Analysis of Marine Aquaculture Developments in Namibia:

Environmental, Economic and Legislative considerations

By

Johannes Angala Iitembu

A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science in International Fisheries Management

Norwegian College of Fishery Science

University of Tromsø, N-9037

Tromsø, Norway

Spring 2005

Abstract

This multidisciplinary analysis of Namibia marine aquaculture developments has found it to have a good potential. Existing Namibian aquaculture laws are comprehensive in nature controlling aspects such as water, land, public health, sanitation and disease, however they ignore fish welfare.

Mean temperature of Namibian marine coastal waters in the150 m water depth strata has averaged at 14.07 °C for the last eleven years (1993-2003). The marine waters in the central area of Namibian coastline are colder than the waters both northward and southward. Temperature decreased with water depth at a gradient of about 0.1°C/m in the 100 m water depth strata. Mean salinity averaged at 34.89‰ with low variation in the 100 m water depth column.

Species which are considered for aquaculture are ranked on the scale of one to ten according to their respective potentials based on both environmental and economic issues: Oysters *(Crassostrea gigas* and *Ostrea edulis)* are ranked at 9/10, Abalone *(Haliotis midae)* 8/10, Mussels *(Mytilus galloprovincialis)* 8/10, Rock lobster *(Jasus lalandii)* 7/10, Rainbow Trout *(Oncorhynchus mykiss)* 6/10, Hake *(Merluccius capensis)* with 5/10 and Cobia *(Rachycentron canadum*) 3/10.

Despite the fact that most of the species considered can live within temperature and salinity ranges of Namibian marine coastal waters at different latitudes and depths, their respective farming successes can be enhanced by research to investigate specie-specific conditions that promote their yields.

Economically farming of shellfish has better potential than finfish due its low production costs which is partly a result of adjacent nutrient rich Benguela ecosystem and promising investment returns as a result increasing shellfish product demands and prices.

Key words*:* Aquaculture, legislative framework, Environmental parameters, Fish biology, Fish Products and Markets, Aquaculture economics.

Table of Contents **Page**

List of Figures and Tables **Page**

Acknowledgments

My thanks and respect to the almighty. My sincere appreciation to my supervisors, Professor Hans Christian Eilertsen, Professor Ola Flåten and Professor Peter Ørebech for putting up with my frequent enquiries and their respective inputs which significantly enhanced this thesis.

My sincere gratitude to the Norwegian Government for financing my study through Quota Scholarship Programme and the Namibian Ministry of Fishery and Marine resources for providing me with data.

I am also indebted the Norwegian College of Fishery Science (NFH)'s students and staff for providing me with a good and world-class working environment.

Many thanks to Martin Parry of Rothamsted Research Institute (Harpenden, England) and Paul Dove of a development team of Bedfordshire County (Bedford, England) for proof reading this paper during II MARISCO research cruise to the Barents sea and Ice edge with "Jan Mayen" (May 2005).

To my parents Petrus Iitembu and Anna-Lisa Iitembu, no words can describe how much I appreciate your encouragements and for being patient.

To my small sister Aina Mpingana, you still have a lot to learn and I won't mind if you give me a chance to be your teacher.

To all people of all walk of life (no names mentioned, no names forgotten) whom, without their help, this thesis could not have been done, I thank you.

Johannes Angala

May 2005

1.1 Introduction

The demand for high quality fish and shellfish products has increased over the last century, both as a result of shifts in consumer preferences as well as a growing world population. Inherent in this is also an increased awareness of healthy food, i.e. in recent years consumers focusing on a low calorie diet and polyunsaturated fatty acids. Global fish production from fisheries peaked with 90 million tonnes in the early 1990s (FAO 1999). About two-thirds of this is used for human consumption with the remaining catch employed as fish meal or fish oils in various industrial applications, inclusive of feed for the agriculture and aquaculture sectors (Noakes *et al*. 2003). Attempts have been made to predict the future capacity of the global food production system due to increasing pressures on natural resources and possible declines in stocks due to increasing environmental stress (Doos and Shaw 1999). The predicted increased regional and global demands for fish and fishery products will fall short of wild fishery. Such demands may be met by aquacultured products, but most aquacultured fisheries are fed by wild fish.
Recently ecologists and economists have , in order to assist development of future aquaculture (Jin et al. 2003), started to recognize the value of multidisciplinary studies including all aspects of aquaculture, i.e. environmental premises, biological aspects and social subjects.
Aquaculture as commonly defined is the farming of aquatic organisms, i.e. aquatic plants, crustaceans, molluscs and fish. The emergence of intensive aquaculture has changed the fish and seafood industry over the last twenty years. Whilst the output from fisheries has stagnated, the total production of fish continues to rise due to aquaculture (Hannesson 2003). With an 11% increase in fish production per annum over the past decade it is the fastest growing sector of the world food economy.
Aquaculture employ sets of techniques that involve the cultivation of hundreds of varieties of fish, shellfish, and aquatic plants. The four main aquaculture techniques are pond, cage, raceway, and recirculation systems, each further categorized by its production output, i.e. extensive and intensive.
Aquaculture provided 20 percent of global fish production (and 29 percent of food fish) in 1996. Most aquaculture production (15.1 million tonnes) originated in freshwater (Fig.1).
Of the remainder, 9.7 million tones were produced in marine environments and about 1.6 million tonnes in brackish water environments. These figures are not inclusive of the production of aquatic plants which amounted to 7.7 million tonnes in 1996 (FAO 1998).

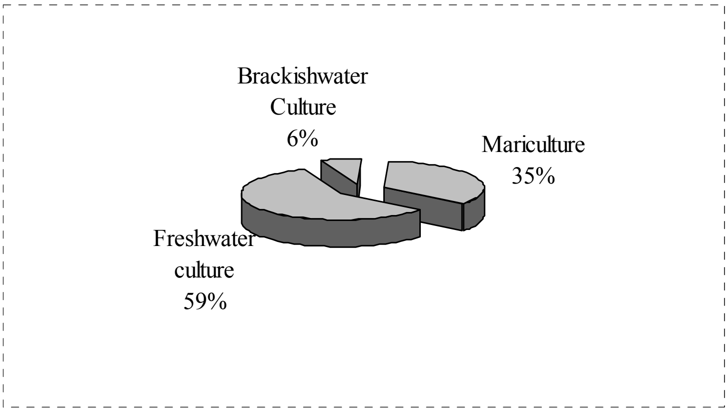


Figure 1: Global aquaculture production by Environment type (Data Source: FAO 2000)

Production is dominated by Asian countries (Fig 2), in particular China that reported increases of 0.7 million tonnes per year until 1992 and 2.6 millions tonnes for the following years. For the rest of the world, combined growth in production has averaged 0.4 million tonnes per year. Within the last decade, Low-Income Food-Deficit Countries (LIFDCs) , excluding China, have shown an overall upward trend in production and, in terms of quantity, the increase has kept pace with that reported in non-LIFDCs (FAO 2000).

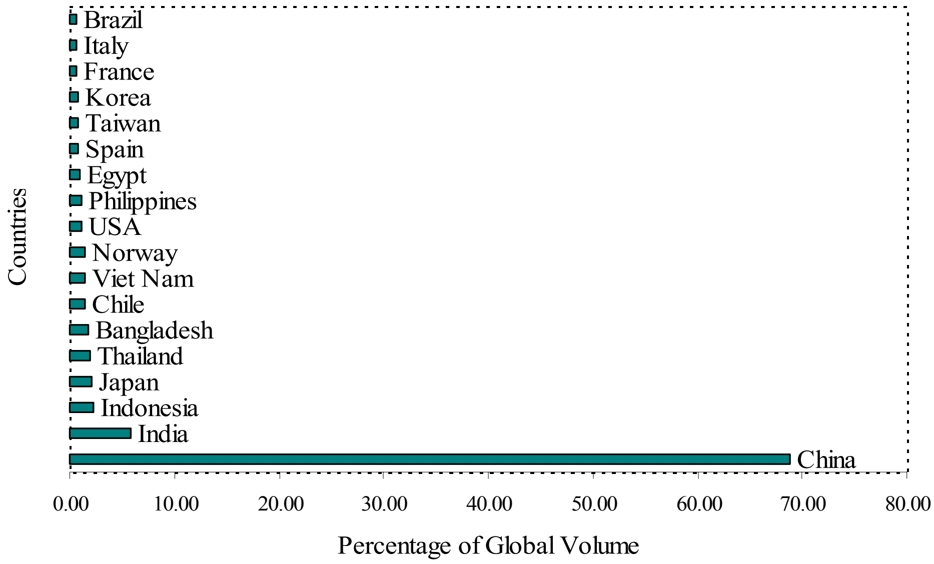


Figure 2: Contribution to global aquaculture production in volume of selected countries based on 2001 figures (Top 18). (Data Source: Brugère and Ridler 2004)

A total of 210 different farmed aquatic animal and plant species were reported in 2000, i.e. 131 finfish species, 42 molluscan species, 27 crustacean species, eight plant species and two amphibian and reptile species (Tacon 2004).

The production by value is led by Cyprinids, while Catfish and Milkfish have the lowest production contribution by value (Fig.3). Production by volume is also led by cyprinids with eels having the lowest production volume (Fig.4). It must also be pointed out that reported production by value and volume could be considerably higher, as over 21.2% of global aquaculture production was not reported to species level in 2000 (Tacon 2004). For example, at present China provides no statistical information to FAO concerning production of marine finfish resolved to species.

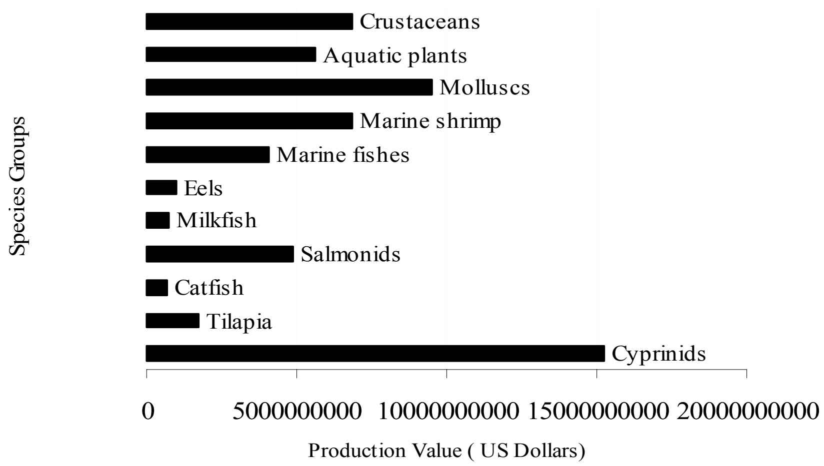


Figure 3: The production figures of species groups by value cultivated in 2000 *(Data source: Tacon 2004)*

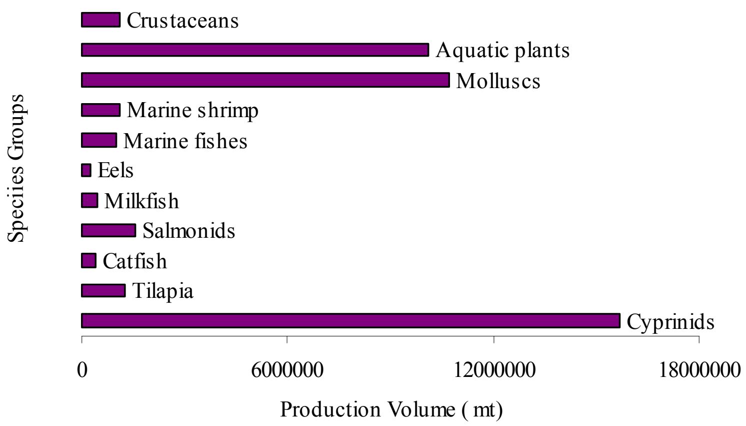


Figure 4: The production figures of species groups by volume cultivated in 2000 (Data Source: Tacon 2004)

1.2 Aquaculture in Africa

Although tilapia may have been cultured in Egypt as long as 2500 years ago, there is little tradition of fish culture in most African countries. This is maybe due to political and socioeconomic constraints resulting in an aquaculture sector that makes only a small contribution to food security and economic development (Brummett and Williams 2000 and references therein). Aquaculture in Africa accounts for less that 2% of total domestic fish production although its contribution has expanded significantly from 50 000 Mt in 1985 to 85 000 Mt in 1990 (Chimatiro 1998). Of the 20 major species cultured, only Nile Tilapia, Africa Catfish and common carp are farmed throughout Africa. The leading fish culture areas are Cote d'Ivoire, Egypt, Kenya, Nigeria, South Africa, Tunisia and Zambia and accounted for more than 95% of Africa production in 1990. In the Southern Africa Development Community countries (SADC) extensive and small scale fish farming has expanded in Malawi, Mozambique, Tanzania and Zimbabwe, while Oysters and seaweed are produced on a modest scale in Namibia. In South Africa aquaculture development is said to be market driven, and production has increased 663 % between 1982 and 1992, making it the country with the fastest growth in aquaculture (Hecht 1994). Hence African aquaculture is still in its infancy. According to Brummett and Williams (2000) this is due to the lack of a tradition of fish and water husbandry, numerous social and political constraints that limit investment and retard expansion, plus the fact that only in recent years some countries have developed appropriate development models to foster its growth i.e. Namibia (Focus on Fishery and Development Newsletter, July 2004) Economic constrains like high input costs, feed costs, and credit costs play a major role in limiting aquaculture expansion, but the main constraints are probably linked to the countries' instability as a commercially-oriented aquaculture requires environments conducive to investment.

While still small, African aquaculture production has now entered a steady phase of expansion since reported production of 121905 tons in 1997 is more than three times the level of 36685 tons reported by the Food and Agriculture Organization of the United Nations (FAO) in 1984. African aquaculture's contribution to total fish intake is still very low and at ca. 1.3% per capita consumption of food fish has stagnated over the last three decades suggesting that only under the most favorable circumstances (i.e. rapid global aquaculture expansion) will it increase. This has clear implications for food security because of the importance of fish as a source of animal protein in some African countries (Ye 1999).

However, driven by a desire to maintain (if not increase) per capita fish consumption, a population that could increase by 50 percent to 1.2 billion by 2020, and accelerated urbanization, demand for fish food is projected to more than double in both North Africa and sub-Sahara Africa by 2030 (Ye 1999).

Cheap labour costs, the increasing demand for fish in Africa, the real achievements to date and the results of studies of market and natural resource potential also indicate that aquaculture still has great potential to contribute to food security, rural development and economic growth in Africa.

1.3 Aquaculture in Namibia

Aquaculture is in fact very young in Namibia, starting in the 1980s with the introduction of carp and subsequently a number of other exotic species for stocking of cattle dams and state water dams. Freshwater aquaculture is dominated by Catfish (*Clarias gariepinus*) and Tilapia species (*Oreochromis niluticus and O. mossambicus*).

Up to the mid 1980s aquaculture production was very small, but from 1985 onwards the private sector became more involved in commercial farming, especially of marine species.

Currently the commercial marine aquaculture is dominated by oyster production in Walvis Bay, Swakopmund and Luderitz (Pacific oyster, *Crossostrea gigas* and European oyster, *Ostrea edulis*). Production in 2002 was reported to be around 6 million oysters (ca. 600 tonnes) per annum, worth about N$6 million, with 70% of the current production exported to South Africa. Mussels (*Mytilus galloprovincialis*) are also cultured around Luderitz. The Seaweed (*Gracilaria verricosa*) which is used for agar production is also grown by one company in Luderitz lagoon with an annual production of around 110 tones of dry-weight.

It is well know that much of the cost of aquaculture is associated with feed requirements. In salmonid and Asian shrimp production this was found to account to more than 50% of total production costs (New *et al.* 1993). Namibia here potentially enjoys a competitive advantage because of its established capture fishery fed by the nutrient rich (primary production) Benquela ecosystem. The Government of the republic of Namibia has identified aquaculture as a priority development. Both Namibia's VISION 2030 and National Development Plan (NDP2) documents prioritize aquaculture development (Focus on Fishery and Development Newsletter, July 2004).

In May 2004, the ministry of Fishery and Marine resources produced an Aquaculture Strategic Plan which set forth short term development priorities, which builds on the existing the Aquaculture policy, the aquaculture Act and Regulations.
While acknowledging the challenges the Namibia aquaculture sector may face in coming years to expand its production this study is carried out with the main objective of contributing to making aquaculture planning based on common understandings of current issues, long-term trends and emerging issues in addition to providing insights into its environmental, economic and legislative implications.

The specific objectives of the present study are:

I. To describe the legislations in place under which licensing requirements and acceptable operational requirements are regulated in Namibia
II. To describe Namibia's physical oceanographical feasibilities and to relate them to the biology of fish species considered as having a farming potential in Namibia
III. To describe the market trends of the species considered for aquaculture in Namibia and in addition apply a theoretical harvesting/Investment model to an oyster species (*Crassotrea gigas*).

2.1 Legislative framework

Regulatory frameworks are important for the aquaculture industry to operate under circumstances, which gives at all times predictable and stable working conditions. Side by side with the growth within the industry, there has always been a goal to develop a suitable and appropriate regulatory framework.

The Namibian laws and regulations discussed in this study have been passed by the parliament and published in term of Article 56 of Namibia constitution as Aquaculture act, No.18 of 2002. Considering the current status of Aquaculture in Namibia, recognizing its potential and convinced of the importance of marine aquaculture development to the Namibia economy, this section aim at having a look at laws in place under which licensing requirements and acceptable operational requirements are regulated in Namibia.

2.2 Competent Authorities

The Namibia Ministry of Fisheries and Marine resources is the main ministry under which the industry will be monitored and regulated. Exception is found in application for license under section 12 of the Act[1], which states that after receipt of an application under subsection (1), the Minister must, with the concurrence of the Minister responsible for environment and in accordance with such legislation or policy dealing with environmental assessments determine whether the applicant is required to submit an environmental assessment of the proposed aquaculture project.

Another exception is when the presence of any diseases or harmful organisms in an aquaculture is reported to the ministry , under section 25 (2) of the Act, The Permanent Secretary may seek advice from the Minister responsible for public health , before taking necessary steps like isolation, quarantine or treatment of aquatic organism infected. Under Section 26(2), it is also states that where any area in Namibia water in which aquaculture is conducted is affected by pollution or natural phenomenon which may have a harmful or detrimental effect on the aquatic environment or any aquaculture product, the Minister may also seek advice from the Minister responsible for public health, to find out whether the aquaculture products farmed therein are fit for human consumption.

[1] Namibian Aquaculture act, No.18 of 2002

Under the same section the Minister of Fishery and Marine Resources may also seek advice from the Minister responsible for trade in order to prevent the sale or marketing of aquaculture products that are found to be unfit for human consumption.

It is stated in the Act that in determining the general policy to be applied in a particular area, the Minister must consult with the regional council and any local authority council or traditional authority in that area.

Therefore Local Authorities Act, 1992 (Act No. 23 of 1992), the Regional Councils Act, 1992 (Act No. 22 of 1992) and Traditional Authorities Act, 2000 (Act No. 25 of 2000) will regulate any aquaculture practice in their respective jurisdictions, in addition to the Territorial Sea and Exclusive Economic Zone of Namibia Act, 1990 (Act No. 3 of 1990) and section 1 of the Water Act, 1956 (Act No. 54 of 1956).

Public Service Act, 1995 (Act No. 13 of 1995) will be consulted when the Minister designate any staff member in the Ministry as an inspector for the purposes of this Act ,while articles seized under section 37, the provisions of Criminal Procedure Act, 1977 (Act No. 51 of 1977) shall apply to such seizure.

The Minister of Fishery and Marine Resources may declare any area of Namibia or Namibian water, including sub-aquatic lands, as an aquaculture development zone, determine the location and extent, and define the physical boundaries of an aquaculture development zone. The above is done in consultation with consult with the advisory council and any Ministry having jurisdiction in the proposed aquaculture development zone.

2.3 Licensing system

Aquaculture under these regulations is defined as the farming and ranching of aquatic organisms and a license will be required for any zone or area in Namibia, including water and land, created for the primary purpose of aquaculture and/or in which specific measures are taken to encourage the development of aquaculture. Aquaculture facility includes any equipment, construction or site in which aquaculture is conducted where aquatic organisms or part thereof, whether alive or dead, are being, or have been farmed or which are being, or have been ranched. The license covers organisms to be farmed or being farmed which include live forms of fauna and flora that exist in water, excluding mammals, birds, amphibians and reptiles, except for those amphibians and reptiles declared to be aquatic organisms.

Geographically the license requirements cover the inland waters of Namibia as well as the internal waters and territorial sea, as defined in the Territorial Sea and Exclusive Economic Zone of Namibia Act, 1990 (Act No. 3 of 1990) and includes the seabed up to the high water mark and further includes private water as defined under section 1 of the Water Act, 1956 (Act No. 54 of 1956).

Any body foreign or Namibian can apply for an aquaculture license as long as the individual, cooperative, business, partnership or company provide its details or statement of association or membership, its address, the type of planned aquaculture that is whether it is freshwater or marine and if marine whether it is shore based, non-shore based or sea ranching .

The location, size and description of the proposed site should also be specified in addition to the sources of the stock of the species to be farmed. The intended maximum annual production in quantity and weight per year should also be provided and if the effluent from the farm is to be discharged in Namibia water its annual quantity and composition should be indicated.

The licenses are granted by the minister of fishery and marine resources .Under section 15 the Minister may, after consulting the advisory council, by notice in the government gazette determine any fees which are payable in respect of licenses, under section 43 prescribe the duration of any license and the conditions which are applicable to the renewal of any such license.

An application for a license as according to under section 12 of the Act, (1) must be made to the Minister in the prescribed manner and form and are accompanied by such documents and information as the Minister may require.

When considering an application submitted the Minister may have regard to

- The technical and financial ability of the applicant to exercise the rights sought in the application in a satisfactory manner;
- The species of aquatic organisms that the applicant proposes to farm and the method of aquaculture that the applicant proposes to employ;
- Any other matters applicable to the license those, in the opinion of the Minister, are relevant.

Licenses are only granted if the Minister is fully satisfied that the applicant has obtained any authorization, permit or approval which may be required under the laws relating to land or water use and where an environmental assessment is required under section 12(2), an environmental clearance for the project has been issued in accordance with the relevant laws.

The license will then be granted provided 1) that no representations or objections received ,2) that a license will not create a significant risk of pollution or otherwise adversely affect the environment, and 3) that the site in respect of which a license is sought is suited for aquaculture or for the type of aquaculture planned, having regard to its general characteristics, traffic requirements, or the risk of conflict with other activities being undertaken or proposed in the vicinity of the proposed site.

2.4 Content of Licenses

A license will only be issued for the site defined in the license and specify the species of aquatic organisms that to be farmed and harvested at the site. Conditions may be attached to the license related to

- the quantities of aquatic organisms which may be introduced and retained at the site;
- the structures and equipment which may be used and the maintenance practices to be followed at the site
- water quality
- the composition of the feed which may be used
- the types of manures or fertilizers which may be used
- the use of hormones for controlling reproduction or promoting growth
- the use of any drugs, antibiotics or other chemicals
- the disposal of dead or diseased aquaculture products, material or waste resulting from aquaculture
- the keeping of records
- the duration of the license and
- Such other conditions as the Minister may consider appropriate.

The licensee has an exclusive right to farm and harvest aquaculture products within the site defined in the license, while where a license is issued for sea ranching purposes, it confers upon the licensee an exclusive right to release and harvest aquaculture products within the site defined in the license

A license issued under this Act is not transferable except with the prior written approval of the Minister. All aquaculture products of the species specified in a license are, while contained within the boundaries of the site, the exclusive property of the licensee until sold, traded, transferred or otherwise disposed of by the licensee.

All aquaculture products which are released or which escape into the natural environment remain the exclusive property of the licensee as long as the licensee can prove their identity.

2.5 Renewal, Suspension and Cancellation of License

Under section 18 of the act the License may be renewed subject to any conditions the Minister considers appropriate, but it can also be refused should the licensee fail to comply with any condition of the license and has failed to remedy such non-compliance within a reasonable period. Under the same conditions stated in section, 18, 19, the Minister may also suspend and/or cancel the license. .

Where the Minister refuses to grant a license to an applicant under section 13 or refuses to renew a license under section 18 or suspends or cancels a license under section 19, the Minister will in writing notify the licensee of the decision and the reasons for the decision.

The Minister may also by written notice require a licensee, a former licensee or any other person who ceases to carry on aquaculture to remove any aquaculture facility or part thereof and to restore the site to the standard specified in the notice or, if no standard is specified, to a condition acceptable to the Minister within the period specified in the notice.

2.6 Management and Control Measures

According to the Aquaculture act, any licensee or other person engaged in aquaculture shall immediately report to the Permanent Secretary or an inspector the presence of any disease or harmful organism in an aquaculture facility.

Water quality monitoring system will be established and maintained to provide timely information to licensees of the occurrence or imminent occurrence of any pollution or natural phenomenon which may have a harmful or detrimental effect on the aquatic environment or any aquaculture product.

Under these regulations a written permission from the Minister will be needed for introduction or cause to introduce into Namibia or any Namibian waters any species of aquatic organism or any genetically modified aquatic organism and Transfer of any species of aquatic organisms from one aquaculture facility in Namibia to another or from any location in Namibia to another. Importing and exporting of live aquatic organisms and removal or transportation, for marketing purposes, from any site or sell, display or offer will also require a written permission from the Minister.

2.7 Concluding Remarks

There are large differences between countries in the sophistication and complexity of their regulation, control and monitoring procedures. I found the Namibian legal and regulatory framework as to have been developed to international requirements as well as national needs.
It is multi-purpose in function and capable of broad application as it impinges on the regulation of matters such as water, land, public health, sanitation and animal health and disease.
However aquaculture is considered to be a segment of agriculture and, like terrestrial animal agriculture, is also subject to social attitudes that impact regulations, marketing and product acceptance. Therefore aquaculture practices must be examined to consider fish welfare the area where the Namibia regulations seems to have not properly covered but this is understandably interlinked to the fact that scientific debate still exists as to whether fish have the neural capability for awareness, fear and pain.
Another omission concerns the question of whether farmers are liable to catching run-away fish in case of technical breakdown to the equipment which needs to be explicitly covered.

3.1 The physical oceanographic feasibilities in Namibia

The waters off Namibia (Fig. 5) are influenced by the Benguela current, which is the eastern South Atlantic boundary current. The Benguela Current is a cold-water system bounded by two warm-water regimes, which makes it unique amongst the worlds upwelling systems (Shannon 1985).

The cold and plant nutrient-rich Benguela current flows along the Atlantic coastlines of South Africa, Namibia and Angola, supporting a vast marine ecosystem due to its high primary production and short food chains making it one of the most biologically productive regions of the World Oceans (Emeis *et al.*2004). The current is driven by the south-east trade wind (SET), this wind system as according to Feistel *et al*.2003, results from gradients in air pressure between the South Atlantic Anticyclone (SAA), which dominates the weather regime between about 15° and 35° S from the Namibian coast in the east to the Brazilian coast in the west, and low pressure of the Intertropical Convergence Zone (ITCZ) in the north and those between the South Atlantic Anticyclone (SAA) and the Angola–Kalahari Low in the east.

Changes in position and intensity of these atmospheric centers cause the variability in the south-east trade wind (SET) at different scales of space and time (Feistel *et al.*2003).

Besides upwelling, the most dominant oceanographic process in the Benquela current area , other important features (Figure 1) are the leakage of warm Angola Current (AC) water from the north (West *et al* 2003), hydrogen sulphide eruption and red tides.

The current is divided into two distinctive areas by the most active upwelling cell around Lüderitz (Boyd and Agenbag, 1985; Shannon, 1985). The southern border is at Cape Point, but sporadically it stretches farther south at Cape Agulhas, 35°S (Shannon, 1985).

The Northern region that is in contact with Namibian waters is characterized by an intense upwelling throughout most of the year (Boyd and Agenbag, 1985). Off Namibia, upwelling is particularly strong during the cooler months, which reinforces the seasonal effect and causes a very definite temperature cycle (Gordoa *et al.,* 2000). Furthermore, as according to Shannon *et al*.1987, seasonal warming of central and northern Namibian waters occurs during late summer and early autumn caused by the intrusion of warm saline water of equatorial origin. The influence of the upwelling regime may be between 150 and 200 km wide on average, but the filamentous mixing area may extend up to 625 km offshore (Campillo-Campbell and Gordoa, 2004).

According to Weeks *et al.*2004, planktonic grazing organisms (herbivorous copepods, etc.) do not maintain large populations near the upwelling zone. This is because of high primary production and associated harmful algal blooms which, sometimes produce red tide accumulations, may inhibit grazing by zooplankton. This results in enormous numbers of phytoplankton cells sinking unutilized to the sea floor, causing large amounts of unoxidized organic matter on the continental shelf and the existence of extensive areas of sea floor hypoxia and at times total anoxia below where poisonous hydrogen sulphide and methane gas are generated within the diatom mud.

It has been recently established that it is possible to identify sulphide outbreaks by satellite remote sensing (Weeks *et al.*2004), there results refuted the conventional belief that eruptions of toxic hydrogen sulphide are isolated near-coastal features, limited both in extent and in ecosystem-scale consequences.

It has also pointed to potential ecological importance of this phenomena to the northern Benguela current marine ecosystem in that Weeks *et al.*2004 concluded with the suggestion that hydrogen sulphide emissions can be held more responsible for hypoxic conditions along the Namibian coast than hypoxic water of Angolan origin and that they may be a major factor in the functional separation of the Benguela current into northern and southern subsystems.

Hydrographically, the region can be separated in the Northern Benguela Region (NBR), north of 28°S, where the upwelling is perennial and the Southern Benguela Region (SBR) with a seasonal upwelling in spring and summer (Lutjeharms and Meeuwis, 1987).

The physical and biological characteristics of northern Benguela ecosystem have been relatively well studied during the past three decade by among others Shannon. 1985; Boyd and Agenbag.1985 ; Payne *et al.* 1987; Stuttaford, 1997; Gordoa *et al*. 2000; Feistel *et al*.2003 ; Emeis et al.2004; Campillo-Campbell and Gordoa. 2004, but less has been done in relation to marine fish farming, which is still is in its infancy in Namibia.

It is however widely known that the farming of marine fish is influenced by a number of environmental factors like salinity, temperature, food availability etc, which are crucial for the effective rearing of the species. Each species has a defined range of the environmental parameters under which it can successfully breed and be reared.

Therefore this section is an attempt to generally look at the most important environmental parameters (Temperature and salinity) in relation to the species that are considered for Aquaculture in Namibia

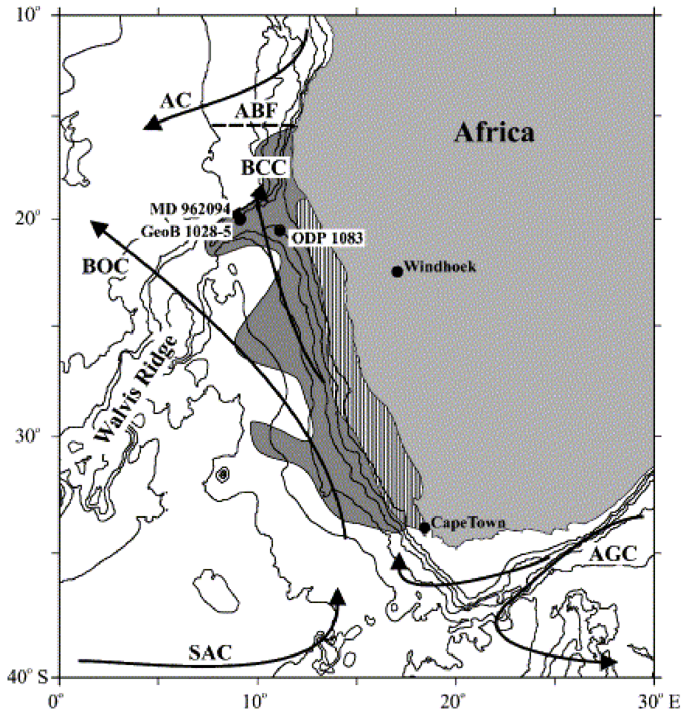


Figure 5: Overview of surface currents in the SE Atlantic Ocean and core positions. AC=Angola Current, ABF=Angola-Benguela Front, BOC=Benguela Oceanic Current, BCC=Benguela Coastal Current, SAC=South Atlantic Current, AGC=Agulhas Current. Striped AREA=coastal upwelling, shaded AREA=filaments of upwelled water. Taken from West *et al.* (2004)

3.2 Methods

The data used are unpublished and were kindly supplied to me by the Namibia Ministry of Fisheries and Marine Resources as collected by its National Marine Information Research Centre (NatMIRC, Swakopmund, Namibia) and Institute of Marine Research (IMR, Bergen, Norway) in the Namibian Waters. Data were received from NatMIRC (Swakopmund, August 2004) in text format. They were verified for logical consistency and analyzed with STATISTICA software at Norwegian College of Fishery Science, University of Tromso, Norway (Tromso, December 2004-February 2005).

The environment in this area of analysis has been monitored by the Namibia's Ministry of Fisheries and Marine Resources since its inception in 1990.

The time period of this study is from 1993 to 2003, and the area of analysis stretches from latitude 14°S to 27°S and longitude 10°E to 17°E (Fig.6).

The data sets used comprises date, time, sampling position, depths, temperature (°C) and salinity (ppt) from 5069 stations, covering 0 to 1000 m depth.

Data on the species under analysis in this study, namely Hake *(Merluccius capensis),* Cobia *(Rachycentron canadum),* Rainbow trout *(Oncornhynchus mykiss),* Rock lobster (*Jasus lalandii)*, Abalone *(Haliotis midae),* Oyster (*Crassotrea gigas* and *Ostrea edulis*), and Mussel (*Mytilus galloprovincialis)*, were collected from publications (see discussion). Most of these species were identified in Namibia's Aquaculture Strategic Plan of May 2004 as having a marine aquaculture potential and some species like oysters , abalone and mussels are either already being farmed or under trials by several companies in Namibia.

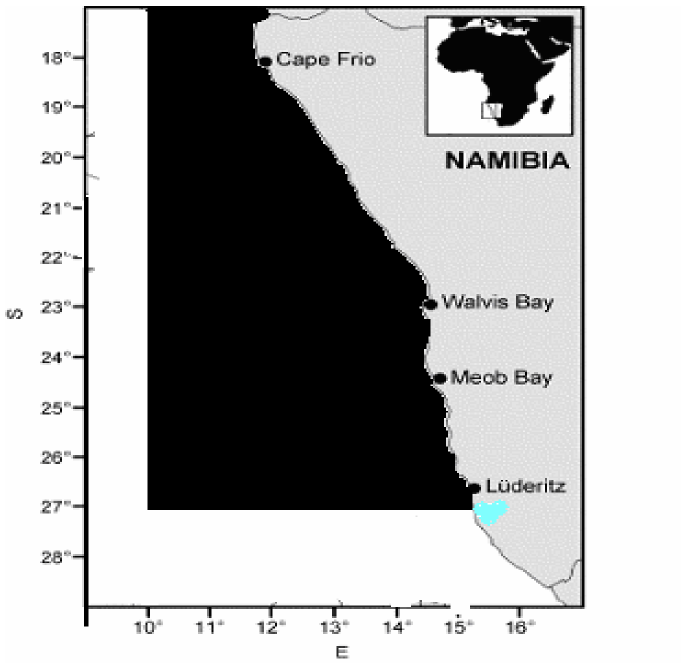


Figure 6: Map of Namibia showing the area under the analysis (shaded in black) as it stretches from latitude 14°S to 27°S and longitude 10°E to 17°E.

3.3 Results

3.3.1 Temperature

Mean temperature of Namibian marine coastal waters in the150 m water depth strata has averaged at 14.07 ^{o}C for the last eleven years (1993-2003) as calculated from 1 146 454 measurements taken at 5069 stations in the area limited by latitudes 14^{o}S to 27^{o}S and longitudes 10°E to 17°E.

The area within latitude of 21^{o}-24^{o} show colder waters at almost all depth as compared to 21^{o} - 14^{o} north and 24^{o}-27^{o} south with a difference of about 1 ^{o}C. This indicates the presence of colder marine waters in the central area of Namibian coastline and warmer waters both northward and southward (Table 1).

The same trends of colder waters in the central part is also demonstrated by the annual mean temperature vs. years with the exceptions of the year 1994, 1997, 1999 and 2003 years where there was a presence of warmer water in the central area (Table 2).

There is a decrease in temperature with respect to water depth with a gradient of about 0.1^{o}C/m in the 100 m water depth column (Table 3) while seasonal water temperature range form 17.4^{o}C in summer to 14.7^{o}C in winter (Table 4).

Annual mean temperature of 75% of the measurements taken varied between 13.3 ^{o}C and 14.4^{o}C while annual mean temperature of 25% of the measurements taken varied between 9.3 ^{o}C and 12.2 ^{o}C (Table 4).

Table 1: Means, maximum and minimum temperatures (^{o}C**)** for entire period 1993-2003 in Namibian waters for depth strata 0 - 150 m vs. latitude

	14^{o} – 21^{o}			**21^{o}-24^{o}**			**24^{o}-27^{o}**		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
0-20 m	22.57	11.15	16.57	22.55	11.09	15.99	22.97	11.79	16.68
20-40 m	21.80	10.80	15.23	21.82	10.79	15.23	21.79	10.99	15.33
40-100 m	19.30	10.30	13.87	19.35	11.30	13.97	19.76	11.34	13.88
100-150 m	15.99	10.98	12.99	15.08	10.77	12.43	15.08	10.77	12.43

Table 2: Annual mean temperatures vs. year and latitude in Namibia waters (0 - 150 m) (- =missing data)

	14° – 21°	**21°-24°**	**24°-27°**
1993	11.02	11.09	14.94
1994	13.96	14.67	13.15
1995	14.40	13.80	15.26
1996	14.09	13.52	15.11
1997	13.57	15.15	14.53
1998	14.04	13.87	14.97
1999	14.21	15.45	14.87
2000	14.47	13.90	15.66
2001	-	13.31	-
2002	13.58	13.73	-
2003	14.01	14.78	13.89

Table 3: Annual mean temperatures vs. year and depth (metres) in Namibia waters (0-100m)

	0-20 m	**20-40 m**	**40-100 m**
1993	16.52	12.21	11.87
1994	16.28	15.77	14.69
1995	16.17	15.95	14.91
1996	16.34	15.74	14.64
1997	15.36	14.97	14.16
1998	16.02	15.64	14.72
1999	16.40	15.78	14.63
2000	17.68	17.10	15.68
2001	13.89	13.51	13.31
2002	14.94	14.51	13.74
2003	15.03	14.68	14.02

Table 4: Seasonal temperature variations in Namibia waters form 0 - 100 m (summer = October to May; winter = June to September), in addition annual mean and the temperature values under which 25% and 75% of the measurement fall are also computed.

Year	Summer			Winter			75%	25%
	Maximum	Mean	Minimum	Maximum	Mean	Minimum		
1993	23.4	17.2	8.5	18.4	14.4	7.6	14.2	10.8
1994	25.6	16.3	7.9	19.9	13.3	4.3	14.1	11.2
1995	23.3	16.4	8.3	17.9	13.9	9.2	13.9	10.3
1996	25.01	15.9	9.1	19.7	13.5	7.3	13.9	10.6
1997	22.9	17.3	8.9	16.8	14.9	7.9	13.6	10.1
1998	24.2	16.9	9.8	19.3	13.2	8.1	13.9	10.2
1999	22.4	16.3	7.7	16.9	13.9	8.3	13.6	9.3
2000	25.3	17.4	7.5	16.4	13.2	6.2	14.4	10.3
2001	20.5	17.9	9.3	16.2	14.7	8.4	14.1	12.2
2002	22.3	17.1	9.6	15.6	13.5	8.1	13.3	11.2
2003	23.9	16.7	7.6	18.7	13.6	7.5	14.0	11.6

3.3.2 Salinity

Mean salinity in Namibian coastal waters, irrespective of depth and latitude has averaged at 34.89‰ as calculated from 1 146 454 measurement taken from 5069 stations in the area limited by latitude 14°S to 27°S and longitude 10°E to 17°E.

The variation in the 100 m water depth column is low at 34.98 ‰ to 35.2 ‰.

At depth range from 100 metres to 200 metres means salinity varied between 34.27 ‰ and 36.27‰ with the eleven years average salinity of 35.14 ‰.

3.3.3 Biology of Species

3.3.3.1 Hake

Merluccius capensis (Castelnau, 1861) is of family Merlucciidae, subfamily Merlucciinae, order Gadiformes (cods), class Actinopterygii (ray-finned fishes) and commonly known as Shallow-water or Cape hake (Fig.7).

It is bathydemersal and oceanodromous specie which lives in marine environments at depth ranges of 50 – 1000 m. It has a minimum population doubling time of 4.5 - 14 years and it grows to a maximum length of 140 cm.

It is found on the continental shelf and slope to depths over 1,000 (Bianchi *et al.*1993) living at an average temperature of 16.0°C (Pauly, 1989). Juveniles of about 64 cm feed on small crustaceans and small deep-sea fishes such as lantern fishes, whereas larger individuals feed chiefly on small hakes and jack mackerel (Cohen *et al.*1990) and cannibalism is common (Bianchi *et al.*1993). It migrates southward in the spring and northward in autumn (Cohen *et al.*1990), while it breeds throughout the year, peaks of reproductive activity in August and September. This species is native in Southeast Atlantic and western Indian Ocean (FAO)

Figure 7: Illustration of Cape or Shallow water Hake (*Merluccius capensis*) (FAO)

3.3.3.2 Cobia

Rachycentron canadum (Linnaeus, 1766) is of the family Rachycentridae, order Perciformes (perch-likes) class Actinopterygii (ray-finned fishes), commonly known as Cobia (Fig.8). It is a marine and oceanodromous specie which live in reef-associated and brackish environment at depth range of 0 - 1200 m with average temperature of 23.33 °C. It has a Medium minimum population doubling time of 1.4 - 4.4 years. It grows to a maximum length of 200 cm and maximum weight of 68.0 kg. It occurs in a variety of habitats, over mud, sand and gravel bottoms; over coral reefs, off rocky shores (Collette, 1999) and in mangrove; inshore around pilings and buoys, and offshore around drifting and stationary objects; occasionally in estuaries

(Shaffer and Nakamura, 1989). It forms small groups and may pursue small pelagic inshore (Kuiter and Tonozuka, 2001).

It feeds on crabs, fishes, and squids (Fischer *et al* 1990) and it also feed on spawns during the warm months in the western Atlantic especially their eggs and planktonic larvae (Shaffer and Nakamura, 1989). It is mostly caught in small quantities due to its solitary behaviour. This species can be found in parts of Atlantic, Indian and pacific oceans of which it native.

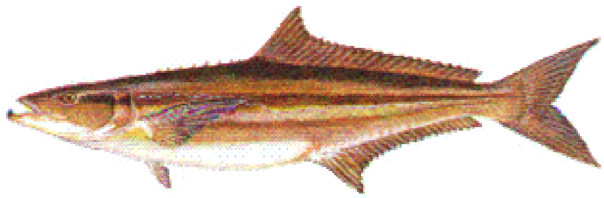


Figure 8: Illustration of Cobia (*Rachycentron canadum*)

3.3.3.3 Rainbow trout

Oncorhynchus mykiss (Walbaum, 1792) is of family Salmonidae (Salmonids), subfamily: Salmoninae, order Salmoniformes (salmons), class Actinopterygii (ray-finned fishes) and commonly known as Rainbow trout (Fig. 9). It is a marine, bathypelagic and anadromous species which live in freshwater and brackish environment at depth range of 0 - 200 m.

It has a medium minimum doubling time of 1.4 - 4.4 years and it grows to a maximum size 120 cm, maximum weight 25.4 kg.

The natural habitat of this specie is fresh water with temperature range of 10 - 24^{o}C. It is unclear whether its anadromy is a truly genetic adaptation or simply an opportunistic behaviour.

It seems that any stock of rainbow trout is capable of migrating, or at least adapting to sea water, if the need or opportunity arises. They require moderate to fast flowing, well oxygenated waters for breeding, but they also live in cold lakes (Kailola, 1993). Rainbow trout survive better in lakes than in streams (McDowall and Tilzey, 1980). Generally it feeds close to the bottom (Bell-Cross and Minshull, 1988). Adults feed on aquatic and terrestrial insects, mollusks, crustaceans, fish eggs, minnows, and other small fishes (including other trout) while young if feed predominantly on zooplankton (Cadwallader and Backhouse, 1983). This species has been introduced in many parts of the world but is native to inland waters of North America and Former USSR, Arctic Sea, Northwest Atlantic, Northwest, Northeast and Eastern central of Pacific oceans.

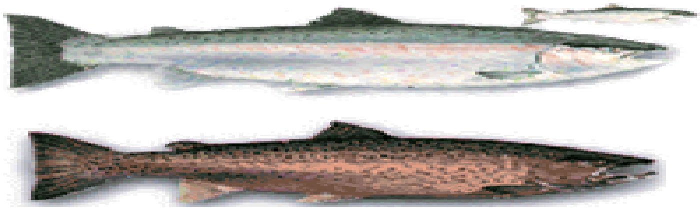


Figure 9: Illustration of Rainbow trout (*Oncorhynchus mykiss*)

3.3.3.4 Abalone

The species under consideration for aquaculture in Namibia is *Haliotis midae (*Linnaeus, 1758). This species is of family Haliotidae, order Vetigastropoda, class Orthogastropoda and commonly known as perlemoen or Midas ear abalone. It is the only one of the six species that occurs in South Africa that is commercially exploited (Fig.10).

Abalone species can live in optimal water temperatures ranging of 22.6°C (Hetch, 1994) and its sizes vary between 120mm to 200mm (Geiger and Poppe, 2000)

Abalone are generally broadcast spawners, releasing their gametes into the water column for fertilization (Leighton 2000) and most temperate species have an annual reproductive cycle. For the farmed species spawning is induced artificially in aquaculture facilities and few mechanisms (except for temperature-related events) leading to synchronized spawning in nature has been identified (Leighton 2000). According to Mottet (1978) their eggs are negatively buoyant and usually hatch within 24 hours of fertilization and a female can produce as many as 10 million eggs.

It is believed that larval viability, predation, and export to unsuitable environments by ocean currents may cause high mortality of wild abalone larvae while longevity varies between a ten years for smaller species to almost 40 years for white abalone (Leet *et al.* 2001).

It is believed that abalone growth rates are highly variable between areas, seasons, and temperature regimes. They also differ widely even among individuals occupying the same area, (Mellisa, 2003). Juveniles feed on benthic microflora; larger adults feed on larger marine algae such as drifting *Macrocystis* and *Nereocystis spp*. (Leighton, 2000).

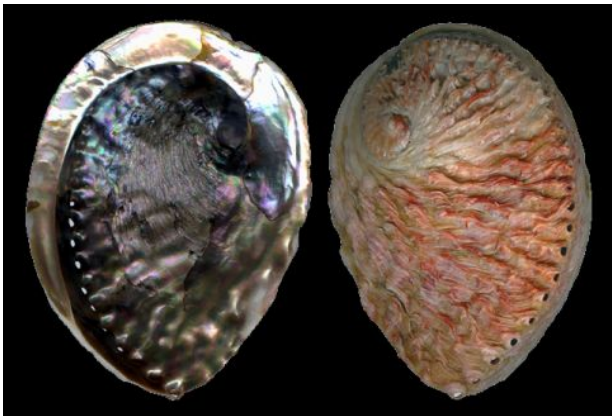


Figure 10: Illustration of Abalone (*Haliotis midae*)

3.3.3.5 Mussels

Mytilus galloprovincialis (Lamarck) is of class Bivalvia, order Cyrtodontida, family Mytilidae and commonly known as the Mediterranean or blue mussel (Fig 11). It was first recorded in south Africa in the late 1970s, but now it covers some 2000 km of the west coast of South Africa and Namibia (Branch and Steffani, 2004).It arrived in central Namibia in about 1980, became dominant and then collapsed. Although still present, it is no longer the dominant, suggesting that central Namibia lies near the limits of its tolerances. This can be because around central Namibia is where the Benguela current is divided into two distinctive areas (Northern and Southern Benguela Region) by the most active upwelling cell (Boyd and Agenbag, 1985). It is however believed to have become more established on the south coast of South Africa as a result of a Mari culture venture (Branch and Steffani, 2004). In the black sea the shell length and live weight were found to be highest when the temperature was 13 ^{o}C – 25 ^{o}C (Karayücel *et al*.2003). *M. galloprovincialis* is a broadcast spawner and has a planktotrophic larval stage where settlement of the larvae occurs at staggeringly high densities of up to 2 million recruits /m^2 (Harris *et al.*, 1998).

It has a high reproductive output as it is more tolerant of exposure to air than any of the indigenous species.

In the wild *M. galloprovincialis* is virtually absent from the subtidal areas, however in aquaculture, its growth in the subtidal areas is far superior to that in the intertidal areas (Branch and Steffani, 2004).There is no known reason for its absence in the subtidal, but possible causes are believed to be selective settlement, siltation and predation on juveniles.

Figure 11: Illustration of Mussel (*Mytilus galloprovincialis*)

3.3.3.6 Rock lobster

Jasus lalandii (H. Milne-Edwards 1837), is of class Malacostraca, order Decapoda, family Palinuridae and commonly known as Cape rock lobster (Fig.12). It is one of the most important lobsters commercially exploited. The wild stocks i.e. South Africa (Dubber *et al* .2004) have declined due to ecological effect of fishing. This has collectively promoted interest in the Mariculture of *J. lalandii* (Hecht and Britz, 1992).

However, as according to (Dubber *et al.*2004) the complex and lengthy larval development has been a major deterrent. Adult *J. lalandii* usually moult once a year, but moulting is more frequent in juveniles (Goosen and Cockcroft, 1995). Copulation and oviposition follow moulting of adult females, through numbers of larval stages that take 9–11 months for completion (Booth, 1997; Booth and Ovenden, 2000).

It is believed that temperature and diet are the primary factors influencing somatic growth rate in spiny lobsters (Lellis and Russell, 1990), and according to Hazell *et al.,* 2001, both factors significantly affect the growth rate of juvenile *J. lalandii*.

Naturally *J. lalandii* occurs within temperature range of 18–20 ^{o}C, but a study on postpuerulus stage of its larval life cycle by Dubber *et al* 2001, indicates that intermoult period is shortest at 18–21 ^{o}C, and prolonged at 12 and 24 ^{o}C growth increment (GI) is greatest at 18 ^{o}C, decline at 21 ^{o}C, and negative at 24 ^{0}C , however the growth rate was found to be highest at 18 ^{0}C and substantial mortality at 24^{o}C.

The same study (Dubber *et al* 2004), found that the rate of food consumption by postpueruli differed significantly among temperatures and was fast at 16–21 ^{o}C, but slow at 12 ^{o}C and at 24 ^{0}C .

The diet of *J. lalandii* is composed of black and ribbed mussels (*Choromytilus meridionalis* and *Aulacomya ater*), sea urchins, mysids, barnacles, sponges and seaweeds (Mayfield and Branch, 2000), but the mussel diet was found by Dubber *et al* 2004 to have highest moult frequency, however they concluded that although an exclusively mussel diet generated high growth rates and must be the favored diet on present evidence, there would be clear advantages to developing a suitable artificial diet.

Figure 12: Illustration of Rock lobster (*Jasus lalandii*)

3.3.3.7 Oyster

Oysters species farmed in Namibia are mainly *Crassostrea gigas,* commonly known as Japanese or Pacific Giant oyster and some *Ostrea edulis*, commonly know as Native or European Oyster (Fig.13)

These two species have been found to be similar in many ways but *C. gigas* (Thunberg, 1793) differs from *O. edulis* (Linnaeus, 1758) in the heavily colored adductor muscle scar as it has much more pink or purple color pattern and the crenulations on the margin is absent.

These species are both of family Ostreidae and class Bivalvia but *C. gigas* is from order pterioida while *O. edulis* from order Ostreidae.

C. gigas is endemic to Japan, but have been introduced into a number of other countries and most of these introductions have been for the purposes of aquaculture making the Pacific oysters the most widely cultured shellfish species worldwide (Zibrowius,1991).

O. edulis is widely distributed naturally around the western European coastline as far north as Spitsbergen and south to Morocco and the Mediterranean, but it has been introduced in many countries for Aquaculture (Heuclin, 2004).

Generally adult oysters are sessile animal which settles and cements themselves to rocks/hard substrata in the intertidal and shallow subtidal zones, to a depth of about 3 meters.

They are filter feeder, feeding by filtration and sieving out the epifaunal and immobile organisms using their gills. Most oyster species (including these species, *O. edulis* and *C. gigas*) change sex during their life, usually spawning first as a male and subsequently as a female. *O. edulis* changes sex regularly, depending on the water temperature. If the temperature reaches 16^{o}C, they become females every three or four years. If the temperature reaches 20^{o}C, they will change to females each year. They only revert to being males during the cooler intervening periods. They spawn at water temperatures of 18.5-24^{o}C and salinities 23-28‰. Temperature appears to be the main limiting factor for reproduction in the wild.

The larvae are planktonic and free swimming, developing for three to four weeks before finding a suitable clean hard surface to settle on. Although they usually attach to rocks, they can also settle in muddy or sandy areas (where they attach to small stones, shell fragments or other debris) or on top of other adult oysters. A very small percentage of oysters survive this phase, those that do are called spat. Fertilization takes place in the water column

They can live within a range 10 -15 years but the usual lifespan is thought to be around six years. They can reach an average size of 150-200 mm; have very high growth rates (they can grow to over 75 mm in their first 18 months) and high rates of reproduction.

Females oyster can produce between 30 and 40 million eggs per spawning, often giving the surrounding water a milky appearance Oysters favor brackish waters in sheltered estuaries, although they tolerate a wide range of salinities and water quality and can also occur offshore

a) b)

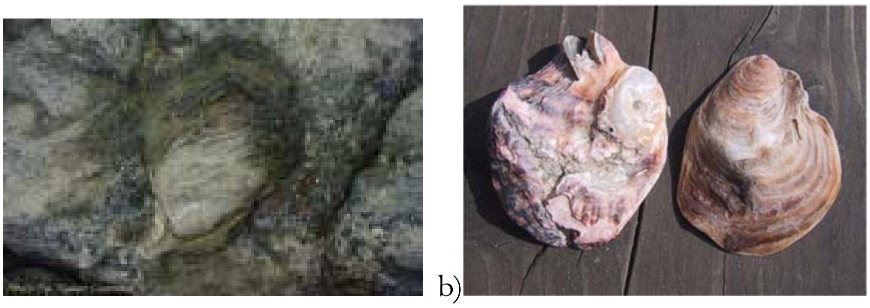


Figure 13: Illustration of Oyster species Farmed (*Crassostrea gigas* **(**a) and *Ostrea edulis* (b))

3.4 Discussions

The geographic distribution of marine organisms is chiefly determined by water temperature and salinity (Luppi et al. 2003) and usually larvae tolerate narrower ranges compared with adults of the same species (e.g. decapod crustaceans; Charmantier, 1998).

Temperature and salinity has been found to be influencing marine fish eggs and larval physiology, having a direct effect on growth and survival (Holliday, 1969).

Water temperature has been found to be influencing hatching rates (Hart and Purser, 1995), larval sizes at hatch (Hansen and Falk-Petersen, 2001), time for yolk sac absorption (Pauly and Pullin, 1988), energy reserve take-up efficiency (Heming, 1982), and larval growth and survival (Akatsu et al., 1983). Salinity has been found to affect hatching rate and egg diameter (Holliday, 1969), and growth (Murashige *et al.*, 1991). In juveniles of the pearl oyster both temperature and salinity were found to affect the speed and success of early development in P. imbricata (O'Connor, 2004). Fish species are also known to have requirements for water temperature and salinity that are specie-specific and well defined (Culberson and Piedrahita, 1996). It is therefore evident that accurate characterizations of temperatures and salinities of the marine environment are mandatory for any development/planning of aquaculture in Namibia.

All species considered in this analysis, with the exception of Cobia *(Rachycentron canadum),* have survival temperatures within temperate range of the Namibian coastal marine waters which ranges from 10.30 ^{o}C to 22.97 ^{o}C in Namibia water as shown in Figure 14.

Their optimal temperature however varies with respect to both depth and latitude as summarized in Table 5. But because fish are obligate ectotherms (with a few exceptions), ambient temperature will have a controlling effect on their rate of growth and food consumption hence this finding doesn't say much about their respective growth rate with respect to temperature. The latter can however only be achieved to some extent by modeling the performance of these species under optimal experimental conditions to establish respective relationships between water temperature and their growth.

A thermal growth coefficient (TGC) predictive model has been widely used for predictive purposes in production planning (Jobling, 2003 and references therein), where TGC is calculated in relation to degree-days (T× t):

$$TGC = \left\{ \left(\sqrt[3]{W_t} - \sqrt[3]{W_0} \right) / (T \times t) \right\} \times 1000$$

Where T is temperature in ^{o}C, t is time in days and W is the weight of a fish. After the growth prediction is made the formula becomes:

$$W_t = \left\{ \sqrt[3]{W_0} + \left[(TGC / 1000) \times (T \times t) \right] \right\}^3$$

The above model however assume 1) that growth increases in a steady and predictable manner with increasing temperature, 2) that the length (L) ^weight (W) relationship is $W \propto L^3$ and 3) growth in length (for any temperature) is constant over time .
As according to Jobling 2003, all the assumptions may be violated under some of the conditions to which farmed fish are exposed to and hence concluded that uncritical use of the TGC model can lead to serious projection errors being made.

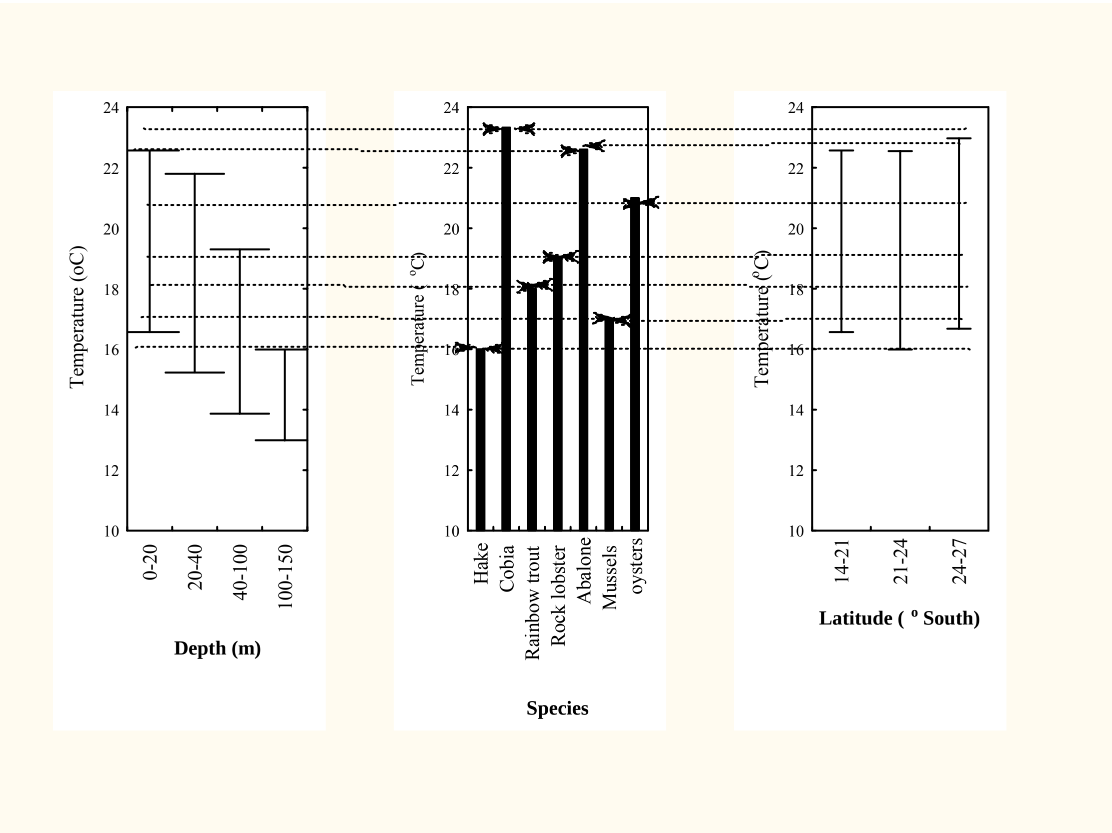


Figure 14: Summarized findings showing species' optimal temperature with respect to depth and latitude (See table 5 for further summarization).

As all species considered in this study are marine, with the exception of Rainbow trout which is anadromous species, I believe they should be able to survive within the salinity range of Namibia water (i.e. 34.9‰ - 35.15‰) but as species specific salinity values were not obtained at times of writing not much can be said about salinity in relation to the species considered.
It must nonetheless be noted that temperature and salinity measurements considered in this analysis are purely environmental (Natural), despite the fact that the body temperatures of most fishes are known to differ from environmental temperatures by only 0.5 to 1.0°C (Sylvester, 1972 and references therein).
Fish farming in most cases however happens in controlled environment and as according to Sylvester (1972) temperature, and salinity when changed from natural tolerances, may become lethal, controlling, or directive factors for fish making them as some of the important factors that farmers have to monitor.

Table 5: Species' farming Latitude and Water depth with respect to their optimal temperature in Namibian water

Species	**Latitude**	**Water depth**	**Optimal temperature**
Hake *(Merluccius capensis)*	21 ° – 24 °	20- 100 m	16.0 °C ,Bianchi *et al.*1993
Cobia *(Rachycentron canadum)*	None	None	23.33 °C, Collette 1999
Rainbow trout (*Oncorhynchus mykiss)*	14 °-27 °	0- 100 m	19 °C ,Kailola 1993
Rock lobster (*Jasus lalandii)*	14 °- 27 °	0- 100 m	18–20 °C ,Dubber *et a.l* 2001
Abalone(*Haliotis midae)*	24 °-27 °	0- 20 m	22.6 °C ,Hetch1994
Mussels (*Mytilus galloprovincialis)*	14°- 27 °	0-100 m	17 °C, Karayücel *et al.*2003
Pacific and European Oysters (*Crassostrea gigas* and *Ostrea edulis)*	14°- 27 °	0-40 m	18.5-24°C ,Goulletquer 1997

Despite the fact that most of the species considered for aquaculture in Namibia can live within temperature and salinity ranges of Namibian coastal waters at different latitude and depth (Table 5) , their farming potentials can however be hindered by a paucity of knowledge about conditions that promote their yields.

In addition to water temperature and salinity, fish growth is influenced by a variety of factors, including fish weight, feeding rates, water quality, diet composition, stocking densities, and environmental conditions where their interactions challenge the prediction of growth rates in a farming environment.

The above also means that results of predictions of fish growth can be very sensitive to small change or errors in these parameter values. Hence, research should focus on better understanding the relationships between these parameters and species. Species specific study like those of among others Jobling (1988) on environmental tolerances and preferences of cod, Hart (1952) on *Micropterus salmoides*, Hart (1947) on *Perca flavescens,* Brett (1952) on *Oncorhynchus gorbuscha,* Hansen and Falk-Petersen (2001) on *Anarhichas minor,* Qin and Fast (1998) on *Channus striatus* have to be carried out first to these species to conclusively evaluate their respective farming potentials.

Lastly, factors such as food availability within the environment, competition, predation, oxygen concentrations, and presence of marine toxins in Namibia marine water can all affect fish farming and thus warrant similar studies.

4.1 Economic feasibilities

Methods of hatching, producing, harvesting, transporting, processing, marketing and exporting cultured fish have progressively improved during the past decade (Bith-Hong *et al.*1999). Consumers are also increasingly becoming well informed about products prices and characteristics, which result not only in increased competitions, but also increased focus on the relationship between market and business performance (Leskiewicz and Sandvik, 2003). Factors like competitive superiority, market uncertainty, market fit, the product development process, technical competence and managerial skill have also been found to determine product success (Wren *et al.*2000). Robert (1979) has also showed that various factors that lead to product success included new product strategies as part of the commercial entity, product's market environment, the firm's internal environment and the nature of the product itself.

In today's highly competitive global marketplace, understanding the factors that determine product success or failure has become crucial for both researchers and practitioners (Robert, 1979; Calantone and Montaya, 1994; Robert and Kleinschmidt, 1995).

Form a theoretical standpoint, the neo-classical theory of consumer demand which is generally based on the assumption that tastes and preferences are static in nature, has also been found as far from reality in a taste- and preference-driven market such as seafood (Spinks and Bose, 2002). This is because the tastes and preferences of consumers for seafood and fish products change over time (Edwards 1992, Kinnucan et al 1993) which makes it of the utmost importance to investigate the factors affecting consumer preference for seafood products. Hence fish marketing data, are vital for any future aquaculture development project because they can influence potential supply and demand, distribution channels of fish, the economics of aquaculture and the relative importance of wild and cultured fish in household consumption (Zhang *et al.*2005). Increased awareness of cultured fish products can also be expected to reduce the uncertainty and risk in the fish market and lead to improved fish marketing systems. In addition to applying a theoretic harvesting model to an oyster species (*Crassostrea gigas*) to find a theoretic harvesting time that maximizes the present value of the returns on investment, this section aims at investigating the trade of the species that are considered for Aquaculture in Namibia as characterized in terms of their respective consumption history, toward better understanding of their demand and market, considering the fact according to Watson (1922) that “consumer is to the manufacturer, the department stores and the advertising agencies, what the green frog is to the physiologist”.

4.2 Application of a theoretic Harvesting model to oyster species (*Crassostrea gigas*) farmed in Namibia Water

From Roman emperors who considered them worth their weight in gold to modern-day Casanovas, oysters have long been valued for their reputed properties as an aphrodisiac. Few sea foods have as much history as oysters and the genus *Crassostrea* (Sacco 1897) is commercially important worldwide.

Crassostrea gigas commonly known as Japanese or Pacific Giant oyster is currently being farmed in Namibia with production of 2002 reported to be around N$ 6 million[2] in value and 70% of this production destined for South Africa Market.

The flavours of oysters vary considerably, depending upon where it's grown. Because their flavour varies, oysters are usually marketed by where they're grown, so there might be scores of market names for the same species. Goulletquer *et al*. (1999) demonstrated also that physiological variability existed among *Crassostrea gigas* strains and are likely to be related to physiological differences between geographical regions and/or genetic adaptation.

Oysters are cultured in many different ways , but according to Parsons(1974) raft culture has market size advantages though off bottom culture by growing unattached oysters intertidally in trays held off the sea-bed is an alternative, which provides higher survival, better growth, higher stocking densities and complete cropping compared with traditional sea-bed culture.

The economics of commercial bivalve culture is dependent upon a range of factors, many of which have a biological basis. According to Askew (1978) the immediate source of revenue is a function of both the growth and mortality of the stock cultured, and the price in relation to size at the times of purchasing and marketing. Variations in mortality rate have a direct influence on the economics, while variations in growth rate exert both direct and indirect influences.

But Walne and Davies (1977) found no statistically significant differences between seasonal mortality rates of *C. gigas* and that the rates of relative growth of bivalves decrease as age or size increases. The cost of production is largely a function of the time required for the organism to reach market size, but the profitability of the operation is very dependent on the time between investment and returns, and on the frequency of financial returns.

Most economic assessments of oyster farming in established operations are based on existing background data, where the essential biological data relates to long periods of time, for example entire years or growing seasons.

---

[2] The currency used is Namibia Dollar ($1 US = N$ 5. 9)

In this analysis a discrete time model based on a continuous time harvesting model[3] will be used as adopted form Bjørndal (1990) which he used for economics of salmon aquaculture, with the objective of finding the harvest time that maximizes the present value of the returns on the investment.

The main objective of this analysis is to theoretically apply the same model (slightly modified and simplified) to oyster species (*Crassostrea gigas)* to find a theoretic harvesting time that maximizes the present value of the returns on investment in oyster production. Though most variables will be theoretic it is done with intentions that the same model can be used by any farmer where real variable data are known to make contribution towards deciding the best harvesting time.

4.2.1 Model application basis and assumptions

One year class of oyster will be considered and the reference point for the analysis is a certain time only known by the farmer after oysters' seed[4] have been planted. The farmer investment is considered to find the harvest time that maximizes the present value of the returns on investment. Important variables that will be considered will be number of oysters, mortality rate and growth. This differs from the harvesting model used by Bjørndal (1990) in that feeding will not be considered as oysters are filter-feeders, drawing water in over it's gills hence don't require food supplements. But as in Bjørndal (1990), it also assumes

- That the plant is fully developed and all fixed costs related to plant costs are disregarded,
- Labour is primarily a fixed cost, spat have been purchased and planted hence only the harvesting time with respect to the number of spat already planted is maximized,
- What happens when the year class is harvested is not considered hence only one time investment is considered and
- That credit is not a limitation with respect to the operations and taxes are disregarded.

Given the aforementioned assumptions and as in Bjørndal (1990), only economic variable relevant to the investment like price of the oyster; interest rate; maintenance cost and harvesting cost in addition to the biological variables will be considered.

[3] Models are a deliberate simplifications of reality

[4] Oyster "seed" is an oyster that is transplanted to another location for the purposes of commercial grow-out or restoration

This differ from the model by Bjørndal (1990) in that there will be no feeding costs however maintenance cost which covers all the day to day costs that the plant incurred will be considered.

The analysis is monthly and based on cash flow that the investment generates with respect to both revenue and expenditure.

In the analysis TR_t = Total Revenue from harvesting in Month t, $E_{t=}$ Expenditures which is the total of maintenance costs and harvesting cost in month t and r = interest rate per month. With references to the time of the analysis t = 1, it is assumed that the oysters have reached market size but not sexual maturity as their meat yields and shelf life are known to decline during spawning .In the analysis the net cash flow is considered to be monthly. In order to find the present value of the investment, the cash flow will be discounted to the time of the analysis. Biomass value, Harvesting costs and maintenance cost will be discounted separately with respect to the time.

Given the fact that the objective is for the farmer to harvest in a month that maximized the investment the farmer now has 12 possible harvesting times. The farmer only needs to find the time (month) that maximizes the present value of returns on investment. In addition to already existing assumptions, price per gram of oysters is assumed to be N$ 0.03, harvesting cost per gram of oyster is assumed to be N$ 0.006, and monthly maintenance cost per gram of oysters is assumed to be N $ 0.002.

The Namibian Banking rate is 7.5 % and the prime lending rate of commercial banks is 12.25%[5] hence in this analysis a monthly interest rate of 0.015% will be used. At the time of analysis there were 120 000 0000 oysters in the plant in the first month with a mean live weight of 0.5 grams. Practically and as according to Toro et al. 1999 the grow rate of oysters is positively correlated with temperature, chlorophylla, phytoplankton biovolume and particulate matters, however in this analysis mean weight of oysters per month is adopted from Askew (1978) as observed in Newton Bay 1967 and will be assumed to be the same for the oyster under the analysis (Table 6).

Natural mortality rates used in the analysis are 0.16 per month which is assumed and 0.0016 per month as adopted from Nunes *et al*. 2003 from a model for sustainable management of shellfish polyculture in coastal bays who assumed it to be 0.005 per day. This was done to show sensitivity of harvesting time with respect to varying natural mortality.

[5] Monetary policy statement of Bank of Namibia (February 2005)

The number of surviving oyster with respect to mortality rates is given by

$$-M = \frac{N2 - N1}{N1}$$

Where by **M** is mortality rate, **N2** is number of oyster in month 2 and **N1** is the number of oyster in month 1.

Mortality rate is assumed to be discrete and constant despite the fact that it normally decreases as oyster size increases. The period within which the farmer has to decide will be the entire year. However where real trends are known the period should be based on past trends and experiences.

Table 6: Number of oysters calculated with the assumed mortality rates and the Mean live weight as adopted from Askew (1978)

Months	Number of Oyster(0.16 Mortality rate)	Number of Oyster(0.016 Mortality rate)	Mean Weight Per Oyster(g)
January	1,200,000,000	1,200,000,000	0.5
February	100,8000,000	1,180,800,000	1.96
March	846,720,000	1,161,907,200	6.17
April	711,244,800	1,143,316,685	13.32
May	597,445,632	1,125,023,618	21.29
June	501,854,330	1,107,023,240	29.15
July	421,557,637	1,089,310,868	34.2
august	354,108,415	1,071,881,894	37.57
September	297,451,069	1,054,731,784	38.77
October	249,858,898	1,037,856,075	42.24
November	209,881,474	1,021,250,378	51.91
December	176,300,438	1,004,910,372	69.95

Assuming that the harvesting decision occurs within a 12 months the following hold (Table 7)[6]

Table: 7. Net cash flow calculation

Time (Month)	t=1	t= 2	t=3	t=4	....t=12
Total Revenue	TR_1	TR_2	TR_3	TR_4	TR_{12}
Expenditures	E_1	E_2	Et_3	E_4	E_{12}
Net cash flow(TR_t- E_t)	NC_1	NC_2	NC_3	NC_4	NC_{12}

All variables in this analysis are assumed and the parameter changes are not taken into consideration. Therefore results in this analysis should not be used to infer relative importance of the parameters/assumptions and they cannot be ranked according to their influence on investment decision.

4.2.2 Results and Discussion

Nominal[7] biomass value and discounted[8] biomass value shows the same trend of increasing with time at both mortality rates (Fig 15). At 0.16 mortality rate the nominal biomass peaked in June at around N$ 4 38 871 612.36, while the discounted biomass value peaked in May at around N$ 4 13 436 911.31.Both the Nominal and discounted biomass decreased to their lows in October of about N$ 6 803 2281 and N$ 2 86 633 038.18 respectively. At 0.016 mortality rate the highest nominal and discounted biomass value were realized in December at N$ 2 108 804 416 and N$ 1 871 456 845 respectively. If the farm objective is to maximise the present value of the revenue from harvesting irrespective of the costs incurred, then June will be the month that gives the farmer maximized present value of the returns of investment at 0.016 mortality rate, while at 0.016 mortality rate the December turned out to be the month that maximise the present value of the revenue from harvesting.

The net cash flow (Fig 16) with respect to the cost incurred increases with time at both mortality rates. At 0.16 mortality rate it peaked in June at N$ 3 03 187 068.29 and the decreased to its low of N$ 2 10 197 561.33 in November. At 0.016 mortality rate the highest net cash flow is in December at N$ 1372401686.

---

[6] see appendix tables for calculation results

[7] Nominal value is measured in the prices ruling at measurement time

[8] Discounted value is where interest rate is used to calculate the present value

At 0.016 mortality rate the net cash flow and both biomass value have a stable period between July and October, where they have a more or less constant value. However they both increased to their respective highest values in December.

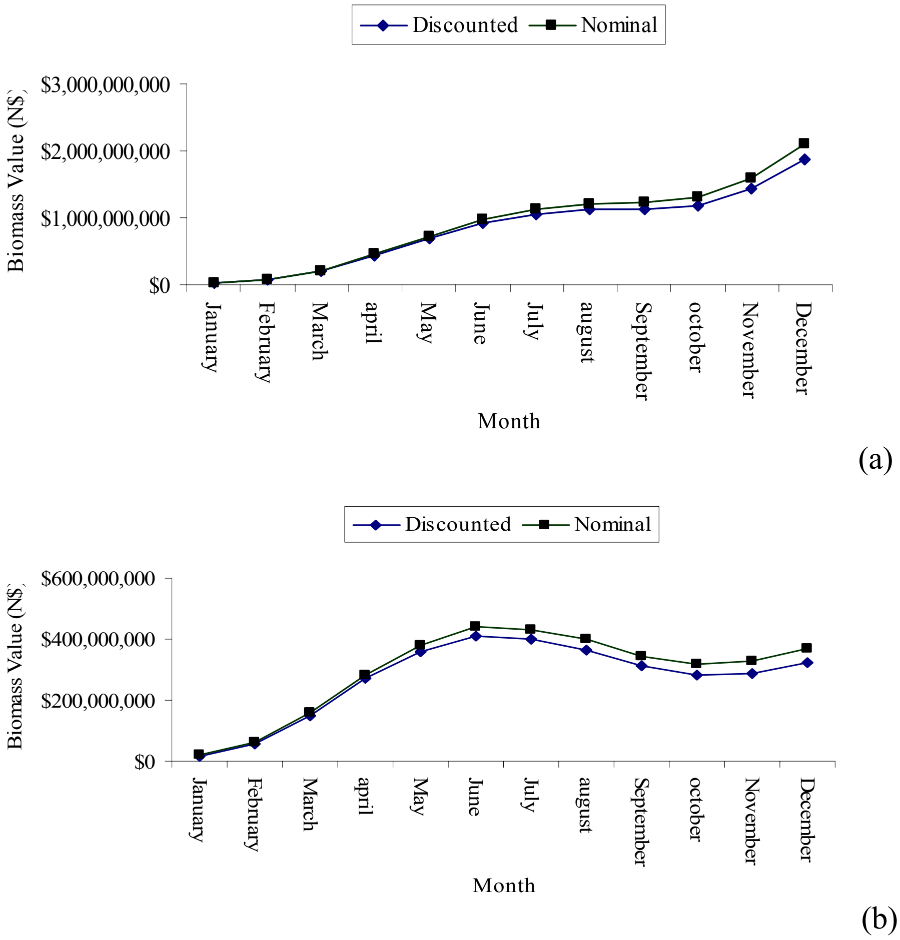
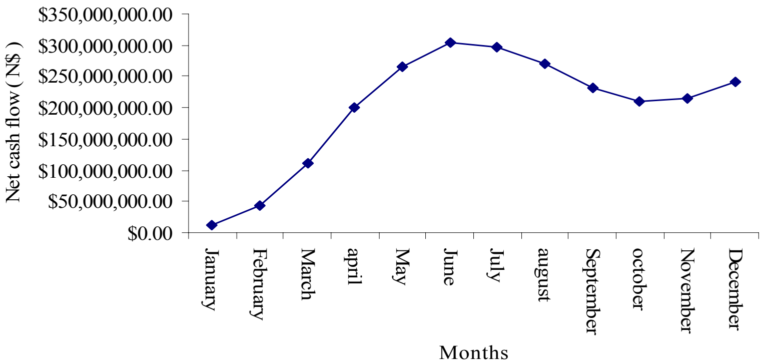


Figure 15: Theoretic trend of both nominal and discounted oyster Biomass at (a) 0.16 and (b) 0.016 mortality rate for the period of the analysis

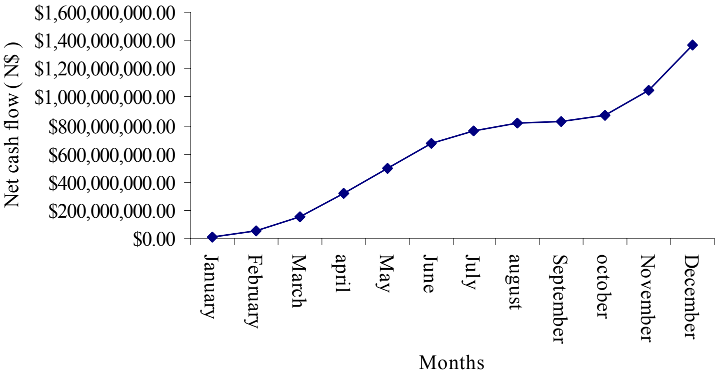
Because the initial objective of oyster production in question was to find harvest time that maximizes the present value of the returns on the investment, June turned out to be the month that maximizes not only the gross value of the returns of the investment, but also the profit the farmer will get at 0.16 mortality rate. While at 0.016 mortality rates the harvesting time that gives the farmer highest returns will be December.

Varying mortality seems to have significant effect of the harvesting time where at a high mortality it is wise for a farmer to harvest in June, while at low mortality rate (0.016) it is wise to postpone the harvesting time until December.

However one can also notice that at 0.016 December value does not necessary mean the maximum returns, but mainly the highest given the period of time of the analysis.
It should also be pointed out that the farmer can harvest in any months at all mortality rates in this analysis without any loss, as all months showed positive net cash flow , despite the difference in value.



(a)



(b)

Figure 16: Theoretic trend of discounted net cash flows at a) 0.16 and b) 0.016 mortality rate for the period of the analysis.

The practical relevance of this analysis is that the choice of harvesting time for any farmer has a major effect on the returns of investment and the decision is not purely of economic nature as biological parameters like the mortality and growth rate have also to be considered.
Another thing shown is that farm specific harvesting model should be employed by the farmers, as different farm incur not only difference production costs, but also mortality and growth rate. Seeing oysters are filter feeders, availability of food will be much dependent on plankton[9] abundance and suspended particulate matters in the farming environment.

[9] Plankton means phytoplankton and zooplankton

Hence their abundance and quality should be measured and considered in the harvesting model as they have a direct effect on the growth of oyster.

While the analysis shows when maximum returns on investment can be realized, it is however limited in scope. As for example the effect of materials management costs and inventory balances on capital requirements and availabilities were not considered

Variables like mortality rates have excluded exceptional events, such as accidental anoxic crises which frequently occur in Namibia water because of sulphur eruption, storms, or predation.

Effective analysis of the financial attractiveness of returns from farming investments is however a very complex task due to, among other reasons, the long planning horizon of these investments, uncertainty of future prices and costs, and uncertainty of the future legal operating conditions. The net present value (NPV) approach used in this theoretic analysis of returns on investment is reasonable but it has, as according to Duku-Kaakyirea and Nanang (2004), the main problem of inability to account for managerial flexibility.

4.3 Species as product in the Market

4.3.1 Oyster

Oysters of the genus *Crassostrea* (Sacco 1897) are commercially important worldwide. In the Pearl River Delta, China, the cultivation of species of *Crassostrea* is reputed to have about 700 years history (Lam and Morton, 2003).

The Pacific oyster, *Crassostrea gigas* a native of the Far East, is the most widely farmed oyster in the world, accounting for about 75% of the total world oyster production. An extremely hardy and adaptable *Crassostrea gigas* is widely grown in Europe, Australia, New Zealand and U.S. European flat oysters, *Ostrea edulis,* often called "Belons," which is the name of a region in France where they are grown, once dominated European oyster production but diseases have sharply reduced their harvests.

Even thought hey might be all the same species, the flavour of oysters will vary considerably, depending upon where it's grown. Because their flavour varies, oysters are usually marketed by where they're grown, so there might be scores of market names for the same species. They are year round products but their meat yields and shelf life decline during spawning.

Oyster farming is already established in Namibia with 70% of the production destined for South Africa Market. Seeing Oysters are filter feeders, siphoning up to 25 gallons of water a day through their system and the flavour of their meat is a function of the trace minerals (especially salt) in the water, the Namibia oyster industry can take advantage of the clean Namibian marine water reputed to be one of the cleanest in the world to market their product, enter new markets and increase their production volume.

4.3.2 Hake

The name Hake is originally and historically associated with the hake specie commonly known as European hake (*Merluccius merluccius)* but biologically all species that are from the genus *Merluccius* are commonly considered as hake.

However, the commercial definition of hake is less strict to the extent that not all the species commercialized under the name hake belong to the *Merluccius* genus.

A total of 12 fish species belong to the *Merluccius* genus, but not all of them are important commercially. *M. capensis* is one of the commercially exploited hake specie from Namibia water and destined mainly for domestic and European market. This Hake species is marketed as smoked, frozen, and fresh on ice and, it is eaten steamed, fried and baked (Frimodt, 1995)

This specie has never been cultured and hence not much is known about introducing cultured version of this product into the market. The fact that the stock in Namibia is still healthy, the uncertainty on the success of the cultured hake in markets and the unknown cost of culturing it as opposed to the cost of harvesting will pose a very tough challenge despite the fact that the market price of the wild *M. capensis* is still favorable.

For discussion sake one can compare the prospect of culturing hake to the farming of cod in Norway, not only because hake is as important to the Namibian fishery as cod is to the Norwegian one but also because they are from the same order Gadiformes (taxonomically, *see* section 2.2.3) and will probably have similar economic challenges.

Atlantic cod have been reared in captivity for over 100 years in both Norway and Canada with operations until 1970s aimed solely at producing yolk-sac fry to restock local wild populations. The intensive farming of cod began in the mid-1980s although commercial production failed to fulfill its potential due to technical factors notably, the scarcity of juvenile fish for on-growing and a fall in market price caused by an increased supply of wild caught fish (Walden,200) .

The same can be expected with hake farming, however, through improved technical knowledge, the industry is much better placed to make commercial-scale hake farming a financially viable proposition today. But despite expectations of a large market potential its success will also still be dependent on knowledge on how to optimize feed for the different life stages, and to which extent feed composition influences not only the growth and feed conversion, but also, the final product quality and the level of supply of wild caught hake .

4.3.3 Cobia

Cobia has many names of which black kingfish is the most common, but others like ling, crab eater, sergeant fish or lemon fish are also used due to its wide distribution and common appearance as a by-catch. Cobia is a new species to aquaculture. Back in 1975, Hassler and Rainville had found cobia to be good potential aquaculture but its farming started a decade ago in Taiwan in seawater ponds and small sea cages, and now it is the main farmed marine fish in Taiwan, occupying 80% of the sea cages.

During the last couple of years numbers of commercial farms have been started in the Philippines and Vietnam, often with Taiwanese private investors and fry involved. Though the Taiwanese grow-out of cobia seems to be achieving relatively good results with the lowest production costs of the marine species (Liao, D.S. 2000), the farming of marine fish in Taiwan have been constrained by an overall heavy mortality of 42% in the sea. During the very cold spell of the spring 2000 mortality of cobia even exceeded 70-80% (Tzen, 2000)

In recent years, successful cases have been reported in the US and Australia .The reason for interests in cobia-farming are that is has many preconditions for becoming a large volume production and if so desired an industrial production. First of all the growth is very fast and normally the weight of 5-6 kg can be reached within one year and 8-10kg in 16 months (Hassler and Rainville, 1975).

The feed used are trash fish, moist and dry pellets, which give Namibia comparable advantages due to her rich adjacent Benguela current area and established capture fishery. Cobia is considered as a very good fish for eating. The meat of the different parts of cobia shows very distinctive qualities as for fat and moisture contents .It is commonly eaten as steamed, fried or broiled and boiled for soups and marketed as fresh , smoked, and frozen.

These properties together with its pan-tropical/subtropical distribution give Cobia a very big market potential.

The main constraint though is the very scattered occurrence on the fish markets, which will therefore require substantial generic marketing efforts to achieve fast development of its consumption.

The fast growth of cobia however may also pose some challenges (or potentials) to (industrial) aquaculturists in developing an optimal feed and feeding regimes.

There is however an increasing demand for cobia in the market place while wild cobia stocks cannot be counted on to meet demands at reasonable prices.

4.3.4 Rainbow Trout

Rainbow trout occur naturally in the eastern Pacific Ocean and in fresh water mainly west of the Rocky Mountains from northwest Mexico to the Kuskokwim River, Alaska (Jonsson *et al.* 1993). Today, this species is widely distributed in all temperate and sub-Arctic regions of the world

The artificial propagation of trout has been associated with angling in many countries since the early 19th century and culturing techniques are now well established. The availability of reliable pelleted artificial feeds also led to a rapid expansion in commercial pond farming of rainbow trout in North America over the last years. Not only are the mechanics of trout culture well known, they are also relatively simple.

Trout is marketed as fresh, smoked, canned, and frozen, while eaten as steamed, fried, broiled, boiled, micro waved and baked (Frimodt, 1995)

Rainbow trout is widely accepted as food fish of high quality (Martyshev, 1983). According to Pillay (1993), in countries where commercial trout farming is well developed, as in Europe, harvesting size ranges from 170-230 g to 350-450 g for the fresh market and 1.5-3 kg for fillets and smoked trout. 200-300g fish are the most suitable size for harvesting because of higher feed efficiency and low production cost.

As Rainbow trout is commercially fed, would be farmers in Namibia are likely to incur that similar production cost as incurred in other places in addition to the competition from established farmers in other parts of the world.

4.3.5 Abalone

Native Chinese have been consuming local abalone species for millennia but as according to Clarke (2004) the first historical account of this product in the market is from Han dynasty (206BC -220 AD). Abalone is still widely enjoyed in Chinese cuisine especially in Banquet or special dinners as dried or canned abalone.

International trades in Abalone date back to as early as 1880s in Tasmania, where the Chinese merchants were reported to be harvesting and drying abalone for export to china, while South Africa started canning abalone for the Chinese market as early as 1953 (Prince and Shepherd, 1992). Omani Abalone is the most expensive and has been dried and exported to china and Japan at least in the 1970s (Clarke, 2004).

As early as 1990s, Japan and China were said to consume over 80% of the world abalone with Japan demanding the premium products in live, fresh and frozen form and china importing the bulk of canned and dried production (Clarke, 2004).

Commercial abalone are derived from at least 25 species (and Subspecies) of the genus *Haliotis* (Clarke, 2004). In most markets the abalone products are identified by brand name rather than be species and particular brands, which may include mix of species, are identified by product size, texture and meat color (Clarke, 2004).

Overexploitation has increased culture of abalone, which in the decades starting 1989 has increased by over 600% mainly based on operation in china and Taiwan (Gordon 2000).

The demand for this unique shellfish has remained quite consistent however the worldwide abalone supply has been seriously depleted. Over-harvesting, criminal poaching activities and a degradation of quality of the oceans of the world have taken a consistent toll on the commercial availability of abalone hence the creation of the relatively new industry of abalone farming.

The market size is still large and price still favorable, the only challenge that the Namibia aquaculturists (to-be) may have to face is that of the cost of culturing the species .However with proper research and experimental studies this may be overcome.

4.3.6 Mussels

Today numerous species of mussels are being farmed. Some species including (*Mytilus edulis L*., 1758, *Mytilus galloprovincialis* Lam., 1819, and *Mytilus smaragdinus L*., 1758) are of economic significance and grow in large quantity (ARAL, 1999).

The blue mussel (*Mytilus* spp.) culture industry has continuously and substantially increased since the mid-1980s. As demand increased, depletion of national beds occurred and aquaculture supplemented wild populations (Harding *et al.*2004).

In Europe demand surpassed supply a long time ago, and their mussel culture has been going on for 300 years. Commercial mussel cultivation in Europe originates from the Netherlands. Mussel cultivation in Germany and Denmark did not begin significantly until in the Netherlands a parasite decimated the Dutch stocks (Batten, Undated but accessed 2005).

Nowadays, the main international traders in Mussels are countries such as China, Korea, Spain, The Netherlands, Denmark, France and New Zealand

The main mussel product forms are live, frozen meats, marinated, and smoked meats. Wild mussels are good, but not as consistent as cultured, which will have a slightly shorter shelf life.

Mussels' aquaculture in Namibia will have an advance of food availability as they are the most efficient feeders compared to other shellfish. The nutrient rich Benguela current area may have a positive impact on their growth rate hence increased production. However they will have to face competition from already established mussels' producers.

4.3.7 Rock lobster

Up until the end of the 19th century lobster was so plentiful that it was used for fish bait, however with lobster's ever-increasing popularity (and price) those days are gone forever. As a result of a global decline in lobster fisheries, attempts have been made to culture lobsters to meet the worlds lobster demand. In Namibia there has been attempt to culture wild-caught pueruli at an oyster farm around Luderitz Bay but puerulus supply was found to be a barrier for lobster culture development (Klueder, 2003).

In 1992 (Namibia) the total allowable catch (TAC) was set at 100 t, and finally limited catches. Subsequently, TACs have been kept low and some fishing grounds have been closed to the industry (Grobler and Noli-Peard, 1998).

Currently the world's largest producers of spiny and rock lobster are Australia, Brazil, the Caribbean countries (led by Cuba and Nicaragua) and U.S, however judging from the increasing price of the product, the demand of this product from the world market seems to have surpassed its supply, hence the importance of starting lobsters aquaculture.

In all rock lobsters, the tail is the part sought for the table. The rest of the animal is often discarded before it is marketed.

The tails are most commonly available frozen .In most market, spiny and rock lobster tails are sometimes subdivided into warm water and coldwater tails, depending upon the species/fishery of origin (Cascorbi, 2004). Coldwater tails, of which the cape rock lobster is one, come from the temperate-water fisheries of Australia, New Zealand and South Africa (SimplySeafood.com, 2004).Coldwater tails are considered superior in flavour and texture to warm water tails, and their costs reflect this; a five-to-six-ounce Australian coldwater tail will retail for $20-$25, while the same-size warm water tail from Brazil might cost $15-$208 (Cascorbi, 2004).

The demand for this product is universal and exporters (including Namibian) from various countries will have to compete with each other for the supply rock lobster.

However as according as study by Mayfield *et al* (2001) lobsters showed a strong preference for mussels over all other prey offered and for juvenile abalone over urchins , therefore a combined mussels-lobsters farming in Namibia may prove to be cost effective.

The major obstacle that lobsters aquaculture development may face is the time of the life cycle of the rock lobster which is a commercial cost. According to Kittaka (1988) soothe mature the adults stage is only reached after 9-11 years, but with further ecological and nutritional investigations this may be shortened.

5. Conclusions

Marine aquaculture in Namibia though still very small has the potential of becoming a significant contributor to Namibian Economy. Different species are currently being considered for aquaculture in Namibia, however, critical questions (e.g. can a species be grown in Namibia? Can it be grown fast enough? And can it be grown economically) must be answered first prior to successful farming. Based on the environmental, economic and legislative issues considered in this analysis I will rank the species considered for aquaculture in Namibia on a scale of 1 to 10 and give the basis of my ranking. This ranking however is just an insight ranking as opposed to a comprehensive ranking of species considered.

Oysters **(9/10)** are globally the most important class of cultured bivalve, and in most market they are considered as relatively high value species. Oyster farming have the potential of becoming the dominant aquaculture product in Namibia. This is due in part to the fact it is already being farmed on a small scale in Namibia but also because they are filter feeders and have low production cost. The fact that nutrient rich Benquela current is adjacent to Namibia will give a competitive advantage for Namibian Oyster farmers. Oyster are highly adaptable, largely disease free and tolerant of a wide range of environmental conditions making it an ideal aquaculture candidate in Namibia. The demand for oyster has been stable for decades, while it fetches a very good market price. The key to the success of any oyster aquaculture project in Namibia is the marketability of the product and having adequate system for transporting them to market centers.

Abalone **(8/10),** globally, abalone aquaculture is relatively new. Abalone farming has also a good potential in Namibia. It is already being widely farmed in South Africa, hence it will be easier for Namibia farmers to import the technology used in South Africa into Namibia. The demand for this unique shellfish has remained quite consistent for year. In as in addition to the meat market abalones are valued for their shells which have been used in jewelry and native crafts for centuries. Most abalone culture involves land based farming systems which is suitable for the Namibian coastline. The only obstacle that this development might face is that Abalone are slow growing species, generally requiring 3-5 years from spawning to marketable animals. Onshore facilities will also require considerable cash investment with break even periods of around 10 years making this a major obstacle to the industry growth.

Mussels **(8/10)** are relatively easy to culture and where attempts have been made to establish mussel culture, the main problem limiting the industry has been related to markets rather than technical or biological problems. Both poor markets and low market prices have historically limited culture in many areas around the globe.

The ideal Namibian environmental conditions available along the coastline and availability of abundant low cost labour give mussels farming in Namibia competitive advantages**.** One of the major factors that can also facilitate the growth of Namibia mussel export markets is the ability to both transport and store products in such a way that they can reach markets in a safe form

Rock lobsters **(7/10)** occur naturally in Namibian marine water hence environmental constraints to it farming will not be determining factor. Due to a high market demand, low wild catches and a continuing increase in prices, the Rock lobster is a very promising candidate for aquaculture in Namibia. The major obstacle that lobsters aquaculture development may face is the time of the life cycle of the rock lobster which is a commercial cost. The life cycle stages take considerable time as adult stage is only reached after 9-11 years. But with further ecological and nutritional investigations it may be possible to shorten this time.

Rainbow trout **(6/10),** the availability of reliable pelleted artificial feeds led to a rapid global expansion in commercial farming of rainbow trout, not only is the mechanics of trout culture well known, they are also relatively simple. Trout farming in Namibia is possible but the fact that this species is widely farmed in many developed countries this will give the Namibian farmer an inferior status in the market in addition to the competition from well established farmers.

Hake **(5/10)** farming of hake if it is to be pursued has a long way to go. This species has never been cultured and hence not much is known is about the success of cultured version of this product into the market. The fact that the stock in Namibia is still health, the uncertainty on the success of the cultured hake in market and the unknown cost of culturing it as opposed to the cost of harvesting it the wild pose a very tough challenge to its farming.

Cobia (**3/10)** this species has good consumer appeal that makes it a good aquaculture candidate. Basic understandings of cobia life history are well known but aspects of larval and juvenile ecology are unknown. Initial attempts to culture this fish have achieved some success, but many aspects of nutrition, disease, and behavior, grow-out and system management remain to be determined. The above and its environmental adaptability can hamper its farming potential in Namibia.

References

Abbott M.R and Letelier R.M. 1998: Decorrelation scales of chlorophyll as observed from bio-optical drifters in the California current. Deep-Sea Research II 45 1639–1667.

Abbott M.R. and Barksdale B. 1995: Variability in upwelling systems as observed by satellite remote sensing. In: Summerhayes, C.P, Emeis, K.C., Angel, M.V., Smith, R.L. and Zeitzschel, B., Editors, 1995. Upwelling in the Ocean: Modern Processes and Ancient Records, Wiley, New York, pp. 221–238.

Akatsu S., Al-Abdul-Elah, K.M. Teng S.K. 1983: Effects of salinity and water temperature on the survival and growth of brown-spotted grouper larvae (*Epinephelus tauvina* Serranidae). J. World Maric. Soc. 14, 624–635

Agenbag J.J. and Shannon L.V. 1988: A suggested physical explanation for the existence of a biological boundary at 24°30′S the Benguela system. South African Journal of Marine Science 6 119–132.

Alice Cascorbi. 2004: Caribbean Spiny Lobster .Seafood Watch Report. Monterey Bay Aquarium available online at http://www.mbayaq.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_CarribbeanSpinyLobsterReport.pdf

Aral Orhan.1999: Growth of The Mediterranean Mussel (*Mytilus galloprovincialis* Lam., 1819) on Ropers in The Black Sea, Turkey. Tr. J. of Veterinary and Animal Sciences 23 183-189.

Aroha S and Shekar B. 2002: Factors affecting households' seafood purchasing decisions in Auckland, New Zealand: An empirical analysis .International Journal of Consumer Studies p 62.

Askew C.G.1978: A Generalized Growth and Mortality Model For Assessing the Economics of Bivalve Culture Aquaculture 14, 91-104

Batten Thomas. Undated but accessed 7 January 2005: Blue Mussels, available online at http://www.ocean.udel.edu/mas/seafood/bluemussel.html

Bell-Cross G and Minshull J.L. 1988: The fishes of Zimbabwe, National Museums and Monuments of Zimbabwe, Harare, 294 p.

Bianchi G. K.E, Carpenter J.P. Roux, Molloy F.J, Boyer. D and Boyer H.J. 1993: FAO species identification field guide for fishery purposes, the living marine resources of Namibia, FAO, Rome 250.

Booth J.D and Ovenden J.R. 2000: Distribution of *Jasus spp*. (Decapoda: Palinuridae) phyllosomas in southern waters: implications for larval recruitment. Mar. Ecol., Prog. Ser. 200 241– 255.

Booth J.D. 1997: Long-distance movements in *Jasus spp*. and their role in larval recruitment. Bull. Mar. Sci. 61 111 –128.

Boyd A.J and Agenbag J.J. 1985: Seasonal trends in the longshore distribution of surface temperatures off Southwestern Africa 18–34°S, and their relation to subsurface conditions and currents in the area 21–24°S. *In*: Bas, C., Margalef, R., Rubiés, P. (Eds.), International Symposium of the Most Important Upwelling Areas off Western Africa (Cape Blanco and Benguela). Instituto de Investigaciones Pesqueras, Barcelona, pp. 119–148p.

Branch G.M and Steffani Nina C. 2004: Can we predict the effects of alien species? A case history of the invasion of South Africa by Mytilus galloprovincialis (Lamarck) J, Exp. Mar. Biol. Ecol. 300, 189–215.

Brett J. R.1952: Temperature tolerance in young Pacific salmon, genus *Oncorhynchus*. J. Fish. Res. Bd Can. 9, 265-323.

Brummett R.E. and Williams M.J. 2000: The evolution of aquaculture in African rural and economic development. Ecological Economics 33, 193–203

Bjørndal Trond.1990: The Economic of Salmon Aquaculture. Blackwell Scientific Publications, London, Great Britain.

Cadwallader P.L. and Backhouse G.N. 1983: A guide to the freshwater fish of Victoria. Government Printers, Melbourne, 249 p.

Campillo-Campbell Carolina and Gordoa Ana.2004: Physical and biological variability in the Namibian upwelling system: October 1997–October 2001, Deep Sea Research Part II: Topical Studies in Oceanography 147-158.

Charmantier, G. (1998). Ontogeny of osmoregulation in crustaceans: a review. Invertebrate Reproduction and Development 33, 177–190.

Cohen D.M, Inada T, Iwamoto T and Scialabba N. 1990: Gadiform fishes of the world (Order Gadiformes). An annotated and illustrated catalogue of cods, hakes, grenadiers and other gadiform fishes known to date. FAO Fish. Synop. 10, 442 p.

Collette B.B.1999: Rachycentridae. Cobias. p. 2655. In K.E. Carpenter and V.H. Niem (eds.) FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Volume 4. Bony fishes part 2 (Mugilidae to Carangidae), FAO, Rome.

Colosimo A, Giuliani A, Maranghi. F, Brix O, Thorkildsen S, Fischer T, Knust R and Poertner H.O.2003: Physiological and genetical adaptation to temperature in fish populations. Continental Shelf Research 23 1919–1928

Culberson D. S and Piedrahita H. R.1996: Aquaculture pond ecosystem model: temperature and dissolved oxygen prediction -mechanism and application. Ecological Modeling 89 231-258.

Daniel Heuclin. 2004: Native oyster, an ARKive publication, available online at http://www.arkive.org/species/ARK/invertebrates_marine/Ostrea_edulis/more_info.html (Accessed on 29/12/2004)

Dubber G G, Branch G M and Atkinson L J. 2004: The effects of temperature and diet on the survival, growth and food uptake of aquarium-held postpueruli of the rock lobster *Jasus lalandii*.Aquaculture 240 249–266

Duku-Kaakyirea A and Nanang D M. 2004: Application of real options theory to forestry investment analysis. Forest Policy and Economics 6 (2004) 539– 552

Edwards S.F. 1992: Evidence of structural change in preferences for seafood. Marine Resource Economics 26, 141-152.

Emeis K. C, Brüchert V, Currie B, Endler R, Ferdelman T, Kiessling A, Leipe T, Noli-Peard K, Struck U. and Vogt T. 2004: Shallow gas in shelf sediments of the Namibian coastal upwelling ecosystem. Continental Shelf Research 24 627-642.

FAO. 1995: Review of the State of World Fishery Resources: Aquaculture Food and Agriculture Organization of the United Nations, Rome FAO Fish. Circ. No. 866.

FAO. 1998: Review of the State of World Fishery Resources: Aquaculture Food and Agriculture Organization of the United Nations, Rome.

FAO. 2000: Review of the State of World Fishery Resources: Aquaculture Food and Agriculture Organization of the United Nations, Rome.

Fischer W, Sousa I, Silva C, de Freitas, A. Poutiers J.M, Schneider W, Borges T.C, Feral J.P and Massinga A. 1990: Fichas FAO de identificaçao de espécies para actividades de pesca. Guia de campo das espécies comerciais marinhas e de águas salobras de Moçambique, Publicaçao preparada em collaboraçao com o Instituto de Investigaçao Pesquiera de Moçambique, com financiamento do Projecto PNUD/FAO MOZ/86/030 e de NORAD, Roma, FAO. 1990. 424 p.

Frimodt C. 1995: Multilingual illustrated guide to the world's commercial coldwater fish. Fishing News Books, Osney Mead, Oxford, England 215 p.

Gangnery A, Bacher C, and Buestel D. 2001: Assessing the production and the impact of cultivated oysters in the Thau lagoon (Mediterranean, France) with a population dynamics model. Can. J. Fish. Aquat. Sci. 58 1012–1020.

Geiger D.L and Poppe G.T. 2000: A Conchological Iconography. The family Haliotidae. Germany, ConchBooks. 1st Edn 35p.

Grobler C.A.F and Noli-Peard K.R. 1998: *Jasus lalandii* fishery in post-independence Namibia: monitoring population trends and stock recovery in relation to a variable environment .Marine and Freshwater Research, 481015-1022

Goosen P.C and Cockcroft A.C. 1995: Mean annual growth increments for male west coast rock lobster, *Jasus lalandii,* 1969–1993. S. Afr. J. mar. Res. 16, 377– 386.

Gordon H.R 2000: World Abalone supply market and pricing .From historical Current and future Perspective. *In* opening speech to the 4th international Abalone symposium, Cape Town, South Africa, 6-11 February 2000. (Accessed online at www.Fishtech.com)

Goulletquer P, Wolowiz M, Latala A, Geairon P, Huvet A and Boudry P.1999: Comparative analysis of Oxygen consumption rates between cupped oyster spat of French, Japanese, Spanish and Taiwanese Origins. Aquat. Living Resources.12 271-277.

Hansen T.K and Falk-Petersen I.B. 2001. The influence of rearing temperature on early development and growth of spotted wolfish *Anarhichas minor* (Olafsen). Aquac. Res. 32, 369– 378.

Harding Joanne, Couturier M, Parsonsa Cyr, Jay G and Ross Neil W. 2004: Evaluation of the neutral red assay as a stress response indicator in cultivated mussels (*Mytilus spp*.) in relation to post-harvest processing activities and storage conditions .Aquaculture 231 315-326

Harris J.M, Branch G.M, Elliott B.L, Currie B, Dye A.H, McQuaid C.D, Tomalin B.J and Velasquez C. 1998: Spatial and temporal variability in recruitment of intertidal mussels around the coast of southern Africa. S. Afr. J. Zool. 33, 1– 11.

Hart, R.P., Purser, G.J., 1995. Effects of salinity and temperature on eggs and yolk sac larvae of the greenback flounder (*Rhombosolea tapirina,* Gu¨nter, 1862). Aquaculture 136, 221–230.

Hart, J. S. 1947: Lethal temperature relations of certain fish of the Toronto region, Trans. R. Soc. Can., 41 57-71.

Hart, J. S. 1952: Geographic variations of some physiological and morphological characters in certain freshwater fish. Pubis Ont. Fish. Res. Lab. No. 72, 79 pp.

Hassler W.W and Rainville R.P. 1975: Techniques for hatching and rearing cobia, *Rachycentron canadum*, through larval and juvenile stages. Publ. UNC-SG-75-30, Univ. N.C. Sea Grant Coll. Prog., Raleigh, NC 27650-8605, 26p.

Hazell R.W.A, Cockcroft A.C, Mayfield S and Noffke M. 2001: Factors influencing the growth rate of juvenile rock lobsters *Jasus lalandii*. Mar. Freshw. Res. 52, 1367– 1373.

Hecht, T. 1994: Behavioural thermoregulation of the abalone, *Haliotis midae*, and the implications for intensive culture. Aquaculture 126, 171-181

Hecht T and Britz P.J 1992: The current status, future prospects and environmental implications of mariculture in South Africa. S. Afr. J. Mar. Sci. 88, 335–342.

Heming, T.A., 1982. Effects of temperature on utilization of yolk by Chinook salmon (*Oncorhynchus tshawytscha*) eggs and alevins. Can. J. Fish. Aquat. Sci. 39, 184–190.

Holliday, F.G.T., 1969. The effects of salinity on the eggs and larvae of teleosts. In: Hoar, W.S., Randall, D.J. (Eds.), Fish Physiology, vol. 1. Academic Press, New York, pp. 293– 311.

Holliday, F.G.T, Jones, M.P. 1967. Some effects of salinity on the developing eggs and larvae of the plaice (*Pleuronectes platessa*). Journal. Mar. Biol. Assoc. UK 47, 39–48.

Jennings S, Kaiser M J and Reynolds J D. 2003: Marine Fisheries Ecology Blackwell Scientific Ltd, Berlin Germany

Jiann-Chu Chen and Wei-Chi Chen. 1999: Temperature tolerance of *Haliotis diversicolor supertexta* at different salinity and temperature levels Comparative Biochemistry and Physiology Part A 124 73–80

Jobling M. 2003: The thermal growth coefficient (TGC) model of fish growth: a cautionary note, Aquaculture Research 34 581-584

Jobling M.1988: A review of the physiological and nutritional energetics of cod, *Gadus morhua* L., with particular reference to growth under farmed conditions. Aquaculture 70 1-19.

Johnson JA and Kelsch S W. 1998: Effects of evolutionary thermal environment on temperature-preference relationships in fishes, Environmental Biology of Fishes, 53 447 – 458

Jonsson B, Hansen L.P. and Aass P. 1993. Coastal movement and growth of domesticated rainbow trout (*Oncorhynchus mykiss* (Walbaum)) in Norway. Ecol. Freshw. Fish 2 152–159

Kailola P.J, Williams M.J, Stewart P.C, Reichelt R.E, McNee A and Grieve C. 1993: Australian fisheries resources. Bureau of Resource Sciences, Canberra, Australia. 422 p.

Karayücel S, Karayücel I, Erdem M, Saygun S and Uyan O.2003: Growth and production in long-line cultivated Mediterranean mussel (mytilus galloprovincialis) in sinop, black sea. The Israeli Journal of Aquaculture – Bamidgeh 55(3), 169-178.

Keulder F. 2003: Monitoring puerulus settlement in *Jasus lalandii* at Lüderitz Bay, Namibia. Unpublished

Kinnucan H.W, Nelson R.G. and Hiariey J. 1993: US preferences for fish and seafood: an evoked set analysis. Marine Resource Economics 26, 273291.

Kittaka J. 1988: 'Culture of the palinurid *Jasus lalndii* from egg stage to puerulus', Nippon Suisan Gakkaishi 54 87-93

Kuiter R.H and Tonozuka.2001: Pictorial guide to Indonesian reef fishes. Part 1. Eels-Snappers, Muraenidae - Lutjanidae. Zoonetics, Australia. 302 p.

Lam Katherine and Morton Brian. 2003: Mitochondrial DNA and morphological identification of a new species of *Crassostrea* (Bivalvia: Ostreidae) cultured for centuries in the Pearl River Delta, Hong Kong, China Aquaculture 228 1-13.

Lannan J.E, Robinson A and Breese W.P. 1980: Broodstock management of *Crassostrea gigas.* II. Broodstock conditioning to maximize larval survival. Aquaculture, 21: 337-345.

Leet W. S, Dewees C. M, Klingbeil R. and Larson E. 2001: California's living marine Resources: A Status Report. Davis CA, University of California Sea Grant. 582 pp.

Leighton, D. L. 2000: The Biology and Culture of the California Abalones. Pittsburgh, PA, Dorrance Publishing Co., Inc. 216pp.

Lellis W.A and Russell J.A. 1990: Effects of temperature on survival, growth and feed intake of postlarval spiny lobsters *Panulirus Argus*. Aquaculture 90, 1 – 9.

Liao D.S. 2000: Socioeconomic aspects of cage aquaculture in Taiwan. *In* Cage Aquaculture in Asia: Proc. of the First International Symposium on Cage Aquaculture in Asia.

Luppi T.A, Spivak E.D and Bas C.C.2003: The effects of temperature and salinity on larval development of *Armases rubripes* Rathbun, 1897 (Brachyura, Grapsoidea, Sesarmidae), and the southern limit of its geographical distribution. Estuarine, Coastal and Shelf Science 58, 575–585.

Lyman C. P. 1968: Body temperature of exhausted salmon. *Copeia,* 1968, pp. 631-3.

Martyshev F.G. 1983: Pond Fisheries. American Publishing Co. Pvt. Ltd. New Delhi.

Mayfield S. de Beer E and Branch G.M. 2001: Prey preference and the consumption of sea urchins and juvenile abalone by captive rock lobsters (*Jasus lalandii*) Marine and Freshwater Research 52 773-780.

Mayfield S and Branch G.M. 2000: Inter-relations among rock lobsters, sea urchins, and juvenile abalone: Implications for community management. Can. J. Fish. Aquat. Sci. 57 2175– 2185.

McDowal R.M and Tilzey R.D.J. 1980: Family Salmonidae, salmons, trouts and chars. p. 72-78. In R.M. McDowall (ed.), Freshwater fishes of southeastern Australia. A.H. & A.W. Reed Pty. Ltd. Sydney.

Melissa M Stevens.2003: Seafood Report of Cultured Abalone (*Haliotis spp*). Seafood Watch, Monterey Bay Aquarium.

Mitzi M. Montoya-Weiss and Roger Calantone. 1994: Determinants of New Product Performance: A Review and Meta-Analysis. Journal of Product Innovation Management 11 397–415.

Moran A. L and Manahan D. T. 2004: Physiological recovery from prolonged 'starvation' in larvae of the Pacific oyster *Crassostrea gigas.* Journal of Experimental Marine Biology and Ecology 306 17-36.

Mottet M. G. 1978: A review of the fishery biology of abalones. Washington Report. Fish. Tech.Report 37.

Namibian Fishery Newsletter.2004: Focus on Fishery and Development. Official quarterly Newsletter of the Ministry of Fishery and Marine resources, No 2

New M.B, Tacon A.G.J and Csavas.I (Eds).1993: Farm-made aqua feed .FAO. Regional office of Asian and Pacific (RAPA) Association of eastern Asian nations (ASEAN). Commission of European Communities, Rome.

Nunes J.P, Ferreira J.G, Gazeau F, Lencart-Silva J, Zhang X.L, Zhu M.Y and Fang J.G. 2003: A model for sustainable management of shellfish polyculture in coastal bays. Aquaculture 219 257–277.

Pauly D. 1989: Food consumption by tropical and temperate fish populations: some generalizations. J. Fish Biol. 35 11-20.

Pauly D, Pullin R.S.V. 1988: Hatching time in spherical, pelagic, marine fish eggs in response to temperature and egg size. Environ, Biol. Fisches 22 261– 271.

Parsons Jasper.1974: Advantages In Tray Cultivation of Pacific Oysters (*Crassostrea gigas*) In Strangford Lough, N. Ireland Aquaculture, 3 221-229

Pillay T.V.R. 1993: Aquaculture Principles and Practices. Fishing News Books, University Press, Cambridge.

Prince J D and Shepherd S A.1992: Australian Abalone Fisheries and Their Management: *in* Abalone of the World fishery, Biology, Fisheries and Culture (Eds S.A Shepherd , MJ Tegner , S.A Guzman del Proo) Fishing News Books. Oxford pp.407 -426

Qin, J.G and Fast A.W. 1998: Effects of temperature, size and density on culture performance of snakehead, *Channus striatus* (Bloch), fed formulated feed. Aquac. Res. 29, 299– 303.

Robert G. Cooper. 1979: The Dimensions of Industrial New Product Success and Failure. Journal of Marketing 43 93–103.

Robert G. Cooper and Elko J. Kleinschmidt .1995: Performance typologies of new product projects Industrial Marketing Management 24 439-456.

Rögnvaldur Hannesson .2003: Aquaculture and Fisheries. Marine Policy Vol 27, Issue 2, Pp 169-178.

Shaffer R.V. and Nakamura E.L. 1989: Synopsis of biological data on the cobia *Rachycentron canadum* (Pisces: Rachycentridae). NOAA Tech. Rep. NMFS 82. 21 p.

Shannon L.V. 1985: The Benguela ecosystem. 1. Evolution of the Benguela, physical features and processes. In: Barnes, M. (Ed.), Oceanography and Marine Biology: An Annual Review 23. Aberdeen University Press, Aberdeen, pp. 105–182.

Shannon L.V, Agenbag J.J and Buys M.E.L. 1987: Large- and mesoscale features of the Angola-Benguela front. *In*: Payne, A.I.L., Gulland, J.A. and Brink, K.H. (Eds) 1987. The Benguela and Comparable Ecosystems, South African Journal of Marine Science, Cape Town, pp. 11–34.

Shell Clarke.2004: Understanding the pressures on Fishery resources through trade statistics: A pilot study of four products in the Chinese dried seafood market, Fish and Fisheries 5 53-74.

Su M.S, Chien Y.H. and Liao IC.2000: Potential of marine cage aquaculture in Taiwan: Cobia culture. *In* Cage Aquaculture in Asia: Proc. of the First International Symposium on Cage Aquaculture in Asia

Sylvester J. R.1972: Possible Effects of Thermal Effluents on Fish: A Review Environ. Pollut. 3 205-215

Svennevig Niels.2001: Farming of cobia or black kingfish (*Rachycentron canadum*) available online at http://www.enaca.org/Grouper/News/2001/02/Cobia-Neils.htm.

Tzen S.C. 2000: Net-cage culture in Taiwan. Fish World, August 2000, pp. 14-21.

Toro E.Jorge, Paredes I. Pamela and Villagra J. Dario.1999: Phytoplankton distribution and oyster, *Ostrea chilensis* (Philippi 1845), growth at Putemun Channel, southern Chile. New Zealand Journal of Marine and Freshwater Research, 1999, Vol. 33: 499-513

Vaught Shaffer R and Nakamura E. L. 1989: Synopsis of biological data on the cobia *Rachycentron canadum* (Pisces: Rachycentridae). NOAA Technical Report NMFS 82, FAO Fisheries Synopsis 153

Walden Jon.2003: The Atlantic Cod, the Potential for Farming in Shetland. Fisheries Information Note No. 3. Available online at www.aquamedia.com (Accessed 04/01/05)

Walne P.R. and Davies G. 1977: The effect of mesh covers on the survival and growth of *Crassostrea gigas*, Thunberg, grown on the sea bed. Aquaculture 11 313-321.

Watson J. B. 1922: The ideal executive. Address presented to the graduating class of young executives, R. H. Macy Co. Typescript contained in the John Broadus Watson Papers, Manuscript Division, Library of Congress, Washington, DC, 20 April 1922

Weeks S.J, Currie B, Bakun A. and Peard K.R., 2004: Hydrogen sulphide eruptions in the Atlantic Ocean off southern Africa: implications of a new view based on SeaWiFS. Deep Sea Research Part I: Oceanographic Research Papers, Feb 2004.

West S, Jansen J. H. F. and Stuut J. B. 2004: Surface water conditions in the Northern Benguela Region (SE Atlantic) during the last 450 key reconstructed from assemblages of planktonic foraminifera. Marine Micropaleontology 51 321-344.

Wildhaber L. Mark and Lamberson J. Peter. 2004: Importance of the habitat choice behavior assumed when modeling the effects of food and temperature on fish populations. Ecological Modelling 175 395–409

Zhang Xiaoshuana, Hu Taoa, Brain Revell and Fu Zetian.2005: A forecasting support system for aquatic products price in China Expert Systems with Applications 28 119-126.

Appendix: Tables

Table I: Biomass and Biomass value calculation results at 0.16 mortality rate, the same was done at the 0.016 mortality rate

Months	Number of Oyster	Mean Weight Per Oyster(g)	Biomass(tones)	Nominal Biomass Value (Price * Biomass)
January	1,200,000,000	0.5	600.0	1,000,000.000
February	1,008,000,000	1.96	1975.7	59,270,400.000
March	846,720,000	6.17	5224.3	156,727,872.000
April	711,244,800	13.32	9473.8	284,213,422.080
May	597,445,632	21.29	12719.6	381,588,525.158
June	501,854,330	29.15	14629.1	43,887,1612.355
July	421,557,637	34.2	14417.3	432,518,136.526
august	354,108,415	37.57	13303.9	399,115,595.526
September	297,451,069	38.77	11532.2	345,965,338.738
October	249,858,898	42.24	10554.0	316,621,195.846
November	209,881,474	51.91	10894.9	326,848,420.269
December	176,300,438	69.95	12332.2	369,966,470.394

Table II: Net cash flow calculation Results at 0.16 mortality rate

Months	Biomass Value (Discounted) $\frac{v}{(1+r)^t}$	Maintenance cost (Discounted) $\frac{C}{(1+r)^t}$	Harvesting Cost (Discounted) $\frac{C}{(1+r)^t}$	Net Cash Flows
January	17,821,782.18	1,188,118.812	3,564,356.44	13,069,306.93
February	58,102,538.97	3,873,502.598	11,620,507.79	42,608,528.58
March	152,118,528.47	10,141,235.231	3,042,3705.69	111,553,587.54
April	273,123,512.26	18,208,234.150	54,624,702.45	20,029,0575.66
May	363,068,388.47	24,204,559.232	72,613,677.69	266,250,151.55
June	413,436,911.31	27,562,460.754	82,687,382.26	303,187,068.29
July	40,341,7474.93	26,894,498.328	80,683,494.99	29,583,9481.61
August	368,576,556.30	24,571,770.420	73,715,311.26	270,289,474.62
September	316,329,887.01	21,088,659.134	63,265,977.40	231,975,250.48
October	286,633,038.18	19,108,869.212	57,326,607.64	210,197,561.33
November	292,961,991.12	19,530,799.408	5,8592,398.22	214,838,793.49
December	328,326,457.53	21,888,430.502	6,5665,291.51	240,772,735.52