, 35th Session, 9−14 May 2011, Rome, Italy. Available at http: //151.1.154.86/GfcmWebSite/GFCM/35/GFCM_ XXXV_2011_Dma.9.pdf (accessed 18 Aug. 2023)
7. Boyer, D. C., & Hampton, I. (2001). An overview of the living marine resources of Namibia. *African Journal of Marine Science,* 23, 5-35.
8. Carpenter, K. E. (1999). Field guide to the living marine resources of Namibia. Food & Agriculture Organization (FAO) of the United Nations
9. Chen, Y. S. (2000). Waste outputs and dispersion around marine fish cages and the implications for modelling.
10. Cunningham, P. L., & van Rooyen, J. (2020). First confirmed record of green turtle (Chelonia mydas) nesting along the Namibian coast. *Namibian Journal of Environment*, *4*, B-18.

11. Davidson, K., Miller, P., Wilding, T.A., Shutler, J., Bresnan, E., Kennington, K., Swan, S. (2009) A large and prolonged bloom of Karenia mikimotoi in Scottish waters in 2006. Harmful Algae 8: 349−361
12. Elwen, S., & Braby, R. J. (2015). Report on a turtle and cetacean assessment survey to the Kunene River mouth, northern Namibia–January 2014. *Afr Sea Turtle Newsl*, *4*, 22-27
13. Elwen, S. H., & Leeney, R. H. (2011). Interactions between leatherback turtles and killer whales in Namibian waters, including possible predation. *South African Journal of Wildlife Research-24-month delayed open access*, *41*(2), 205-209.
14. Gowen RJ. (1994). Managing eutrophication associated with aquaculture development. *Journal of Applied Ichthyology*, 10: 242-257.
15. Griffiths, M.H. (1996). Age and growth of South African silver kob*, Argyrosomus inodorus* (Sciaenidae), with evidence for separated stocks, based on otoliths. *South African Journal of Marine Science* ***17***, 37 – 48.
16. Griffiths, M. H. (1997). The life history and stock separation of silver kob, *Argyrosomus inodorus,* in South African waters. *Fishery Bulletin* ***65***, 40.
17. Griffiths, M.H. and Heemstra, P.C. (2000). A contribution to the taxonomy of the marine fish genus *Argyrosomus* (Perciformes: Sciaenidae), with the description of two new species from southern Africa. *Ichthyology Bulletin. J.L.B. Smith Institute of Ichthyol*ogy ***65***, 40.
18. Halajian, A., Smales, L., Heckmann, R., Amakali, A.M., Wilhelm, M. R., Tjipute, M., Luus-Powell, W. J. (2020). *Corynosoma australe* and *Bolbosoma vasculosum* (Polymorphidae: Acanthocephala) from *Arctocephalus pusillus pusillus* (Otariidae) and *Argyrosomus* spp. (Sciaenidae) from the Namibian Coast of Africa. *Journal of Comparative Parasitology,* 87 (1), pp. 1 – 8
19. Harrison WG, Perry T, Li WKW (2005) Ecosystem indicators of water quality, Part I. Plankton biomass, primary production and nutrient demand. In:Hargrave BT (ed) Environmental effects of marine finfish aquaculture. Handbook of environmental chemistry, Vol 5M. SpringerVerlag, Berlin, p 59−82
20. Heggberget, T. G., Hansen, L. P., & Næsje, T. F. (1988). Within-river spawning migration of Atlantic salmon (*Salmo salar*). *Canadian Journal of fisheries and Aquatic sciences*, 45(10), 1691-1698.

21. Iwanowicz DD. 2011. Overview on the effects of parasites on fish health. In *Proceedings of the Third Bilateral Conference between Russia and the United States. Bridging America and Russia with Shared Perspectives on Aquatic Animal Health*. 176-184.
22. Johnsen, E., & Kathena, J. (2012). A robust method for generating separate catch time-series for each of the hake species caught in the Namibian trawl fishery. *African Journal of Marine Science,* 34(1), 43-53.
23. Kibenge, F.S. (2019). Emerging viruses in aquaculture. *Journal of Current Opinions on Virology*, 34, pp. 97–103
24. Klakegg, Ø., Salonius, K., Nilsen, A., Fülberth, M., & Sørum, H. (2020). Enhanced growth and decreased mortality in Atlantic salmon (*Salmo salar*) after probiotic bath. *Journal of Applied Microbiology*, *129*(1), 146-160.
25. Krkošek, M. 2010. Host density thresholds and disease control for fisheries and aquaculture. *Journal of Aquaculture Environment Interaction*, 1, pp. 21–32
26. Ngupula GW, Kayanda R (2010) Benthic macrofauna community composition, abundance and distribution in the Tanzanian and Ugandan and offshore waters of Lake Victoria. *African Journal of Aquatic Sciences* 35(2):185–192
27. Ngupula GW, Ezekiel CN, Kimirei IA, Mboni E, Kashindye BB (2012) Physical and chemical characteristics of the Tanzanian inshore and offshore waters of Lake Victoria in 2005–2008. *African Journal of Aquatic Sciences* 37(3):339–345
28. Norrgård, J. R. (2011). Landlocked Atlantic salmon *Salmo salar* L. and trout *Salmo trutta* L. in the regulated River Klarälven, Sweden: implications for conservation and management (Doctoral dissertation, Karlstad University).
29. Nurliyana, M., Amal, M.N.A., Yasin, I.S., Saad, M.Z., Nashruddin, N.S., Al-saari, N., Mino, S., Sawabe, T. (2019). Viriosis in culture marine fish: a review. Journal of Aquaculture, 512, pp.
30. Masser M (2008) What is cage culture? SRAC publication No. 160
31. Pringle, B. A. , Duncan, M.I. , Winkler, A. C. , Mafwila, S. , Jagger, C. , McKeown, N.J. , Shaw, P.W. , Henriques, B. , Potts, W.M. (2023). Ocean warming favours a northern *Argyrosomus* species over its southern congener, whereas preliminary metabolic evidence suggests that hybridization may promote their adaptation.

32. Mast, R. Bailey L., Hutchinson B., Rowe, M. (2006). State of the World's Sea Turtles report: Burning Issues in Conservation. Vol:1. Washington DC. USA.
33. Ministry of Fisheries and Marine Resources. (2009*). Namibian Islands' Marine Protected Area.* Windhoek: MFMR.
34. Mirimin, L., Kerwath, S.E., Macey, B.M., Bester-van der Merwe, A.E., Lamberth, S.J., Bloomer, Roodt-Wilding, P. (2014). Identification of naturally occurring hybrids between two overexploited sciaenid species along the South African coast. *Journal of Molecular Phylogenetics and Evolution*, 76, 30 – 33
35. OIE. 2000a. International Aquatic Animal Health Code. 3nd edn. Office International des Epizooties, Paris, 153 p.
36. Petersen, S., Nel, D., & Omardien, A. (2007). Towards an Ecosystem Approach to Longline Fisheries in the Benguela: An assessment of impacts on seabirds.
37. Rivero-Wendt C.L., Miranda-Vilela A.L., Domingues A., Oliveira R., Monteiro S.M., Moura-Mello M.A.M., Matias R., Mortágua A.V.M., Grisolia C.K., (2020): Steroid androgen 17 alpha methyltestosterone used in fish farming induces biochemical alterations in zebrafish adults, *Journal of Environmental Science and Health,* Part A, DOI: 10.1080/10934529.2020.1790954
38. Roux, J. P., van der Lingen, C. D., Gibbons, M. J., Moroff, N. E., Shannon, L. J., Smith, A. D., & Cury, P. M. (2013). Jellyfication of marine ecosystems as a likely consequence of overfishing small pelagic fishes: lessons from the Benguela. *Bulletin of Marine Science*, *89*(1), 249-284.
39. Manuel Romero, Beira Aquaculture
40. Mr. Stephanus Hamutenya, Ministry of Fisheries and Marine Resources
41. Mr. Koos Blauw, Tetelestai Mariculture