

National Aquaculture Master Plan for Namibia Part 2: Freshwater aquaculture

Section 2: Situation analysis and challenges for developing the potential of freshwater aquaculture in 12 regions of Namibia



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Compiled for
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For
Ministry of Fisheries and Marine Resources
Republic of Namibia

April 2012

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Abbreviations and Acronyms

AA	Aquaculture Act 2002
BC	Blue Claw
BEE	Black Economic Empowerment
BW	Body Weight
CAPEX	Capital Expenditure
DA	Directorate of Aquaculture
DET	Department of Environment and Tourism
DM	Dry Matter
DO	Dissolved Oxygen
DOA	Department of Agriculture
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EUS	Epizootic Ulcerative Syndrome
FAO	Food and Agriculture Organization of the United Nations
FCR	Food Conversion Ratio
FW	Freshwater
GAP	Good Aquaculture Practice
GIS	Geographic Information System
GMP	Good Management Practice
GRN	Government of the Republic of Namibia
GS	Government Sector
HACCP	Hazard Analysis and Critical Control Points
IAC	Inland Aquaculture Centre
INFOSA	INFOPECHE Unit in the SADC Region
KIFI	Kamutjonga Inland Fisheries Institute
LRF	Legislation and Regulatory Framework
MAS	Motile Aeromonas Septicaemia
MET	Ministry of Environment and Tourism
MFMR	Ministry of Fisheries and Marine Resources
MT	17 α Methyltestosterone
MTI	Ministry of Trade and Industry
NAMP	National Aquaculture Master Plan
NAMP-FW	National Aquaculture Master Plan for Freshwater Aquaculture
NAP	Namibia's Aquaculture Policy
NASP	Namibia's Aquaculture Strategic Plan (2004)
NDP	National Development Plan
NGO	Non-Governmental Organization

NPC	National Planning Commission
OC	Orange Claw
OIE	World Organisation for Animal Health
OPEX	Operating Expense
PL	Postlarvae
PPP	Public-Private Partnership
PS	Private Sector
RAS	Recirculating Aquaculture Systems
SADC	Southern African Development Community
SEA	Strategic Environmental Assessment
SGR	Specific Growth Rate
SMME	Small, Medium and Micro Enterprise
SSC	South-South Cooperation
SWOT	Strengths, Weakness, Opportunities and Threats
TAS	Turnaround Strategy
TNA	Training Needs Assessment
TOR	Terms of Reference
TSP	Triple Super Phosphate
UN	United Nations

Master Plan for Freshwater Aquaculture in Namibia (hereafter called NAMP-FW) is advocated to kick-start production.

1.2 Objectives of this Study

The purpose of the feasibility study (Part 2, Section 2) is to determine the potential of inland freshwater fish farming in 12 regions of Namibia shown in Figure 1. Specifically, the objectives were to conduct:

- i. An in-depth situation analysis;
- ii. Technical evaluation of freshwater aquaculture in 12 Namibian regions;
- iii. Socio-economic evaluation of freshwater aquaculture; and
- iv. Mitigation of fish farming risks identified as serious.

1.2.1 Outline of tasks and location of outputs

The tasks for assessing the potential of inland freshwater fish farming in 12 regions of Namibia were:

No.	Consultancy Tasks	Outputs: subsection
Situation Analysis		
1	Identify areas with ongoing freshwater fish farming	5
2	Analyse successes in initiatives conducted to date in Namibia	3,5,6
3	Analyse constraints to freshwater fish farming to date	4,5,6,7,9
Technical Evaluation of Freshwater Aquaculture in 12 Namibian regions		
4	Determine the physico-chemical properties of the water (dams, rivers, springs, wells)	4, 14
5	Identify native and non-indigenous species most likely to succeed at sites identified	16,18
6	Identify the species recommended to be farmed and their ecological risks	18,19
7	Identify required infrastructure to carry out viable fish farming and fingerling supply, and materials and technology required	17
8	Look into possibility of integrated aquaculture and green scheme projects	7,8,9
9	Indicate feed availability of suitable feeds, sources of feeds and transport costs	13
10	Propose the aquaculture method most likely to be successful	14
Socio-Economic Evaluation of Freshwater Aquaculture		
11	Identify all stakeholders and undertake consultations on the needs, constraints, scope and desired results of fish farming per region/area	9
12	Analyse the potential impact of aquaculture in a gender perspective. It should, in particular, take into consideration that in some of the northern regions 60% of family heads are women.	10
13	Identify training needs and skills for the community/small-scale fish farmer/business entrepreneur to effectively run a fish farm	11,12
14	Prepare fish farming yield projections based on various stocking models and make recommendations on appropriate stocking densities	15
15	Indicate feasibility of processing of fish offal into other products such as fishmeal and include costs into the overall costing of the project	19

No.	Consultancy Tasks	Outputs: subsection
16	Ensure that all components necessary to ensure the smooth running of a fish farm are included in the design	12,20
17	Identify markets for products and use indicative market prices in the feasibility calculations	10,18,
18	Assess market demand for Namibian-grown freshwater fish on a commercial scale	10,18
19	Make a recommendation on the minimum production in tonnes of fish per year to render a fish farm economically feasible. Take into account servicing of capital costs, running expenses and personnel expenses.	20
20	Collect data for economic and technical feasibility analysis, including costs of production, market considerations, water availability and quality, and human resource capacities to support activities etc.	20
21	Design and layout a standard farm – compile a model business plan for a commercial tilapia and catfish farm. Describe buildings and services required, and provide cost approximations which would qualify for a commercial run fish farm and a community based initiative; however, both initiatives to be commercially viable, self-sustaining and profitable.	20
22	Identify pilot areas where the conditions are most favourable to the development of inland fish farming. The criteria to the selection of these pilot areas should include, in particular, the environmental conditions (access to water) and the existence of a significant number of fish farmers (clusters).	4,8
23	Produce one model business plan following the Bank's format.	20
Risk Mitigation		
24	Propose mitigation steps for risks that are identified as "serious" and assess the impact on the water resource caused by fish farming per region or site. Indicate mitigating measures planned into the design of a fish farm to counter the envisaged problems.	19

1.3 Development Process for the NAMP-FW: Structure of this Document in Relation to Consultancy Tasks

Aquaculture development deals with several **interrelated and cross-cutting** technical and socio-economic issues and thus many topics within the consultancy tasks cross refer to one another. Therefore, although the 24 tasks presented above are addressed in this document, their outputs may not be presented as independent tasks described in the order above. Instead an approach and order typical for developing a sector were used and outcomes are presented as three main clusters: situation analysis (Subsections 3-8), developing the NAMP-FW (Subsection 9) and challenges and considerations for promoting the NAMP-FW (Subsections 10-20) in this document and cross-referenced with consultancy tasks under "Outputs" above.

To place Namibian aquaculture in context, a summary of global and regional perspectives of aquaculture development and production is presented. A situation analysis was then conducted, initially through literature review to present the freshwater aquaculture status and developments in Namibia to date. Additionally, information on potential geo-physical areas where aquaculture may be feasible was assessed. This was followed by extensive field visits to assess (i) current private

aquaculture initiatives, (ii) government aquaculture centres and community fish farms and (iii) potential sites for future aquaculture development. The above assessments were contextualized with a series of six regional stakeholder workshops representing 12 regions where freshwater aquaculture exists or is being considered. These consultative workshops generated regional SWOT (strengths, weakness, opportunities and threats) analyses which were used to distil a national SWOT analysis table. The national SWOT table and outputs of tasks were principally used to construct the National Aquaculture Master Plan for Freshwater Aquaculture (Part 2, Section 1), the principal outcome of this exercise.

The promotion and implementation of the National Aquaculture Master Plan for Freshwater Aquaculture presents country-specific challenges and considerations for its implementation. To support and guide the implementation process a second cluster of relevant supporting assessments ranging from market demand and potential, human capacity and training needs, potential production systems and technical requirements, modelling of farm yield, identification of potential species for freshwater farming and a basic business model were made and presented.

2 OVERVIEW OF THE GLOBAL AQUACULTURE SECTOR

2.1 Definition and Classification of Aquaculture

Aquaculture is often not clearly defined leading to confusion in legislation and regulations and therefore for this assignment the internationally accepted Food and Agriculture Organization of the United Nations (FAO) definition is recommended for adoption in Namibia.

“Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. Aquatic organisms which are harvested by an individual or corporate body who has owned them throughout their rearing period contribute to aquaculture while aquatic organisms which are exploitable by the public as a common property resource, with or without appropriate licenses, are the harvest of fisheries.” (Rana, 1997).

Furthermore, it should be noted that all economic activities are internationally agreed and harmonized by the UN Statistical Division under “International Standard Industrial Classification of All Economic Activities” to which Namibia is a signatory. Aquaculture is classified under Section A: Agriculture, Forestry and Fishing and not under Section B: Manufacturing (<http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=27&Lg=1>). As such, aquaculture is classed as a farming, rather than an industrial, activity. This harmonized classification is also used by Customs and Excise Authorities.

2.2 Preamble

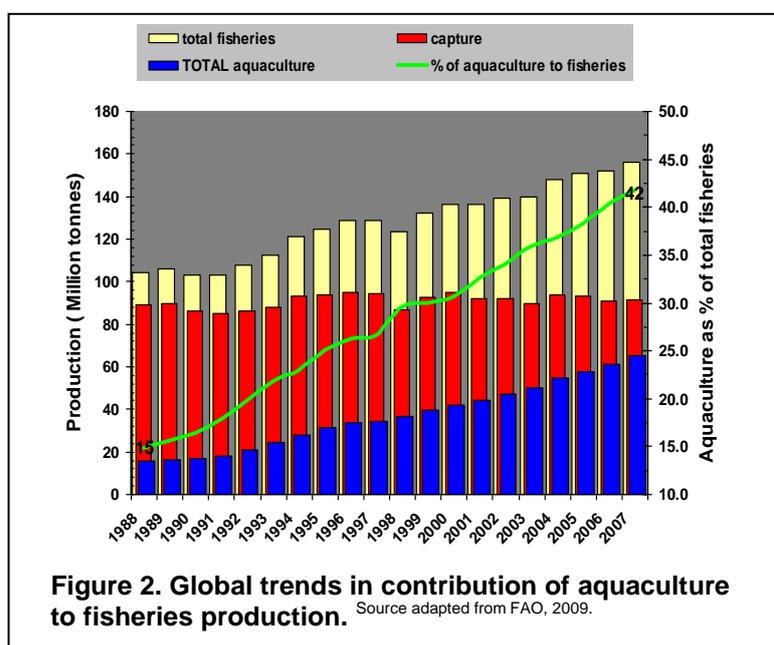
It is useful to understand the current position of Namibia in relation to global aquaculture production in order to contextualize the challenges Namibia faces in promoting aquaculture and creating and ensuring the enabling regulatory environment required to optimize its opportunities, and to actively contribute to world and regional aquaculture. In doing so Namibia should craft a clear and succinct path and take due cognizance of the similarities and differences between itself and a range of countries engaged in successful aquaculture, with respect to, in particular, (i) climate, (ii) water availability and access, (iii) nature and topography of land and coastline, (iv) market dynamics and (v) socio-economic environment.

2.3 Global Overview: Scale, Diversity and Recent Profile of Aquaculture

Whilst the global demand for aquatic products is increasing, wild harvest fisheries, facing considerable pressure, are either remaining stagnant or declining. It is now internationally accepted that an increased supply of fish products to meet this demand cannot be sourced from wild fisheries. Nations around the world are seeking alternative technologies to farm a range of aquatic organisms in order to meet their local and international demand.

National achievements in aquaculture development (as production), however, vary notably with a strong geographic bias towards Asia. This uneven historic pattern is a function of several cumulative and synergistic primary factors between enabling regulatory environments, enforcement and industry driven **voluntary codes** and (i) tradition of fish cultivation and eating habits, (ii) favourable climate, (iii) availability and access to suitable water and land resources and sites and (iv) easily accessible markets. In those countries where this equilibrium is perturbed, the rate of aquaculture development at the micro and macro level has been compromised.

In 2009, global aquaculture production reached 73 million tonnes growing at an annual rate of 8-10% since 1998, while increasing its proportional contribution to total fisheries around threefold in two decades. In 1988, aquaculture contributed only 15% of total global fisheries production but this had risen almost threefold in 2007 (Figure 2) and by 2009 reached 45% of total



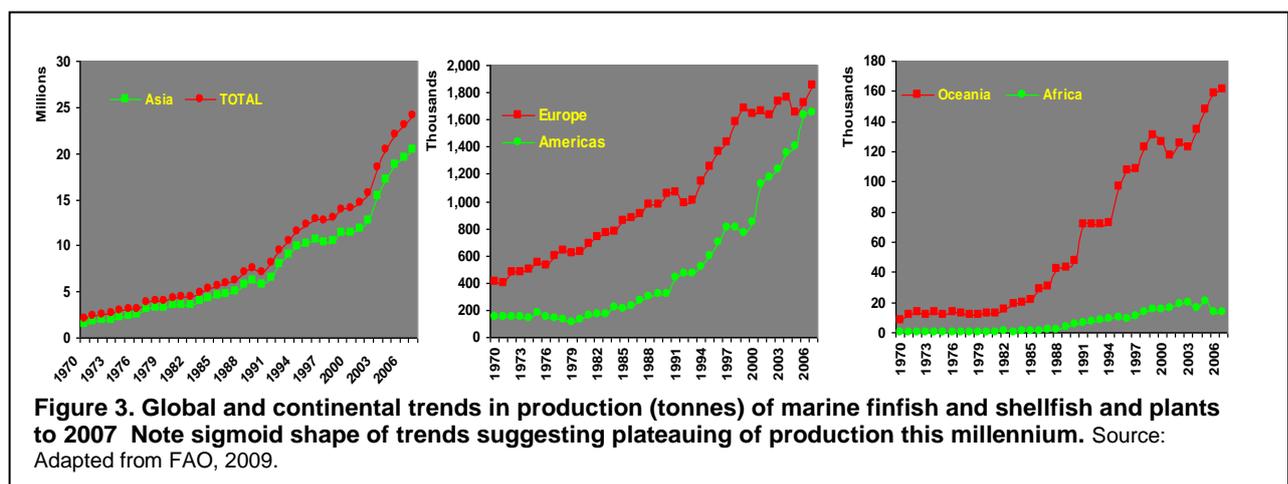
fisheries production. This contribution, however, is largely an Asian phenomenon, as Asia accounted for 67 million tonnes or 91% of total world aquaculture production in 2009, while the Americas, Africa and Europe, contributed 4%, 3% and 2%, respectively. In terms of value, global production was valued at US\$110 billion with the Asian region's share contributing US\$89 billion or 81% of total world aquaculture value. The Asian and world contribution, however, is significantly skewed by China; when China is excluded, the contribution of Asian aquaculture output to total world

aquaculture drops dramatically from 91% to 28% in terms of quantity and 31% in terms of value.

Over the past 15-20 years, over 60 countries have engaged in the farming of approximately 220 species or species categories of aquatic animals and plants in a vast range of production systems, ranging from low-input extensive to high-input intensive aquafarms using ponds, caged enclosures and tanks. In broad terms aquaculture production systems used for the production of these aquatic animals and plants can be divided into feed-dependent systems or fed aquaculture (e.g. finfish and crustaceans) or non-fed aquaculture systems, where culture is predominately dependent on the natural environment for food, e.g. aquatic plants and molluscs.

Although there are large inter-country differences in sector growth, collectively aquaculture has achieved the highest average growth rate amongst the animal production sector, averaging around 8%/year. This increasing trend is projected to continue in future decades and consequently the aquaculture sector is expected to play a significantly greater role in contributing to food security, poverty alleviation and economic upliftment of the poor.

The historic trend in aquaculture development at global as well as continental and country levels is not linear but sigmoid and typically reflects three classical phases of development: (i) a lag phase where the foundation of production is being



established, (ii) a second rapid growth phase and finally (iii) a mature, stationary or plateau phase when cumulative and crucial limiting factors including markets and competition slows or stagnates growth (Figure 3). This trend is most noticeable for culture in marine environments where access issues, site availability and environmental pressure are more likely to constrain further development and often requiring renewed government and technological interventions. Typically, in most

developing and developed countries, government interventions in aquaculture development occurred during the mature phase of the sector cycle when the contribution of aquaculture to the national economy and job creation becomes significant, warranting government intervention.

A global snapshot and profile of aquaculture production in 2007 by region and key aquaculture countries is presented in Table 1. This table also provides an assessment of scale, measure of biodiversity utilized in aquaculture and key purpose of production. In addition, the production by countries is ranked within each region, and countries included represent 80-97% of their region's total aquaculture output and 99.8% of world output. Overall, freshwater fishes are by far the most widely farmed group. An understanding of the fate of national aquatic output is valuable as it may shed some light on macro-government policy on food security and economic development.

The main destinations of national aquatic products are coded in blue and purple font in Table 1. It is noteworthy that the vast majority of species/groups of farmed aquatic products, which are freshwater fish, are destined for domestic consumption. According to FAO, around 826 thousand tonnes of freshwater fish (aquaculture and capture) entered the export market globally (FAO, 2008). This estimation includes products in all forms (fillets, fresh, frozen etc.) and therefore whole body weight equivalent is likely to be double. Nevertheless, this quantity is still a small proportion of the total freshwater production. By contrast, 30 million tonnes of marine finfish and shellfish (aquaculture and capture) were exported globally but the proportion of marine farmed finfish and shellfish is unknown. Known species of shrimps which are mainly farmed accounted for 360 thousand tonnes of exports in 2007 (FAO, 2009), but given the final product forms the whole body weight equivalents will be higher. Around 2.5 million tonnes of shrimps were farmed (Table 1). With rising living standards in many Asian countries, a greater share of these products will enter the domestic and regional markets. The species utilization and significance to food security are discussed in Subsection 2.4 - 2.6.

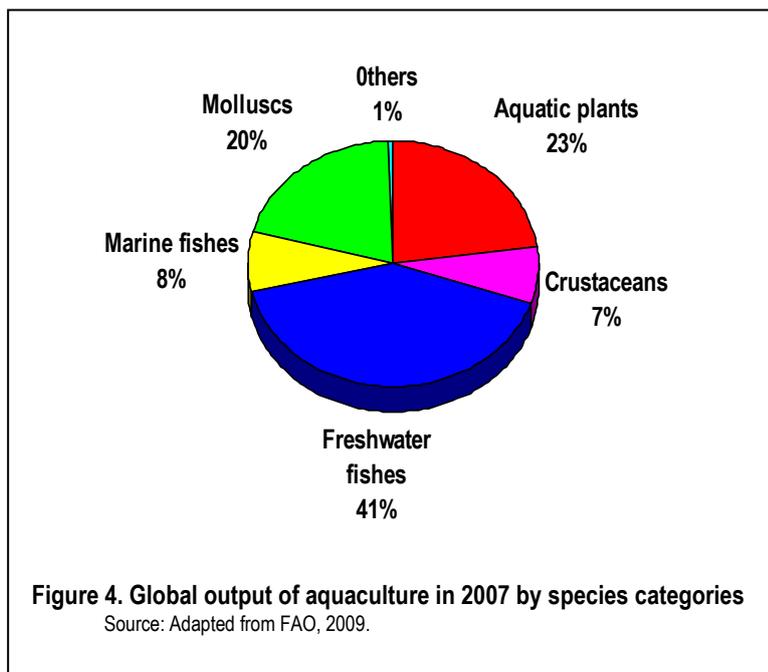
Table 1. Aquaculture production hotspots by species/clusters ranked by countries within regions. Product destination: numbers in blue-largely domestic; purple-largely exports. Green cells denote exotic species introduced for farming. Source: Data adapted from FAO, 2009

Region	Country	Production of Species/ Species Cluster in 2007 (x 1 000 tonnes)																				Country total	% of country total and regional total (% world share)
		Finfish										Shellfish						Seaweed					
		Salmon	Trout	Chinese carp	Indian carp	Common carp	Tilapia	Catfish	Milkfish	Grey mullet	Sea bream	Sea bass	Freshwater fish nei	Mitten crab	Freshwater prawn	P.monodon	P.vannamini		Clam	Oysters	Mussel & abalone		
Asia	China			11035		2228	1133	830			258	552	490	125	62	1065	3624	3509	449	9451	41173	84	
	India			295	2626			40				169		27	101						3355	97	
	Indonesia					264	248	164	263			28			133	164				1728	3121	87	
	Philippines					241			350						40					1499	2215	96	
	Viet Nam							850				680			170	153				38	2195	86	
	Thailand					190	199							28		490		22	275		1390	87	
	Bangladesh			183	462	34						180		23							946	93	
	Myanmar				125	63						340			48						605	95	
Total				11513	3213	2589	1812	2083	613		258	1949	490	78	492	1872	3624	3531	724	12716	55000	59396 (91)	
% of regions species total				19	5	4	3	4	1		0.4	3	1	0.1	1	3	6	6	1	21	93		
Americas	Chile	481	175																149		853	94	
	USA	11	24					256									27	125			526	82	
	Brazil					37	95									65					290	68	
	Ecuador						20									150					171	99	
	Canada	117	5								7							14	23		169	97	
Total		609	204			37	115	256			7					215	27	139	172		2009		
% of regions species total		24.4	8.3	0.0		1.5	4.7	10.4			0.3					8.8	1.1	5.7	7.0		81	2454 (3.7)	
Africa	Egypt						266		253												636	82	
	Nigeria						9	52													85	72	
	Uganda						17	34													51	99	
	Madagascar					3									8						11	98	
	S. Africa		1				0.25											0.8	1.27	3	6	82	
Total			1			3	292	86	253						8				0.5	3	789		
% of regions species total			0.1			0.4	36	10.4	30.7						1.0				0.1	0.4	95	823 (1.3)	
Europe	Norway	736	73																		830	98	
	Spain		25							20	9									210	281	94	
	France		33															111		73	238	91	
	Italy		38							8	9						62			58	179	98	
	UK	130	15																	25	174	98	
	Greece									50	35									22	113	94	
	Russia		14	24		44															106	78	
	Ireland	10	0.8																8	37	57	96	
Total		876	203	24		44			78	53							62	119	425		1998		
% of regions species total		37	9	1		2			3	2							3	5	18		91	2340 (3.6)	
Oceania	New Zealand	9.4																3	99.5		112	99	
	Australia	25																15			54	74	
Total		34.4																		18	99.5	166	
% of regions species total		20																10	58		97	172 (0.3)	

2.4 Global and Country Profiles of Biodiversity in Aquaculture

Although over 200 species/species clusters are farmed, the majority of production stems from a relatively few species and species clusters producing aquatic products with minimum impact on the environment when compared with other food production sectors such as agriculture and livestock, whilst still maximizing benefits to society.

In 2007, freshwater fish accounted for 41% of global production, whilst the remaining 59% of production was of marine origin (Figure 4). Of this 59%, around 70% were aquatic plants and shellfish which are not dependent on feed (except abalone) and therefore actually remove nutrients such as nitrogen and phosphorus originating from



anthropogenic activities, especially agriculture and sewage. Seaweeds and algae utilize these nutrients for growth and shellfish filter the resultant algae as food. Similarly, freshwater and marine fish species that filter algae and zooplankton can also have the same positive impact. This removal of nutrients from the water reduces the risk of coastal algal blooms and ameliorates the negative impacts of the agricultural sector, which is a significant contributor of these nutrients through the use of fertilizers. Indeed, in 2007, over 200 million tonnes of fertilizers (NPK) were used globally in agriculture; much of this eventually enters the aquatic environment, both through runoff and via groundwater. Similarly, in South Africa over 2.5 million tonnes were applied to land in 2006.

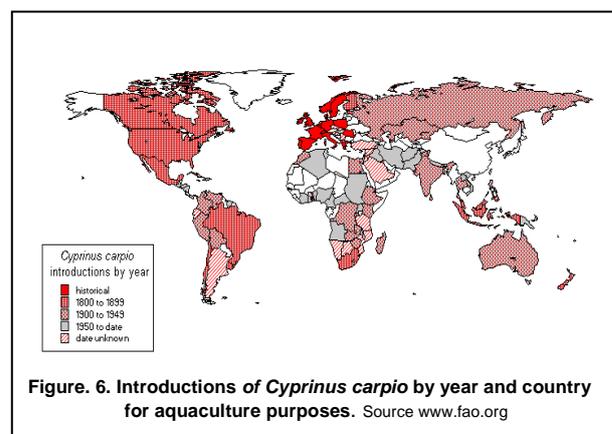
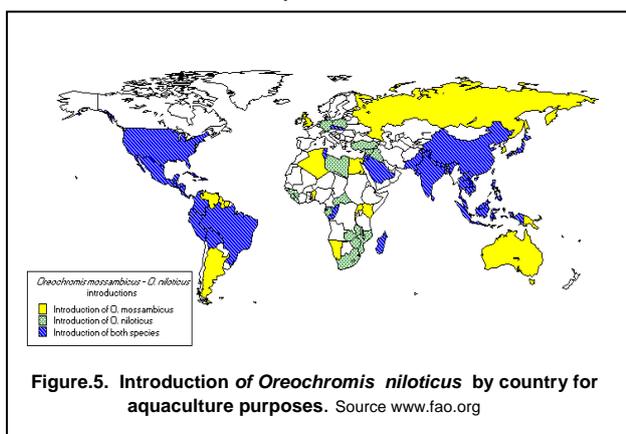
2.5 Range of Species/Clusters Used in Aquaculture around the World

In 2007 around only a dozen species/species groups accounted for almost all the world's finfish production (Table 1). In Asia, 35% of aquaculture production was accounted for by only three species groups, Chinese and Indian carps, tilapia and catfish, with seaweeds accounting for 21%. Apart from shrimps in Asia and catfish in Viet Nam, aquaculture production is largely for local consumption. Also recently a notable proportion (133 000 tonnes in all forms in 2006) of tilapia is being exported

from China. In the Americas, salmon, trout and catfish predominate, accounting for 43% of the region's production. In Chile, salmonids, destined for export markets to the USA, Japan and Europe dominated aquaculture production, whilst in the USA catfish was produced predominately for the domestic market. In Europe, almost half (46%) of the region's production originates from just two species i.e. salmon and trout and, in both cases, most is exported, but largely within the European region. Species diversity within Africa is also narrow, with over 77% of regional production originating from three species; tilapia (*Oreochromis niloticus*), catfish and mullet, all for domestic consumption, with Egypt being the focus of production. Similarly, in Oceania, two species i.e. salmon and mussels account for nearly 80% of the region's production, with mussels mainly exported. Around half of the salmon farmed in Australia and New Zealand are consumed domestically.

2.6 The Utilization of Exotics or Introduced Species in Aquaculture

While recent attention has focused on the negative impacts of introduced or exotic species, it is important to note that, on balance, the culture of these species can offer significant economic and social benefits (FAO: http://www.oceansatlas.com/world_fisheries_and_aquaculture/html/resources/aqua/introspec/default.htm). The significance of such introductions to national production in all continents is shown as green cells in Table 1. It is noteworthy that species were introduced into every continent and, in most cases, have made a significant national contribution to food and economic security. Of all continents, Africa, including South Africa, introduced the least number of species and is also the least productive in the world. Fish and shellfish have been historically, as well as recently, introduced in both developed and developing countries. The extent of movement of tilapias carps around the world for aquaculture purposes is illustrated in Figures 5 and 6. In Asia, around 11 to 40 species have been introduced. In North and South America between



6 and 40 species were introduced, while in Europe between 6 and 20 species were introduced for aquacultural purposes.

To date these exotic species account for around 25% of world finfish and shellfish production (see Table 1: green cells). Rainbow trout have been introduced for food or sport to at least 45 countries outside their natural range with over half a million tonnes produced in 2007. Although indigenous to Africa, tilapias are now widespread in all countries of the subtropical and tropical region (Figure 5) and in 2007 these countries produced around 2 million tonnes of relatively low cost protein for domestic consumption. Similarly, the common carp introduced to most countries outside its native Europe since the late 1800s (Figure 6) accounted for 2.7 million tonnes of fish production in 2007 for domestic consumption. The salmonids, introduced to Chile, now support a thriving aquaculture industry that is responsible for approximately 20% of the world's farmed salmon and directly employs approximately 30 000 people, although recently has suffered huge losses due to inadequate biosecurity surveillance. The Pacific oyster, native to Japan, was introduced to around 30 countries (including the UK, France, USA, Canada, Korea, China and New Zealand) where around 4 million tonnes were produced in 2007.

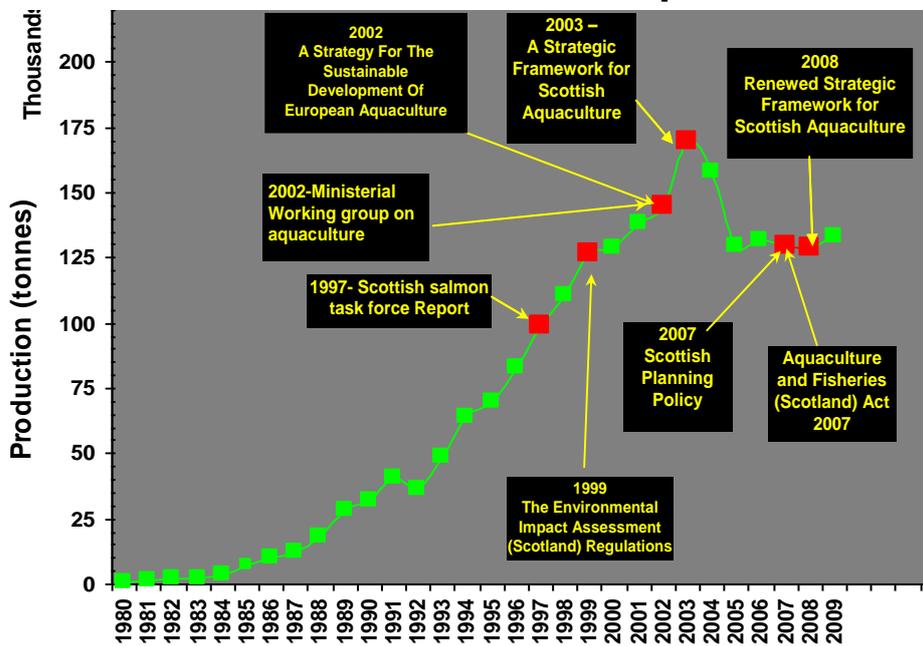
2.7 Regulatory Environment for Aquaculture in Developing and Developed Countries: Assessment of Government Interventions

2.7.1 When and where government interventions have occurred

All countries regulate economic activities, including aquaculture, to ensure orderly development. The degree of interventions and timing along their develop trajectory, however, varies widely between countries (also see Figure 3). The roadmaps charting the legal milestones for a developed country such as Scotland and a developing country such as India are presented in Figure 7. In these and many other developed and developing countries aquaculture has successfully developed without **specific** legal and regulatory frameworks. Interventions occur near the mature phase of the development cycle. In these and other examples (Rana, 2011) it is clear that government interventions occurred during the mature phase of the sector cycle when contribution to national economy and job creation becomes significant, **warranting** government intervention. This occurs when production reached 70-80% of maximal production of the countries. It is therefore important to understand the national or, in the case of the EU, the regional context of these interventions, as the reasons for interventions may be country/region specific. In developed regions, e.g. Europe, restricted access to new natural resources (e.g. sites and water), competition, food safety and environmental pressure were key challenges requiring action to spur on growth. Such interventions and outcomes which are country or regional specific are often considered as international benchmarks and used as such by other countries. Applying such models and their outcomes without due consideration to freshwater aquaculture development in Namibia is therefore likely to be disabling.

In many instances countries, especially developing countries, inadvertently apply such models, often with the assistance of regional and international agencies, without due consideration of national relevance. In doing so prematurely, development is hamstrung often due to inability of mandated institutions to implement and legal compliance is compromised creating a disabling environment.

Scottish Roadmap



Indian Roadmap

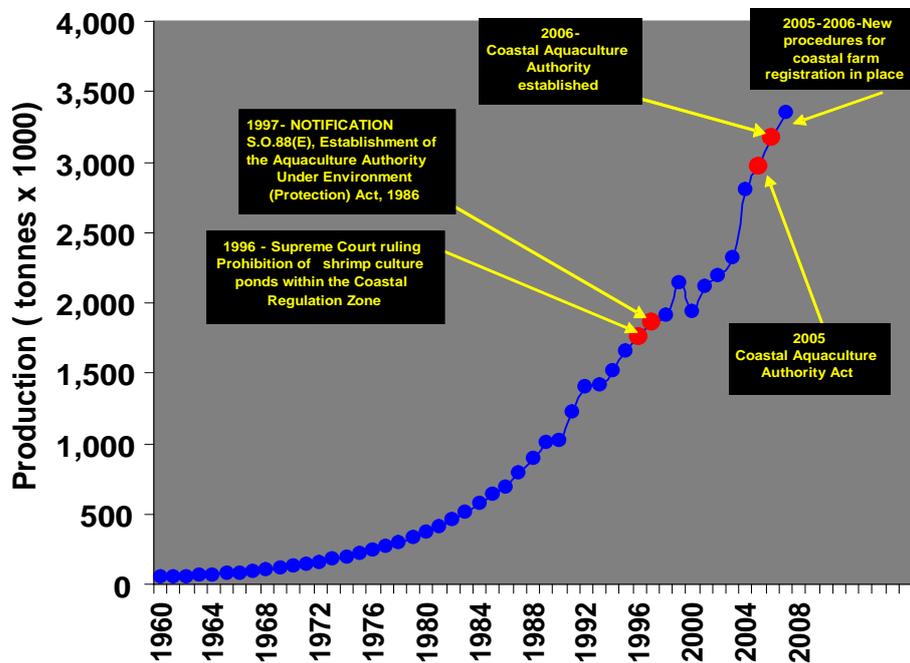


Figure 7. Road map of the key interventions for developing aquaculture and resulting key legislation and regulations for Scotland and India.

Source: adapted from Rana, 2011.

2.8 Aquaculture in Africa

In spite of its vast natural and human resources, Africa's contribution to global aquaculture production is extremely low. Additionally, aquatic species indigenous to Africa (e.g. prawns, tilapias, catfishes and abalone) have developed into aquaculture species of international importance outside Africa.

Africa contributed only 2% of global aquaculture production for 2009 and much of this production originated from Egypt (705 000 of 1.1 million tonnes). However, in line with global trends, the aquaculture industry in Africa, although small, has also experienced considerable growth. For example, during the period 1997 to 2007 aquaculture production in sub-Saharan Africa increased from 55 000 tonnes to 193 000 tonnes.

Fish supply cannot currently meet the regional demand. Throughout Africa, per capita consumption of fish has decreased by an average of 2.1 kg/person/year over the last two decades and marine fish imports have increased by 177% during this period. The increasing price of fish has clearly been influenced by this supply deficit which has driven the development of commercial aquaculture (FAO, 2006).

Subsistence aquaculture farming in sub-Saharan countries plays an important role in contributing towards household food security, improved nutrition and rural employment. Cash income from aquaculture production contributes to general household costs and living expenses. Such aquaculture production, however, is unlikely to make significant contributions to fish supply on a national basis in the short to medium term. However, most countries in sub-Saharan Africa consider aquaculture to have a positive effect on sustainable and improved livelihoods, opportunities for employment and income and poverty alleviation at a family level in disadvantaged rural areas (FAO, 2006).

Aquaculture production in sub-Saharan Africa contributes less than 2% of the total fish supply. Based on 1997 levels, aquaculture production would have to increase by 267% by 2020 to maintain the current consumption level in Africa. Since wild fisheries cannot meet the demand for fish, aquaculture will have to play a pivotal role in supplying fish to meet demand in the region (FAO, 2006).

2.8.1 Recent initiatives in regional aquaculture development

Attempts by donor and other agencies to have a positive impact on African aquaculture production were evidently limited. The African Development Bank

(AfDB) is a major driver for developing capture fisheries and aquaculture in the region. By 2005 it supported 21 projects to the value of around USD 383 million but with a focus on capture fisheries. Only 8 of these projects were on aquaculture totalling around USD 4 million. Overall the projects are reported as having limited success (<http://www.afdb.org/fileadmin/uploads/afdb/Documents/Evaluation-Reports/Review%20of%20the%20Performance%20of%20the%20Current%20Fisheries%20and%20Aquaculture%20Portfolio%20of%20the%20African%20Development%20Bank%20EN.pdf>).

Following a recent review of constraints faced in aquaculture development in the region, NEPAD (New Partnership for Africa's Development) launched "The NEPAD Action Plan for the Development of African Fisheries and Aquaculture" in 2005 (http://siteresources.worldbank.org/INTARD/Resources/ACTION_PLAN_endorsed.pdf), which reinforced known constraints and challenges for developing regional aquaculture and promotes improved productivity through expansion and intensification of aquaculture, promoting environmental sustainability, and market development and trade and ensuring food security and nutrition.

The objective of the GRN is to promote freshwater aquaculture production targeted primarily to ensure food security in local communities, as well as for local, regional and international markets whilst creating opportunities for income generation and improved rural livelihoods through a pro-poor policy. The GRN will draw on relevant aspects of The NEPAD Action Plan for the Development of African Fisheries and Aquaculture to meet these objectives and priorities.

2.9 Status of Freshwater Aquaculture in Namibia

Although inland (freshwater) aquaculture in Namibia is reported to have commenced in the late 1800s, it has only been promoted in earnest since 2003. Post-independence studies by aquaculture experts from a number of countries indicated that Namibia's fledgling aquaculture sector has a place in the socio-economic development of the country (Namibia, Office of the President, 2004).

Initial promotion of freshwater aquaculture was mainly to enhance food security by facilitating the provision of fingerling production to farmers and rural communities for fish farming but this approach is shifting towards encouraging economic activity in freshwater aquafarming.

To realize this potential the government has undertaken a series of coordinated freshwater initiatives to maximize the potential of aquaculture with a pro-poor focus. With an established stable political and business climate the GRN in 2000 was advised to establish an **aquaculture policy and legal framework** to promote

rights-based aquaculture. To obtain a national perspective on the potential and scope for development, the government then commissioned a series of feasibility, marketing and value addition studies. To support technical development, the government established a series of Inland Aquaculture Centres (IACs) and farms in the Omusati and Oshana, Kavango and Otjozondjupa, and Caprivi Regions in the north and Khomas and Hardap Region in the south. To encourage production, a fish feed plant with an annual capacity of 1 200 tonnes was established with the assistance of the Spanish Government in Omahenene. The status of aquaculture in Namibia is elaborated further in Subsection 3.

A hatchery has been constructed at the Inland Aquaculture Centre (Omahenene/Onavivi), Omusati Region with the purpose to supply small-scale farmers with fingerlings. Six community based pilot fish farming projects exist, three in the Kavango and three in the Caprivi Regions, respectively. Eco-Fish Farm successfully produces tilapia (*O. niloticus* x *O. mossambicus* hybrid) and catfish (*Clarias gariepinus*) in the Hardap Region.

Accurate data on the resulting aquaculture production from these interventions is limited but is currently estimated at around 50-100 tonnes/yr, mainly from government farms.

3 SITUATION ANALYSIS OF FRESHWATER AQUACULTURE IN NAMIBIA: Institutional Initiatives

3.1 Progress of Aquaculture Development in Namibia

The GRN has placed high priority on the development of the aquaculture sector, in particular freshwater aquaculture, to contribute towards alleviating poverty and unemployment in rural communities. This intention is embodied in the current National Development Plans (NDP 2 and 3) as well as the country's VISION 2030 document which calls for the promotion of aquaculture activities throughout the country.

The Ministry of Fisheries and Marine Resources (MFMR), Directorate of Aquaculture and Inland Fisheries, has embarked on proactive promotion and implementation of aquaculture initiatives this millennium. This vision was translated into Namibia's Aquaculture Policy of 2001, Aquaculture Act of 2002 and five year Aquaculture Strategic Plan of 2004, followed by an intensive period of capital expenditure on infrastructure.

3.1.1 Government's overarching objectives

The primary national objective of the Government of the Republic of Namibia is to increase economic activity in the rural areas where unemployment can exceed 50% and to promote food security and poverty reduction. Freshwater aquaculture (and inland capture fisheries) is perceived as one such economic activity to address this national objective.

Acknowledging the populous north, the GRN's aim was to achieve social and economic benefits for 90% of the households living along the perennial rivers and seasonal rain-filled pans in the northern provinces. The MFMR developed aquaculture projects in four of these northern regions, namely Kavango, Caprivi, Omusati and developed small-scale community based fish farms in Otjozondjupa, Omaheke, and Oshana Regions. In addition, projects in the south viz in Hardap and Khomas Regions were also initiated. These initiatives together with the main intended activity location, species focus and production systems are listed below in Table 2.

Table 2. Current and proposed government initiatives to promote aquaculture across the different regions in Namibia

OMUSATI AND OSHANA REGION

INITIATIVE	PRIMARY ACTIVITY	LOCATION	SPECIES FOCUS	PRODUCTION SYSTEM CONSIDERED
Epalela Fish Farm	On-growing	Olushandja Dam	Tilapia, catfish	Semi-intensive flow-through ponds
Onavivi Inland Aquaculture Centre, MFMR	Hatchery, on-growing	Omahenene	Tilapia, catfish	Semi-intensive flow-through ponds
Ongwediva Inland Aquaculture Centre, MFMR	Phase 1 complete, Phase 2 on-going	Ongwediva	Tilapia, catfish	Labs complete, semi-intensive flow-through ponds under construction

KAVANGO AND OTJOZONDJUPA REGION

INITIATIVE	PRIMARY ACTIVITY	LOCATION	SPECIES FOCUS	PRODUCTION SYSTEM
Kamutjonga Inland Fisheries Institute (KIFI), MFMR	Research, hatchery, training	Kamutjonga	Freshwater species	Intensive recirculation tanks, semi-intensive ponds
Rundu Extension Office, MFMR	Extension, hatchery under development	Rundu	Tilapia, catfish	Recirculation
Mpungu Fish Farm	Community farming	Kurenkuru	Tilapia, catfish	Semi-intensive flow-through ponds and integrated irrigation
Karovo Fish Farm	Community farming	Kangongo	Tilapia, catfish	Semi-intensive flow-through ponds and integrated irrigation

CAPRIVI REGION

INITIATIVE	PRIMARY ACTIVITY	LOCATION	SPECIES FOCUS	PRODUCTION SYSTEM
Katima Mulilo Extension Office, MFMR	Extension services	Katima Mulilo	Tilapia, catfish	N/A
Likunganelo Fish Farm	Community farming	Lisikili	Tilapia	Semi-intensive flow-through ponds & integrated irrigation
Kalimbeza Fish Farm	Community farming	Isize	Tilapia	Semi-intensive flow-through ponds & integrated irrigation

KHOMAS AND HARDAP REGION

INITIATIVE	PRIMARY ACTIVITY	LOCATION	SPECIES FOCUS	PRODUCTION SYSTEM
MFMR Head Office	Regulatory	Windhoek	N/A	N/A
Eco-Fish Farm	Commercial	Hardap Dam, Mariental	Red tilapia, catfish, common carp	Intensive tanks and ponds in agricultural tunnels, flow-through
Hardap Inland Aquaculture Centre, MFMR	Hatchery, Extension services	Hardap Dam, Mariental	Tilapia, catfish, common carp	Tanks and ponds, flow-through
Leonardville Fish Farm	Under development	Leonardville	Tilapia, catfish	Intensive recirculation tanks

Source adapted from Kibria, pers. comm.

Table 3. Annual development budgets for specific activities in freshwater aquaculture development in Namibia

DEVELOPMENT BUDGET FOR AQUACULTURE	Fiscal Year¹ (N\$ millions)						
	03-04	04-05	05-06	06-07	07-08	08-09	TOTAL
Kamutjonga Inland Fisheries Institute	0.00	3.00	7.00	10.93	9.00	12.00	41.93
Aquaculture Development Project Olushandja Dam/Onavivi	1.00	1.50	4.00	4.40	4.10	18.35	33.35
Aquaculture Development Project in Caprivi	3.00	1.00	0.50	0.50	6.27	0.83	12.10
Aquaculture Development Project in Kavango	3.00	0.45	0.40	0.50	6.27	0.83	11.45
Upgrading of Ongwediva Hatchery and the Construction of New Offices	0.00	0.00	0.00	0.35	4.30	5.40	10.05
Upgrading of Hardap Facilities /Ponds	7.10	0.00	0.00	0.35	0.00	0.20	7.65
Leonardville Fish Farming Project	0.00	0.00	0.00	0.35	0.00	3.00	3.35
Construction of MFMR Regional Office in Caprivi	0.00	0.00	0.00	0.35	1.50	0.00	1.85
Construction of MFMR Regional Office in Kavango	0.00	0.00	0.00	0.35	1.50	0.00	1.85
Aquaculture Development Project Lake Oponono	0.50	1.00	0.00	0.00	0.00	0.00	1.50
Upgrading of Keetmanshoop Fonteintjie Fish Farm Community Project	0.00	0.00	0.00	0.00	0.00	0.35	0.35
Construction of Noordoewer Fish Farm	0.00	0.00	0.00	0.00	0.00	0.35	0.35
TOTAL (N\$)	14.60	6.95	11.90	18.08	32.94	41.32	125.80

¹ Source: compiled by author from MFMR annual reports

3.1.2 Investment in Namibian freshwater aquaculture development

The commitment of the GRN to promote and develop freshwater aquaculture is evident in the annual development budget allocated for the various initiatives across Namibia. These have been collated and presented in Table 3. Between 2003 and 2009 over N\$125 million was spent, much of it on capital infrastructure in the way of regional offices and research centres (Figure 8) and government financed farms. It is assumed that Table 3 refers only to MFMR budgets and excludes any contribution of the Ministry of Works to these developments; the actual funds used for freshwater aquaculture development may, therefore, be significantly higher.

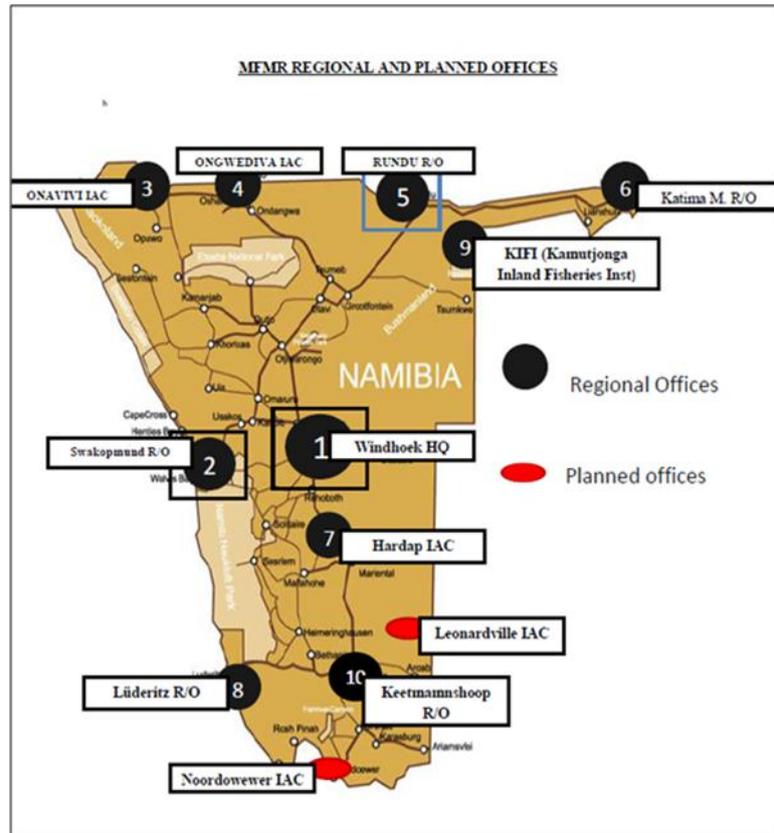


Figure 8. MFMR regional and planned offices

Around 60% of these funds, however, were spent on just two facilities: KIFI in Kavango and a research station in Onavivi. An evaluation of these facilities is provided in Subsection 6.

Outcomes of investments

The government's investments were centred on developing fingerling production centres, government and community based on-growing fish farms and research and training facilities in freshwater aquaculture (Table 2). These included:

1. Onavivi Inland Aquaculture Centre in the Omusati Region (for fingerling production and distribution, and training in aquaculture);
2. Ongwediva Inland Aquaculture Centre in the Oshana Region (for fingerling production and distribution, and training in aquaculture);
3. Hardap Inland Aquaculture Centre in the Hardap Region (for fingerling production and distribution, and training in aquaculture);
4. Epalela Fish Farm in the Omusati Region (for on-growing of fish to market size);

5. Mpungu Fish Farm at Nkurenkuru in the Kavango Region (community based fish production); and
6. Kamutjonga Inland Fisheries Institute (KIFI) at Divundu, in the Kavango Region (fingerling production, research and training in aquaculture).

The actual employment created nationally through freshwater aquaculture development is unclear. One estimate, however, suggests around 76 jobs were created within government and around 95 persons are engaged within cooperative farms. Indirect employment was estimated at over 100 (Kibria, personal communication). The team could not find much evidence of research outputs from these stations but it could be that these facilities are new and appropriate management structures are not fully operational. Nevertheless, no needs-driven freshwater aquaculture research strategy was apparent.

The total inland aquaculture production, however, was estimated at only 85 and 95 tonnes during 2007 and 2008, respectively. This output included one commercial farm (Eco-Fish Farm), small-scale fish farmers and government-funded pilot fish farms. The government-funded pilot fish farms and small-scale fish farmers produced a small proportion (10 and 12 tonnes) of total production in 2007 and 2008, respectively (Table 4). Given the degree of investment and about five years of development, this **productivity is extremely low and average fish size produced small**, but nevertheless provides a firm platform to improve production and production efficiency.

Nationally, the extension services identified and inspected 147 sites, monitored 146 farms and supplied 160 000 fingerlings to 140 farms. Of these 140 farms it would appear that in 2008 only around 35% of farms stocked were harvested, yielding around 56 500 fish weighing a total of 12 tonnes and worth N\$182 000 (Table 4). Thus the average market fish size harvested was approximately 200 g. Over 80% of the reported harvest originated from just two regions: Kavango and Caprivi. The major species farmed is probably *O. andersonii*. Based on the number of farms and fish stocked, an average of just 1 000 fingerlings/farm was distributed, suggesting that these sites are very small indeed. Such small-scale activities suggests that these activities should be classed as fish rearing rather than fish farming but offer the possibility of these activities expanding into fish farming.

Despite interest in freshwater aquaculture, government goodwill and a pro-poor aquaculture agenda, uptake appears to be limited, despite MFMR granting 47 licenses (37% of all licenses) for inland freshwater aquaculture during 2004-2009. Reasons for limited uptake are unclear but feedback from regional stakeholder workshops suggest disillusionment amongst stakeholders regarding financial rewards from aquaculture claimed by government officials that did not materialize.

Data, however, suggest the possibility of building on current achievements. Extension efforts also included advocating integrating fish rearing with agriculture or aqua-agri farming. Recent outcomes of such initiatives are presented in Table 5. Where available, data shows that farmers earned significantly more from fish sales than from vegetables suggesting that such integration, if improved, can play an

Table 4. Freshwater production data for all fish farms in all regions for 2007 and 2008¹

REGION	No. of sites identified & inspected		No. of farms inspected / monitored		No. of farmers who received fingerlings		No. of fingerlings distributed		No. of farms harvested		Total no. of fish harvested		Fish harvested (tonnes)		Value of fish harvested (N\$×1000)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
KUNENE	5	5	0	1	0	1	0	3300	0	0	0	0	0.00	0.00	0	0
OHANGWENA	16	11	23	22	16	19	43962	25520	11	6	6788	1540	0.48	0.12	7.20	1.76
OMUSATI	27	28	63	23	22	24	20547	28358	19	10	11537	9801	3.16	0.83	47.36	12.45
OSHANA	7	5	16	7	8	7	3355	6413	8	2	3365	925	0.11	0.02	1.67	0.27
OSHIKOTO	11	50	43	38	2	39	11330	62131	6	14	11782	3783	1.44	0.18	21.65	2.70
OTJOZONDJUPA	1	0	2	0	1	0	1100	0	0	0	0	0	0.00	0.00	0	0
KHOMAS	1	2	1	2	8	8	600	1680	0	1	0	500	0.00	0.11	0	1.65
OMAHEKE	6	10	4	13	12	14	1200	1900	0	7	0	1500	0.00	0.21	0	3.08
HARDAP	6	9	8	11	11	11	1400	2400	0	2	0	1760	0.00	0.40	0	6.07
KARAS	6	10	2	3	4	5	1600	3200	0	1	0	650	0.00	0.16	0	2.44
ERONGO	0	2	0	2	1	0	10000	0	0	0	0	0	0.00	0.00	0	0
KAVANGO	3	6	6	9	0	0	0	0	2	2	11360	16500	3.25	5.70	48.80	85.50
CAPRIVI	5	9	12	15	6	12	0	24000	2	2	7400	19500	2.00	4.38	30.00	65.70
TOTALS	94	147	180	146	91	140	95094	158902	48	47	52232	56459	10.45	12.10	156.68	181.62

¹ Source: adapted from Kibria, pers. comm.

Table 5. Income distribution from fish and vegetables at sites practising aqua-agri integrated activities¹

FARM NAME	2004				2005				2006				2007				2008			
	Fish (N\$)	Veg. (N\$)	Totals	% from fish	Fish (N\$)	Veg. (N\$)	Totals	% from fish	Fish (N\$)	Veg. (N\$)	Totals	% from fish	Fish (N\$)	Veg. (N\$)	Totals	% from fish	Fish (N\$)	Veg. (N\$)	Totals	% from fish
Likunganelo	0	0	0		2000	1512	3512	57	9000	2000	11000	82	8000	460	8460	95	17800	0	17800	100
Litapi	0	0	0		0	610	610	0	0	0	0		2500	0	2500	100			0	
Kalimbeza	0	0	0		4593	2203	6796	68	14900	1500	16400	91	0	0	0		0	0	0	
Karovo	2549	1034	3583	71	16577	3320	19897	83	5000	500	5500	91	12300	6900	19200	64			0	
Mpungu	0	0	0		6927	1501	8428	82	5074	400	5474	93	13000	12000	25000	52			0	
Shipapowa Mba	0	0	0		5185	60	5245	99	7439	1400	8839	84	11398	792	12190	94			0	
TOTAL	2549	1034	3583	71	35282	9206	44488	79	41413	5800	47213	88	47198	20152	67350	70	17800	0	17800	100

¹ Source: adapted from Directorate of Aquaculture, MFMR and Kibria, pers. comm.

important role in poverty alleviation and enhancing food security. On average, data suggest that at least 70-90% of farm income was derived from fish. Even though small, the income from plants, which can have a shorter production cycle, should be viewed as a mechanism to support OPEX (operating expense), a major challenge for most farmers.

3.2 Previous Feasibility Studies on Sustainable Fish Farming at Fonteintjie, Noordoewer and Divundu

As part of the government agenda to develop inland aquaculture, several feasibility studies were commissioned by the Ministry of Fisheries and Marine Resources to develop potential sites for freshwater aquaculture; two in the south and one in the north namely:

- i. The Fonteintjie Fish Farm in Keetmanshoop, Karas Region (Burmeister and Partners, 2010a)
- ii. Noordoewer Fish Farm in Karas Region ((Burmeister and Partners, 2010b)
- iii. Divundu Fish Farm in Kavango Region (Burmeister and Partners, 2010c)

These three feasibility studies, undertaken concurrently by Burmeister and Partners of Namibia, Aqua-Eco and Deep Blue Aquatic Systems of South Africa, are briefly evaluated below.

Assessment of previous feasibility studies

The initial intention was to evaluate these studies separately. On reading, however, it was clear that all three reports are almost identical with only slight differences in some sections e.g. section 2.6 and 3.1, parts of section 7 and 8 and these differences related to physical site differences whilst others were superficial. Therefore, all three studies were combined for this review. The studies provide comprehensive useful generic information on the various aspects of site development for aquaculture, in particular the physico-chemical background of the selected sites but contain critical shortcoming in design and operation for intended production.

The principal task of the studies was to conduct a feasibility study to establish the potential for sustainable fish farming with intensive production facilities and good aquaculture practice (GAP).

The consultants seem to have copied sections of the TOR from their Noordoewer study with limited due diligence. For example, it is unclear why their first TOR for the Fonteintjie site, which is some 300 km north of Noordoewer, and which has a spring as a water source, would require the properties of the water of the Orange River as well as impacts on the water source caused by fish farming.

Collectively, there are several ambiguities with the production models proposed and the implementation of proposals should be carefully re-evaluated ensuring appropriate technical expertise is consulted.

The assumptions in the production model will determine the outcome of the economic viability and its interpretation. For these feasibility studies the following should be carefully re-evaluated:

- i. **Whilst desirable, the mortality rate used (0.15%/week) over the production cycle is far too low** for this type of production system. For all three studies, the authors have assumed a flat mortality rate of 0.15%/week, using 5 g fingerlings. Over the proposed 39 week growth cycle this amounts to just 6%. Typically, overall mortality ranges between 20-25%. The use of such low mortality rates will underestimate the initial fingerling requirements, feed costs and therefore operational costs. The sensitivity analysis has not tested the effect of changing mortality. This is considered important as it will impact on harvested yield, income from sales and profitability.
- ii. **Stocking densities and biomass for fingerlings and on-growing proposed for tilapia in the studies are unrealistic** given the design of the recirculation system proposed. In all studies the authors have only proposed ordinary aeration using low compression blowers as a means of routine oxygen supply for fish (see figure 7 of Divundu study). The production model proposed for all sites, however, substantially exceeds the biomass that can be reared in such systems. Normally, aeration is adequate for tilapia stocking densities up to about 30 kg/m³. In these three studies, this density is predicted to be reached by week 9 of the 13 week fingerling production cycle and week 24 of the 39 week on-growing cycle (see tables 4 and 5 of the Fonteintjie study). Therefore, with the proposed pod design, heavy mortality would be anticipated as the system will probably fail to provide adequate quantities of oxygen to meet fish requirements. Bottled oxygen is proposed only for emergency use but has a very short lifespan.
- iii. **Feeding rates.** The production model proposed in all three studies uses specific feeding rates as an indication of feed requirement. This is the amount of feed given per day based on the percentage of body weight (BW) of the fish. These values, which are stated as “conservative” range from 36% BW/day for 5 g fish to 3% for 600 g fish but are over twice the recommended values to those generally used (see Table 6). This will artificially inflate the feed cost, perhaps doubling OPEX for this item.

Table 6. Suggested feed size and feeding of tank-cultured tilapia¹

Average fish weight (g)	Standard feed size	Feeding rate (%BW/day)
Post-hatch – 0.5	#00, #0, #1 Crumble	20 – 15
0.5 – 5	#2 Crumble	15 – 10
5 – 18	#3 Crumble	10 – 5
18 – 75	#4 Crumble (1 mm)	5 – 3
75 – 150	1/8 inch (3 mm)	3 – 1.5
150 to market	3/16 inch (5 mm)	3 – 1.5

¹ <https://srac.tamu.edu/index.cfm/event/getFactSheet/whichfactsheet/52/>

- iv. **Allocation of tanks for fingerling and on-growing is probably inadequate.** The pod unit proposed consists of just one 4.4 m tank to generate 12 000 fingerlings required to stock 4-7 m diameter production tanks. Such an allocation makes no allowances for tanks required for the two or three gradings of juveniles acknowledged by the authors. Grading is essential for tilapia and catfish during the 13 week fingerling and 26 week production cycles. Hence the number of tanks identified for fingerling production per pod is likely to be inadequate. Further, the study acknowledges that fish over 50 g may need to be sorted for sex to ensure monoculture. These designs, however, make no provision for such management requirements.
- v. **On-growing production plans are unlikely to achieve production predicted.** The study suggests that “one production pod consisting of four production tanks and a fingerling supply tank can yield approximately 6 900 kg of 600 g fish every 13 weeks, if the pods are stocked in pairs and 12 000 fingerlings are supplied in a corresponding 13 week cycle” and two such pods can yield 55 tonnes of tilapia/year (see Fonteintjie study). This production is unrealistic to achieve, given the time frames proposed and tank numbers allocated.
- vi. **Water requirements are probably underestimated.** Each pod model system proposed for all sites incorporates a drum filter for removal of solids. These filters have a fine meshed screen (100 µm proposed) which strains the suspended solids. Each unit, however, requires a significant volume of clean water to back flush these screens to keep them functional. Six such pods are proposed, however, no information could be gleaned from the studies that accounts for this requirement. Instead only a 10% recharge rate of system volume is proposed. Given that water is a limiting factor at these sites the design needs further evaluation.
- vii. **Requirements and design of required broodstock units not available.** The Fonteintjie and Noordoewer study state the need for a broodstock facility but basic requirements, such as those for fingerling and on-growing phases, are not given. Only generic information on how tilapias breed is provided. The floor space allocated for the hatchery of only 54 m² is inadequate, especially as the project proposes production of sex-reversed fingerlings.
- viii. **The clarity of design provided is ambiguous in places.** The pod system design for the Fonteintjie study is unclear in relation to the text. The study states that each grow-out pod or pod will contain 1 fingerling tank (4 m) plus 4 x 7 m on-growing tanks. Yet, the fingerling tank does not feature in pod drawings provided in figure 3 of their study. This could effect the floor space requirements and CAPEX (capital expenditure).
- ix. **Rationale for indoor building design is unclear.** Although agricultural or greenhouse tunnels are offered as a possibility, a light industrial type building (972 m² approximately 50 x 20 m) is proposed at a CAPEX cost of N\$2 million and annual OPEX (operating expenditure) of N\$131 000 on the basis of better

temperature control and lower maintenance cost. It is suggested that maintenance costs for the greenhouse system are higher.

It is proposed that this position be re-evaluated with improved due diligence. A double span greenhouse should be considered for the following reasons:

- a. Although the borehole water temperature is 31 °C, it will soon cool to the ambient temperature. Given the lower than optimum air temperatures, costs will be reduced by using solar radiant energy under greenhouses.
 - b. The **average** annual air temperature at this site is 22 °C. The assertion that the heat exchanger (10 kW) will only function 25% of the time is probably a gross underestimation, given diurnal and seasonal fluctuations.
 - c. The cost of a 20 x 50 m greenhouse is estimated at about 15% of that of the building proposed. The average recorded wind speed was only 17 km/hr.
 - d. Given that the project has already included a 2% maintenance cost (N\$131 000) it should cost no more to maintain.
- x. **The cost of the projects seems grossly overestimated.** For Fonteintjie the CAPEX and OPEX are estimated at N\$17.4 million and N\$5.1 million, respectively, while the **production facility** alone is estimated at N\$4.2 million and excludes electrics and plumbing. For the pod design and components given, this appears to be an overestimation of the equipment provided in table 8 of their study. For Divindu, CAPEX and OPEX are estimated at N\$47 million and N\$11 million, respectively.
- xi. **The site selection for the Noordoewer project is poor.** As with other sites the team were shown this site. It is **wholly unsatisfactory** and an alternative/better site in the area should be identified. The authors of the feasibility studies state the site “area is generally characterized by extensive mountains, hills, rock outcrops and severely dissected terrain resulting from run-off rain water (p. 54). The locality of the site is extracted and presented below in Figure 9. The following reasons are offered:
- a) The site is located on a slope and is south facing i.e. in the sun’s shadow. Note the tight contour lines on the location map.
 - b) The site is located some 3 km away from the water source and thus increasing CAPEX significantly. Better sites are available and were shown to the team near the canal and river and away from flood lines.

- c) The authors suggest “The high rates of evaporation that are common in Namibia will also have a cooling effect on the production system” (p. 57). The system proposed at Noordoewer and other site is an indoor facility in which case this should not be a consideration.

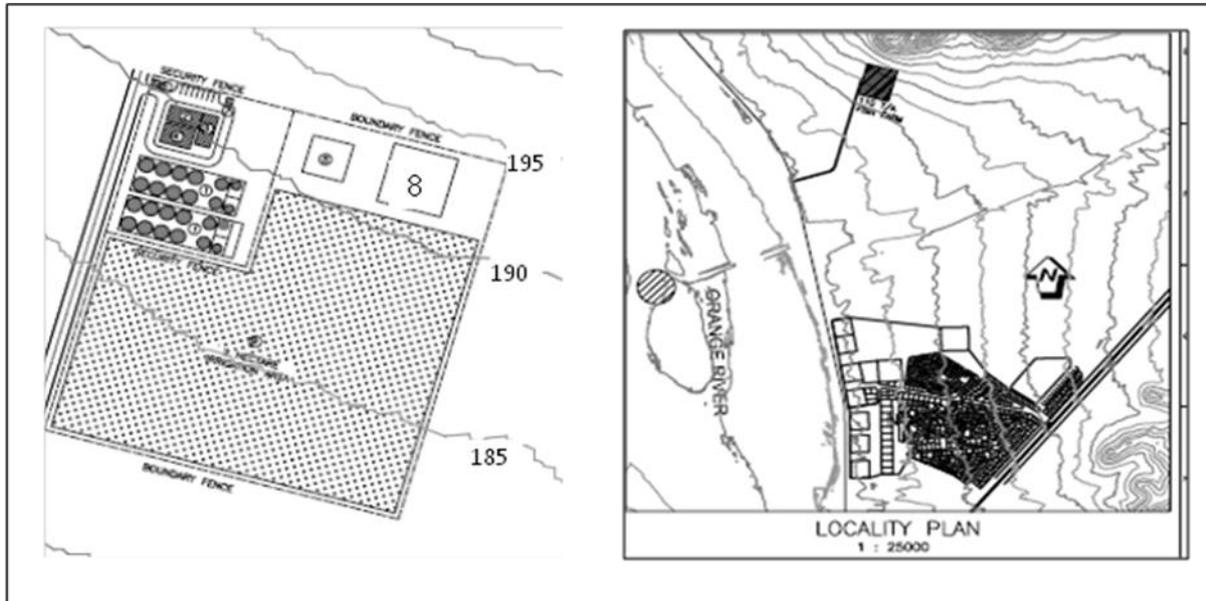


Figure 9 Site Drawings extracted from Noordoewer feasibility study

- d) On p.60 the consultants state that “Since the effluent water from the production operation will be disposed from the production facility at an almost constant rate, the water has to be stored to allow for the fluctuation in irrigation patterns. Provision has been made for a storage dam that can store at least 10 days’ effluent water, i.e. 1,365m³.” This dam is marked “8” in Figure 9. Such design features are likely to increase CAPEX and OPEX unnecessarily. The effluent dam is located some 7 m **above** the pods and thus effluent water will have to be pumped into this dam at cost. Locating this below the pods will be more practical and cost effective.
- e) To propose plant production in this soil type and in particular on this slope should definitely be discouraged. Assuming a 100 x 200 m plot size and contours above, a slope of 1:10 is likely. Thus making crop production more complex.

3.2.1 Conclusions and recommendations of previous feasibility studies

- All projects have excluded CAPEX from the financial models and therefore depreciation and capital interest are unlikely to affect financial statements.

- Despite this exclusion, all studies suggest that a production farm of under 300 tonnes is not profitable. Some measure of profitability is attained by farming catfish.
- There are many design flaws in all these studies

3.2.2 Recommendations and the way forward

We strongly recommend that the GRN revisit these studies to establish alternative options or to modify designs and sites.

3.3 Legal and Regulatory Frameworks Impacting on Aquaculture Uptake and Development

The purpose of this section is not to review the purpose of these instruments since we assume that this is known to originators of these documents. Instead we refer to and bring to the attention of MFMR specific issues within these instruments that may have a positive or negative impact on the uptake of freshwater aquaculture in Namibia in relation to other economic activities promoted by GRN.

The policy and gazetted instruments of relevance are:

- i. Namibia's Aquaculture Policy (2001)
- ii. The Aquaculture Act (2002) and its ensuing regulations
- iii. The Application for Aquaculture Licences
- iv. Regulations relating to import and export of aquatic organisms and aquaculture products: Aquaculture Act (2002)
- v. The Regulations for Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA)
- vi. 2008 Draft Procedures and Guidelines for Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP)

3.3.1 Namibia's Aquaculture Policy: Towards Responsible Development of Aquaculture (2001)

Background to policy

The main objective of Namibia's Aquaculture Policy (NAP) is to promote development and uptake of aquaculture to achieve socio-economic benefits for all Namibians and to secure environmental sustainability. This was followed by legislating the Aquaculture Act of 2002 (AA). A decade and several initiatives later, however, the uptake of freshwater aquaculture is still limited.

The NAP gives various reasons for limited progress in post-independence aquaculture uptake, citing limited availability of freshwater across most of Namibia's land area, competition for the use of the available freshwater supplies and the high cost of developing aquaculture facilities in relatively unsheltered waters along most of Namibia's coastline. Additionally, aquaculture has also received low priority in government policies and programmes because higher priority was afforded to developing Namibia's rich wild fish resources.

The NAP seeks to redress this balance through putting in place instruments and institutional measures to give effect to the high priority now given to aquaculture in the NDP-3 initiative.

The policy rests on advocating four pillars:

- (a) Establishing legal and administrative frameworks for aquaculture, including establishing systems of tenure for commercial aquaculture;
- (b) Establishing institutional arrangements for aquaculture;
- (c) Maintaining genetic diversity and the integrity of the aquatic ecosystem; and
- (d) Ensuring responsible aquaculture production practices.

The policy direction for aquaculture is framed within the principle of optimum sustainable yield in the exploitation of living natural resources and ecosystems. Hence, it appears that the government is obligated to promote and regulate responsible and sustainable development and management of aquaculture within its EEZs (exclusive economic zones).

However, having recognized the limitations of the objectives of the strategy (NAMIBIA, OFFICE OF THE PRESIDENT, 2004) calls for incorporation of economic support to the industry as an objective to ensure that seed money is made available to stimulate sector development.

Feedback on policy

The preparation of this policy involved consultation with stakeholders but the issues in the policy direction seem to emanate mainly from the mariculture sector. Although the current content is pertinent, the policy has missed the broader opportunity of addressing sector-wide development. This is reflected in the three major issues which form the trust of the policy: namely establishing a legislative and administrative framework, maintaining genetic diversity and the integrity of aquatic ecosystems and

ensuring responsible aquaculture production practices; which principally reflect a first world perspective and that often pertains to that of a mature aquaculture sector rather than a developing sector that in essence does not yet exist. Even though aquaculture is a primary farming activity akin to agriculture, the policy focuses on attempting to develop an industry rather than a diverse sector. In agriculture we commonly refer to developing a sector and not an industry unless it refers to agro-processing. Thus the opportunities for addressing sector issues are not as prominent and this is further reinforced in the Aquaculture Act 2002, which focuses principally on rights based issues associated with mariculture. Freshwater was given limited attention and this is reflected in the significant lag time between the Act and freshwater aquaculture initiatives compared with the marine sector.

3.3.2 The Aquaculture Act and related environmental regulations and aquaculture development

3.3.2.1 Clarity on what is aquaculture and its implications for EIA and uptake

Aquaculture is defined in the Aquaculture Act of 2002 as “***the farming and ranching of aquatic organisms***”.

There are two key issues that should be explored by MFMR:

- i) The Act acknowledges that aquaculture is a farming activity and as such should be **treated equally as any other farming activity e.g. livestock**. Currently this does not seem to be the case as aquaculture is treated differently to other farming subsectors with respect to the EIA assessment process even though the activity is as similar to agriculture in Namibia. This position can potentially frustrate entrants and negatively affect uptake of freshwater aquaculture.
- ii) Reference is made to **Schedule 1** of the “Regulations for strategic environmental assessment (SEA) and environmental impact assessment (EIA)” under section 56 of the Environmental Management Act, 2007 (Act No. 7 of 2007). This schedule, given in Table 7, makes no reference to livestock (ranching or feedlot) requiring any form of EIA under this Schedule, instead only aquaculture is singled out despite significant implications of livestock farming on size and clearance of land and on biodiversity, bush clearances etc. as stated under the EIA process. The schedule refers only to:
 - ✚ “The erection or construction of any structure associated with aquaculture (farming) activities where such structures are not situated within an aquaculture development zone declared in terms of section 33 of the aquaculture act, 2002 (act no. 18 of 2002);
 - ✚ The declaration of an area as an aquaculture development zone in terms of section 33 of the aquaculture act, 2002 (act no. 18 of 2002).”

Whilst aquaculture zones are discrete areas in marine environments where there is potential conflict with shipping, navigation, recreation etc., for example Walvis Bay, inland aquaculture, particularly under Namibian conditions, is unlikely to conform to such concentration of activities. Additionally aquaculture farms in Namibia are unlikely to be large. There is, therefore, limited merit or case for considering freshwater aquaculture zones, akin to mariculture zones in Namibia.

Additionally, and more importantly, Schedule 1 provides no required threshold for aquaculture production levels that will trigger the EIA process or requirement. Therefore, currently **all** aquaculture activities, irrespective of size will be required to undergo an EIA process. This is not a tenable position. The MFMR is urged to review such triggers in other **developing countries** and establish a reasonable threshold EIA trigger such that it provides an enabling environment to proactively promote uptake and reduce the unnecessary bureaucratic burden for potential farmers, especially entrepreneurs who intend to enter the subsector. A trigger of 250 tonnes is proposed. It should be recalled that a 500 head of cattle (approx 350 tonnes) produces as much waste as a town with 100 000 inhabitants.

The Act also frustrates other aspects of uptake and progress. These include paragraphs b, j, k and i of section 39 of the Aquaculture Act (2002).

Is the current EIA process imposed on freshwater aquaculture development justifiable? The short answer is that when compared with other economic activities in Namibia, in particular dairy and livestock, it is unjustifiable. The objective of the Environmental Management Act 2007 (Act No. 7 of 2007), as stated under section 2(a) is to prevent and mitigate **significant effects** of activities on the environment. Its inclusion as a Schedule 1 activity implies that in Namibia, aquaculture has a significant effect and therefore for freshwater aquaculture an EIA is deemed necessary. This is not the case for Namibia, where aquaculture is intrinsically small scale.

Table 7. List of Activities Requiring an Environmental Assessment¹

The following list shall act as a guide for the Environmental Commissioner. When the scale of activities is not provided or is unknown, it is up to the Commissioner to use his/her discretion as to whether they should be subject to EIA or not.

1. Construction and related activities

- (a) The erection or construction of facilities for the commercial generation of electricity with an output of more than **one** megawatt;
- (b) The erection or construction of facilities for the commercial transmission and supply of electricity with the exception **of power supply lines of less than 2 kilometres in length**;
- (c) The erection, construction or upgrading of nuclear reactors and installations for the production, enrichment, reprocessing and disposal of nuclear fuels and wastes;
- (d) The erection, construction or upgrading of manufacturing, storage, handling or processing facilities for any hazardous substance, including transportation routes, structures and facilities connected therewith, and for the purpose of this clause "hazardous substance" means any substance declared as hazardous substance in terms of section 3(1) of the hazardous substances ordinance, 1974 (ordinance no. 14 of 1974), or in terms of any other law relating to the control of hazardous substances;
- (e) The construction of public roads;
- (f) The construction or upgrading of railways and harbours and associated structures;
- (g) The construction or upgrading of airports, airfields and associated structures;
- (h) The erection or construction of any structure below the high water mark of the sea;
- (i) The erection or construction of any structure associated with aquaculture activities where such structures are not situated within an aquaculture development zone declared in terms of section 33 of the aquaculture act, 2002 (act no. 18 of 2002);**
- (j) The erection or construction of cableways and associated structures;
- (k) The erection or construction of communication networks including towers, telecommunication lines and cables as well as structures associated therewith including roads;
- (l) The erection or construction of motor vehicle and motorcycle racing and test tracks;
- (m) The construction of canals and channels including the diversion of the normal flow of water in a riverbed and water transfer schemes between water catchments and impoundments;
- (n) The construction of dams, reservoirs, levees and weirs;
- (o) The erection and construction of tourism facilities and associated structures including all wheel drive trails or activities related to tourism that may have significant effects on the environment;
- (p) The erection and construction of sewage treatment plants and associated infrastructure;
- (q) The erection and construction of buildings and structures for manufacturing, processing, industrial or military activity;
- (r) The erection and construction of veterinary, protected area or game proof and international boundary fences;
- (s) The erection and construction of waste sites, including any facility for the final disposal or treatment of waste;
- (t) The erection and construction of oil refineries; and
- (u) The construction of oil, water, gas and petrochemical and other bulk supply pipelines.

2. Land use planning and development activities

- (a) The rezoning of land from -
 - (i) residential use to industrial or commercial use;
 - (ii) light industrial use to heavy industrial use;
 - (iii) agricultural use to industrial use;
 - (iv) use for nature conservation or zoned open space to any other landuse;
- (b) Reclamation of land from below or above the high-water mark of the sea or associated inland waters;
- (c) Alteration of natural wetland systems;
- (d) Any activity entailing a scheduled process referred to in the atmospheric pollution prevention ordinance, 1976 (ordinance no. 11 of 1976);
- (e) The establishment of resettlement schemes; and
- (f) The declaration of an area as an aquaculture development zone in terms of section 33 of the aquaculture act, 2002 (act no. 18 of 2002).**

3. Resource extraction, manipulation, conservation and related activities

- (a) Prospecting, quarrying, mining, mineral extraction or mineral beneficiation activity;
- (b) The farming or importation or release or contained use of any genetically modified organism or plant or animal species that may have a significant impact on the environment;
- (c) The genetic modification of any organism with the purpose of fundamentally changing the inherent characteristics of that organism;
- (d) The abstraction of ground or surface water for industrial or commercial purposes; and
- (e) Clearance of forest areas, reforestation and afforestation.

4. Other activities

- (a) Pest control programmes;
- (b) The import, processing and transit of genetically modified organisms; and
- (c) The import, processing, transit or export of waste
- (d) Any such other undertaking as the minister may from time to time determine.

¹ Source: GOVERNMENT NOTICE NO. 1 (2008) Draft Procedures and Guidelines for Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP)

In the team's view there is also potential discrepancy on how any impacts are viewed. The stepwise process to guide if an activity has a **significant** environmental effect is given in **Government Notice No. 1 Draft procedures and guidelines for environmental impact assessment (EIA) and environmental management plan (EMP)** and,

The "Criteria for determining the likely significance of effects on the environment is presented in Schedule 2 as follows:

"In accordance to the relevant procedures and guidelines, characteristics of the effects and of the area likely to be affected, by the proposed policy, plan, programme or project having regard, in particular, to –

- (a) The probability, duration, frequency and reversibility of the effects;
- (b) The cumulative nature of the effects;
- (c) The transboundary nature of the effects;
- (d) The risks to human health or the environment (for example, due to accidents);
- (e) The magnitude and spatial extent of the effects (geographical area and size of the population likely to be affected).

In our view, freshwater aquaculture in Namibia is unlikely to have a "significant effect" because of:

a) *The probability, duration, frequency and reversibility of the effects*

The **organic by-products** generated by fish will mainly be in the form of uneaten food (mainly grain products) and fish faeces. The combination of fish farming with plant production will neutralize this waste and render this concern irrelevant. Such waste is significantly lower than cattle on a weight for weight basis. Additionally, and in general terms, such by-products should be embraced given the organically deprived Namibian sandy soils.

The scale of farming operations will be relatively small. The typical size of a **single** salmon farm in Europe is 10 000-15 000 tonnes. Freshwater fish farm sizes in Namibia at best are likely be 1-2% of these i.e. 100-300 tonnes.

Given the organic nature of the by-products and good management practices, any effects will be reversible due to decomposition of waste.

b) *The cumulative nature of the effects*

Being organic, the by-products will decompose negating any long-term negative cumulative effects. In water bodies waste products will be assimilated into aquatic plant life. Given the large flow of perennial rivers in the north and flowing agricultural canals, the high dilution factor of these water bodies will cancel any negative cumulative effects (see subsection 19)

c) *The transboundary nature of the effects*

These effects will principally affect the northern and southern regions. It should be noted that with regards to introduced species such as *O. niloticus*, the species are already present in neighbouring countries such as Angola and Zambia and known to be in the Zambezi river system and therefore such transboundary concerns should be put in context. On the issue of translocation of fish, it should also be noted that water transfer schemes between water catchments via canals and pipes in Namibia is historical and this has already led to translocation of many aquatic species of fish, questioning the thesis and rationale pristine ecosystems and biodiversity integrity. There seems to be no pristine watersheds of note in Namibia due to inter-basin water transfer schemes both within and between bordering countries.

The effluent from freshwater aquaculture, irrespective of intensity of production, is minuscule given the river flow patterns, rainy seasons and other water uses along these waters(see subsection 19).

d) *Risks to human health or the environment (for example, due to accidents)*

There are no anticipated human health risks from freshwater aquaculture. Accidental fish release, mainly as a result of flooding in vulnerable farms can be limited by using species local to that catchment, most of which are not likely to be pristine.

(e) *The magnitude and spatial extent of the effects (geographical area and size of the population likely to be affected)*

The water shed in Namibia cover an area of around 361000 km² (Table 47). It is this huge magnitude and spatial distribution of water bodies, especially in transboundary areas that will mitigate the effects of any by-products and none is anticipated. On the contrary, any increase in fish production in natural or artificial water bodies resulting from freshwater aquaculture will actually contribute to the GRN's objective of food security.

It should also be recalled that most of the freshwater surface waters in Namibia are **artificial** i.e. reservoirs and impoundments and measures applied to natural waters may not be applicable. Such application only serves to create a disabling environment for freshwater aquaculture.

3.3.2.2 Other areas of the Aquaculture Act 2002 of relevance

There are other key areas in the AA that MFMR should consider revisiting to create a better enabling environment for freshwater fish farming. These include:

- a. ***Aquaculture to be conducted only with a licence.*** Backyard farming should be exempt. Such licences are unlikely to be required for agriculture?

- b. ***The conditions of any licences should be re-examined.*** The use of anabolic drugs to invert the phenotype of fish is globally used especially in Asia. The prescriptive nature of licences should be pragmatic. Good farming practices cover all those listed in section 14(4).
- c. ***Report of disease or harmful organism.*** The requirements in this section are excessive. Akin to livestock, there is an obligation to report only **notifiable diseases**. This is not made clear in the AA and burdens the farmer. It does not follow that fish health is a trivial matter for the farmer.
- d. ***Introduction and transfer of aquatic organisms.*** The MFMR must conclude this matter with other relevant authorities in favour of the use of more appropriate freshwater farming candidates if it wishes to optimize its goal of poverty alleviation and food security. We do not see the case for not substituting a poor exotic species performer for another faster growing species.

3.3.3 Regulations relating to import and export of aquatic organisms and aquaculture products: Aquaculture Act, 2002

The MFMR should consider the following:

Although the GRN has already gazetted regulations on the above but we are unaware of any appropriate state or private freshwater quarantine facilities. This effectively currently curtails the issuing of any import licenses or importation of freshwater aquatic organisms for the furtherment of freshwater aquaculture by the government.

Additionally, these regulations are inconsistent with the broad objectives. The regulations list aquatic species which are allowed to be imported (Import regulations - Appendix I) and those prohibited (Import regulations - Appendix J). These two lists are separated based on the purpose of intended use. The former for ornamentals and the latter for food purposes, yet both pose the same risk. The former, may arguably pose a greater, disease and biodiversity risk than the latter. In fact many of the freshwater ornamental species have established feral populations in waters of Southern Africa.

Moreover, the ornamental species list (Import regulations - Appendix I) contains Asian *Puntius spp.* (listed under OIE: World Organisation for Animal Health) and gourami species which are known to be carriers of epizootic ulcerative syndrome (EUS), a notifiable disease which has been identified in Namibia. These regulations could, therefore, have inadvertently contributed to the origins of EUS in the region.

3.3.4 Conclusion

- Whilst it is acknowledged that every anthropogenic activity does have some effect on the environment, freshwater aquaculture in Namibia is unlikely to have any cumulative **significant** effect, locally or nationally or in the circumstances raise any notable transboundary issues, nor are there in all probability any likely negative spatial effects given the relatively small scale of freshwater aquaculture in Namibia.
- We see no justifiable need for freshwater aquaculture to be listed as a Schedule 1 activity; especially as no other farming activity is so regulated.
- At present, no internationally comparable large-scale aquaculture exists in Namibia to regulate and given water limitations and geo-physical conditions this is unlikely to be the case in future. The MFMR should therefore ensure the promotion of freshwater aquaculture through a more pragmatic regulatory environment which minimizes the burden for all new entrants into the subsector and increase production and efficiency.
- There are inconsistencies in some regulations which compromise freshwater aquaculture uptake.
- Some gazetted regulations are premature in that government facilities (e.g. state quarantine facilities) are not in place for compliance and this order of progress will compromise development.

3.3.5 Recommendations and way forward

The MFMR, as the mandated institution, should:

- i. Conduct a study to confirm the likely impacts of freshwater aquaculture based on a national and regional plan of action for freshwater aquaculture.
- ii. Specifically, to allow species already introduced, such as *O. niloticus* and red claw to be made more accessible for farming and promote other species advocated.
- iii. Remove aquaculture from Schedule 1 of Government Notice No. 1 (2008) to make transparent and comparable with other forms of livestock farming or gazette an EIA trigger of 300 tonnes/year facilitating small-scale farmers to enter the subsector.
- iv. Reconsider the procedures for movement orders for live freshwater fish to be more pragmatic.
- v. Revisit the validity of the gazetted import regulations.
- vi. Ensure regulations on fish health are limited to notifiable diseases, such as EUS.

- vii. Develop pragmatic and practical good management practices recalling that it is in the farmers' best interest to maximize production and production efficiency.

3.4 Namibia's Aquaculture Strategic Plan (NASP)

3.4.1 Evaluation of NASP

In response to the Aquaculture Act 2002, MFMR under the Directorate of Aquaculture (DA) produced an Aquaculture Strategic Plan in 2004. This is a useful and promising document but the degree of implementation is unclear.

With regards to freshwater aquaculture, the strategy targets six areas for action these are: regulatory framework, economic development and marketing; aquaculture technology; environmental matters; aquaculture education and training; research and development; and aquatic animal health certification and quarantine inspection.

Regulatory framework

The strategy aims to take forward the 2001 Aquaculture Policy: Towards the Responsible Development of Aquaculture and implement the Aquaculture Act (No. 18 of 2002) and Aquaculture (Licensing) Regulations (3rd December 2003).

It is unclear if the action to establish a "one stop shop" has materialised as this was not pointed out to the team. However, the stated need to produce an "Aquaculture Regulatory Handbook" in itself would suggest that the process is complicated.

The language of action point 4.11(g) ensuring proper effective enforcement leaves the impression of a system intending to over regulate. It is unclear what compliance measures are proposed or are in place for freshwater aquaculture. The team has not observed any enforcement of such conditions on government or private farms.

Economic development and marketing

One aspiration of the implementation stated in the NASP was to increase the value of aquaculture from N\$20 million in 2004 to N\$250 million in 2009. This, unfortunately, does not appear to have materialized. Instead, according to the MFMR annual report of 2009 the value of fish produced was only 10% of this projected value at N\$24.5 million, of which only N\$185 000 was from freshwater aquaculture. According to the MFMR report there was no noticeable increase in freshwater fish production



Figure 10. Expansion of promotion trust facilities. Opened by Hon. Minister Bernard Esau.

between 2007 and 2009 which stagnated at 11-12 tonnes/year. Such stagnation questions the vigour and rigour of any implementation plan.

The NASP addressed “Obstacles to Financing” and in 2011 MFMR together with The Agricultural Bank of Namibia made available low interest (5%/annum) funds to finance aquaculture projects requiring no collateral. This is a very promising, especially for the governments target groups and an encouraging step to the boost the uptake freshwater aquaculture, provided it is applied equitably.

In an attempt to increase fish consumption MFMR launched the Namibia Fish Consumption Promotion Trust to make fish accessible and affordable in all thirteen regions of Namibia (Figure 10). This trust continues to expand but its effectiveness in increasing national fish consumption is unclear. Currently the trust distributes cheap, mainly frozen, marine pelagic fish such as horse mackerel and hake. This strategy, though noble, is likely to distort the market and will undermine the ability of MFMR to develop an economically vibrant freshwater aquaculture subsector.

Aquaculture technology

Whilst NASP states that the government should attempt to secure funding to provide seed funds to enhance aquaculture research and development under “aquaculture technology” the actions so recommended, in our view, do not appear to be aligned with technology development. Instead the bulk of these recommendations relate to market promotion of the sector through trade fairs and international visits. This is a missed opportunity as locally bred technologies based on the range of environment types in Namibia should be promoted to ensure diversity and sustainability.

Environmental matters

Environmental matters are limited to two items: site selection and monitoring. As in many of the other action points, this section focuses on aquaculture zones for mariculture to produce maps for licensing purposes and for monitoring of these zones. It has limited bearing for freshwater aquaculture. Inland freshwater aquaculture is practised in diverse climatic and geophysical regions of Namibia and will require a different approach.

Education and training

The NASP highlights that presently there are very few opportunities for aquaculture training and education in Namibia. This has to be balanced with the job requirement in the market place. This action calls for **a training needs assessment study** which to our knowledge has not been done. We agree that the government should support aquaculture awareness in schools but differ on the approach that should be adopted. The NASP acknowledges an awareness programme on the merits of freshwater aquaculture in Namibia. We agree that this is timely but needs to be well structured and involve other line ministries and linked to market promotion.

Research and development (R&D)

With regards to freshwater aquaculture NASP targets R&D at Hardap and community based fish farms and at other facilities such as the IAC at Onavivi, and KIFI. However, during our extensive field trip assessments we could see no structured research. Some good initiatives on feed development have been undertaken at Onavivi. Given the huge investment in such R&D facilities the government should re-evaluate its management approach to R&D.

Aquatic animal health certification and quarantine inspection

The focus of this section is for mariculture and international trade. Currently this is of limited value to the freshwater aquaculture subsector. The reporting of EUS, however, is of relevance following the identification of EUS in the Zambezi River. Given that this water catchment may be used as a source of water EUS monitoring is required on farm in affected areas.

3.4.2 Conclusions

- Overall, NASP has a clear mariculture focus due to its current economic significance. The NASP proposes action points for each of the areas it covers.
- For freshwater aquaculture, its implementation appears limited and impact unclear. Perhaps this is expected given that the freshwater facilities are relatively new and human capacity at all levels limited.
- This being the case it highlights the shortcomings of prematurely putting in place regulations which then cannot be implemented, thus creating a disabling environment for development.

3.4.3 Recommendations and way forward

We propose that the NASP should have a broader agenda to address specifically the challenges for developing freshwater aquaculture.

- i. The need to produce a “Regulatory Handbook” for farmers should be re-evaluated. Instead we propose the procedures be simplified.
- ii. Freshwater production has not shown any increase of merit in production. We recommend that MFMR review their management structure and conduct an analysis of the activities to identify how it can better achieve its targets.
- iii. The Fish Promotion Trust should **increase the price of fish** to market levels. All institutions should aim to achieve a retail price of a **minimum of N\$30/kg** and promote consumption of fresh, freshwater fish.

- iv. The Fish Promotion Trust together with competent authorities and organizations to conduct a proactive marketing campaign to increase freshwater fish consumption.
- v. AgriBank funds should be equitably distributed to small-scale freshwater farmers. This should include provision for assisting farmers with developing business plans as well as on-farm training.
- vi. The diverse climatic conditions in the regions will require different production systems. We propose an action plan be initiated for selected types of systems and locations for their piloting.
- vii. The MFMR should re-evaluate its approach to freshwater aquaculture technology to develop home-grown systems, involving local farmers and vocational trades to ensure sustainability and develop local capacity.
- viii. There is a clear lack of human capacity to promote and develop freshwater aquaculture. We advocate MFMR conduct a **training needs assessment study**, which to our knowledge has not been done.
- ix. No structured research in freshwater aquaculture was apparent. We propose that MFMR develop a **needs-driven** freshwater aquaculture research strategy.
- x. Given that EUS has been identified, we propose a detailed map to identify and monitor the epidemiology of the disease.

3.5 Feedback on Draft Turnaround Strategy for Six Cooperative Farms (2006)

The GRN commissioned a turnaround strategy (TAS) for six ailing cooperative freshwater fish farms established by the Ministry of Trade and Industry (MTI) but managed by MFMR since 2004. The executive summary of the TAS highlights the salient constraints and proposes recommendations for the way forward.

The draft report provides a comprehensive analysis/audit of all six farms, four of which (i.e. Mpungu, Likunganelo, Kalimbeza, and Kalavo) were visited by the freshwater team. It is our understanding that the remaining two farms are now decommissioned. The key concern for all farms is significant underperformance resulting in unacceptably low income generation for its members and resulting lack of motivation and community interest.

The freshwater team largely concurs with the observations and constraints contained in the TAS, encapsulated in the SWOT analysis (Subsection 9) and the three main conclusions. We, however, differ on a few (minor) points in their SWOT analysis. We do not regard “suitable climate” a good strength due to altitude and suboptimal rearing temperatures at farms and we do not see “Turn-key

management agency” and on-farm feed production as opportunities. Currently, feed produced by Onavivi is well priced but this may change in the future.

There are four fundamental issues that we believe should be firmly addressed by **any** TAS: (i) the **ownership** issue of these cooperatives **MUST** be resolved ASAP, (ii) stakeholders need a paradigm shift to appreciate that aquaculture is an all-year-round activity, (iii) a workforce **committed to work** must be put in place, and (iv) effective mechanisms, in particular training, to **increase farm income** be put in place, especially given the historic expectations given to communities.

We concur with many of the observations but suggest modifications/additions to some of the proposed recommendations. On the:

a) Organogram

- i. We do not see the merit of the structure proposed in the draft TAS since the cooperatives are unlikely to attract private investors in a public-private partnership (PPP) structure. The development of social capital partners is more likely to succeed, if well managed.
- ii. We prefer the executive summary recommendation of establishing a 49:51 partnership but with an option of the co-op buyout of the 51% government share.
- iii. Government, as part of their role should explore and secure repayable OPEX for these ventures. The recovery of OPEX should be linked with cooperative style marketing structure that needs to be developed which can be used to facilitate the recovery of OPEX.

b) Profitability

- i. The data provided in both the draft TAS and executive summary date back to October 2006 and therefore considered outdated and therefore do not merit comment.
- ii. Given the date of the TAS, it is also unclear what aspects, if any, were implemented and hence unable to comment on “cost estimates in the executive summary.
- iii. In any case, the fish production capacity of 20 tonnes/farm (revenue of N\$300 000 @ N\$ 15/kg or N\$400 000 @ N\$20/kg) will compromise any exit strategy.

c) Management:

- i. We agree with GRN that a management company/agency as proposed in the draft TAS may not be required, provided good governance measures are in place.
- ii. We concur with the need for one Namibian project manager but propose that finance and marketing manager roles be merged into one post given that the overall project is not large, perhaps with an enhanced salary and to be reviewed later. Funds may be better spent consolidating on-farm production.
- iii. We regard the immediate establishment of a cooperative marketing structure (fish and plants) for all farms an imperative. This could be a separate enterprise or government run.
- iv. Clarification is required on the costing of four technical managers proposed. These costs are not included in the “Detailed Remuneration of Management” section of the executive summary? Additionally we suggest that given that the two regions are adjacent, two and not four production managers, (one for fish and one for plants) could be adequate.
- v. We propose that all managers be based in these regions and not in Windhoek, but with access to transport.

d) Fish production

- i. The MFMR, as part of the NAMP-FW, immediately begin a programme for broodstock development for *O. andersonii* to supply all the cooperatives and other freshwater initiatives with improved broodstock.
- ii. An operational and seasonal production calendar be mapped out for each farm following a in-depth technical audit taking into account site-specific flooding patterns, water temperature and pond configurations and other farming activities.
- iii. In keeping with overall recommendations in the NAMP-FW, the size of fingerlings stocked for on-growing be immediately increased to a minimum of 30-50 g, ideally using all-male tilapia seed.
- iv. Species for culture be limited to improved *O. andersonii* and African catfish.
- v. On-farm capacity to manage broodstock and raise juveniles, including overwintering, if required, be put in place on farms to reduce transport costs, mortality and stress.

- vi. Where possible, ponds be immediately deepened to 1.5-2 m and if space and conditions allow increase on-growing capacity by constructing new deep ponds.
- vii. Such ponds should be **manually** dug using local casual labour preferably cooperative members under supervision. Such inputs should be considered as their contribution to TAS.
- viii. Efforts must be made to increase gate prices of fish to N\$20/kg.
- ix. Based on current production achieved at Epalela fish farm (10 tonnes/ha), a maximum of only 12 tonnes of fish may be produced from these farms (6 x 2 000 m² ponds). Therefore the 20 tonnes/farm proposed in the TAS may be an overestimate.
- x. Additional recommendations are given under situation analysis (Subsection 7).

e) Plant production

- i. We offer no comment on the costs associated with plant crops and assume these are best possible estimates and selection. However, we propose the inclusion of shorter cycle crops (4-6 weeks) to generate cash flow.
- ii. The TAS suggests the use of greenhouses (4 x 0.25 ha) for paprika production but we could not find any clear indication of the CAPEX for these structures in the report.
- iii. We concur that aqua-agri integration should be promoted but propose that the Ministry of Agriculture be more closely involved to secure extension services, agricultural incentives (including water and electricity tariffs) including CAPEX and OPEX for the plant component.
- iv. We observed that the soils were deficient in organic matter. This could be corrected with bio-intensive gardening approaches familiar to the author to improve production and reduce fertilizer costs.
- v. A seasonal calendar and market prices of fish should be constructed to take advantage of better seasonal prices.
- vi. Where possible the marketing of plant and fish produce should be coordinated with feed delivery to minimize transaction costs.

3.5.1 Conclusions

- The freshwater team largely concurs with the observations and constraints contained in the TAS, encapsulated in their SWOT analysis (section 5.2) and the three main conclusions.
- The four farms visited remain unproductive and key issues remain unresolved.

3.5.2 Recommendations and way forward

- (i) The ownership of the cooperatives **MUST** be resolved ASAP. We concur with the GRN, and propose a government (51%): cooperative (49%) PPP provided good governance measures are in place.
- (ii) A time bound exit strategy (community buyout) should be put in place.
- (iii) The GRN structure and support both CAPEX and a **recoverable** OPEX.
- (iv) Gate price of fish must be increased to a minimum of N\$20/kg.
- (v) An integrated agri-aqua approach is advocated for all farms but a more effective fish and plant farming practices are required.
- (vi) The GRN should develop a marketing structure for farm produce.
- (vii) Number of managers proposed in the draft TAS and by GRN be reduced to five.
- (viii) Stakeholders need a paradigm shift to appreciate that aquaculture is an all-year-round activity.
- (ix) A committed workforce, ideally from the community, must be put in place.
- (x) Effective mechanisms, in particular on-site training, to **increase** farm **income** should be put in place, especially given the historic expectations given to communities.

4 SITUATION ANALYSIS OF FRESHWATER AQUACULTURE IN NAMIBIA: Varying Possibilities of Inland Aquaculture in Geographic Regions of Namibia

4.1 Introduction

The nature, scope and potential geographic locations for freshwater aquaculture development in Namibia will be determined primarily by climate, availability and access to water and the water temperature. Ambient water temperature is of key significance which would dictate which species can be targeted for aquaculture, taking due cognizance of the primary driver for aquaculture production: optimizing growth performance to farm fish economically. Warm water species will be best suited for freshwater aquaculture but the scope and efficiency will be dictated by the rearing water temperature and access to water. The rearing environment is included since several freshwater species can tolerate a range of saline conditions and therefore species that usually live in freshwater, e.g. tilapias, can be cultured in brackish or saline water, thus extending the potential areas in Namibia where aquaculture can be practised. Layered on these primary conditions will be potential local markets and infrastructure required to support such development and influence their scope.

The purpose of this evaluation therefore is to objectively examine key interrelated macro climatic and physico-chemical parameters to identify swathes of areas in Namibia, in the first instance, which could be conducive for freshwater aquaculture. Within these areas, more detailed site-specific surveys to assess suitability would be required at a later date. For such assessments, the following factors should be included: (i) elevation, (ii) air temperature and (iii) hydrographs using national GIS (geographic information system) based maps.

4.2 Implications of Elevation for Freshwater Aquaculture Development

Altitude is inversely related to ambient air temperature and pressure. Thus at elevation the water temperature will be lower and, in particular, the diurnal water temperature range larger. The relationship between altitude and temperature when sea level air temperature is 15 °C is given in Table 8. In general, for every 1 000 m ascent, the ambient air temperature and pressure will decrease by 6.5 °C

Altitude/elevation (m)	Temperature (°C)	Pressure (hPa)	Density (kg/m ³)
0	15	1013	1.2
1000	8.5	900	1.1
2000	2	800	1
3000	-4.5	700	0.91
4000	-11	620	0.82
5000	-17.5	540	0.74

and around 100 hPa to around 8.5 °C and 1 013 hPa, respectively (Table 8). This decrease is significant for aquaculture since under ambient conditions, water temperature at 1 000 m will be significantly lower than at the coast resulting in lower growth rates of warmwater fishes.

The Namibian terrain consists primarily of a large low-lying coastal desert belt and semi-desert plateau with an average elevation of 1 080 m separated by a northward curving escarpment of over 2 500 m (Figure 11: dark brown). A 3-D view of the topography of Namibia showing these main features is shown in Figure 11.

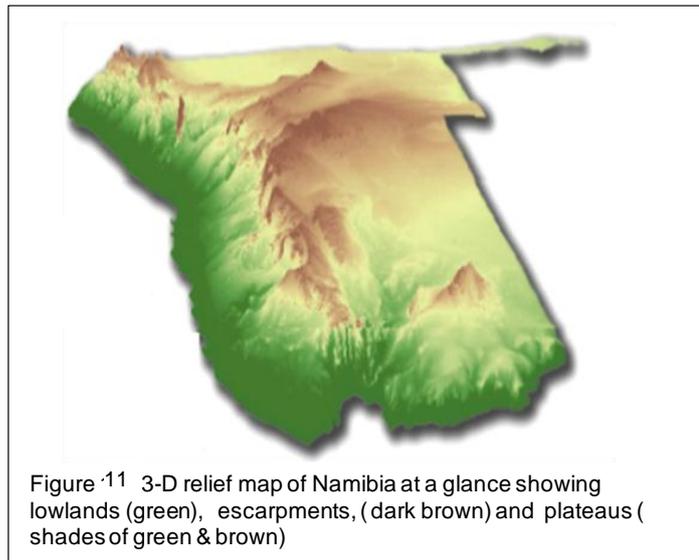


Figure 11 3-D relief map of Namibia at a glance showing lowlands (green), escarpments, (dark brown) and plateaus (shades of green & brown)

The east-west elevation transects from latitudes 18° S to 28° S together with a 2-D composite relief map of Namibia are presented in Figure 12. The elevation of between 1-500 m stretches for around 100-150 km landward from the

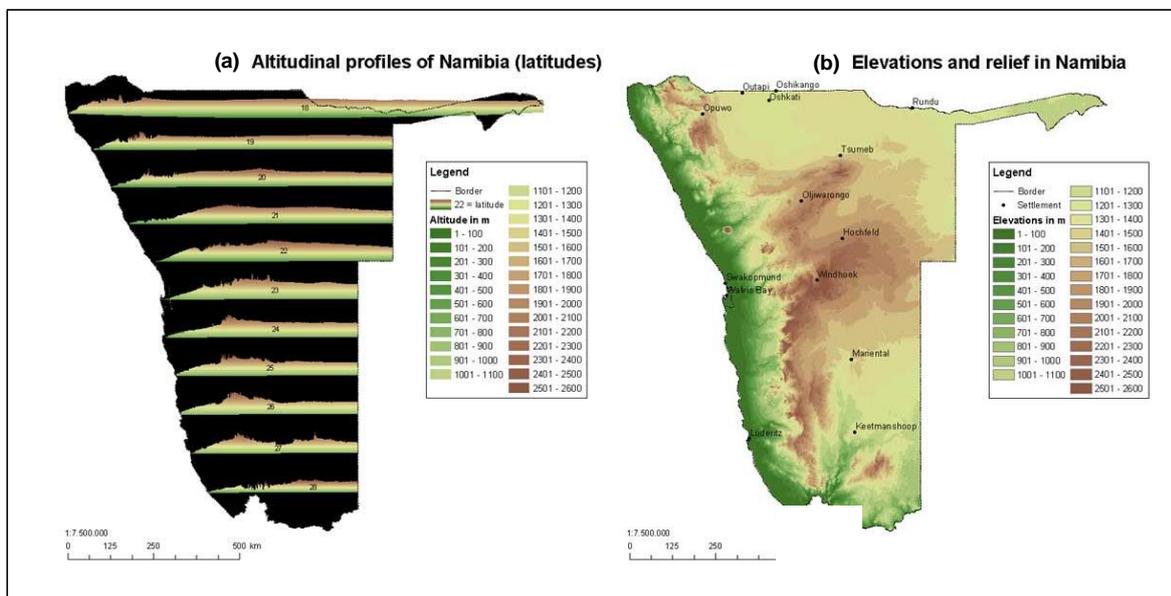


Figure 12. Typology of Namibia. (a) East-west altitude transects from latitude 18°-28°S and (b) transcribed altitude relief map of Namibia.

coastline in Kunene, Erongo, Hardap and Karas Regions and extends further inland into riverine valleys (green areas in Figures 12a and 12b). Low-lying land is also noted in the south of the Gomcab basin and Nama-Karoo basin notably along the Noordoewer-Aussenkehr corridor (Figure 13: areas 5 and 13 on map).

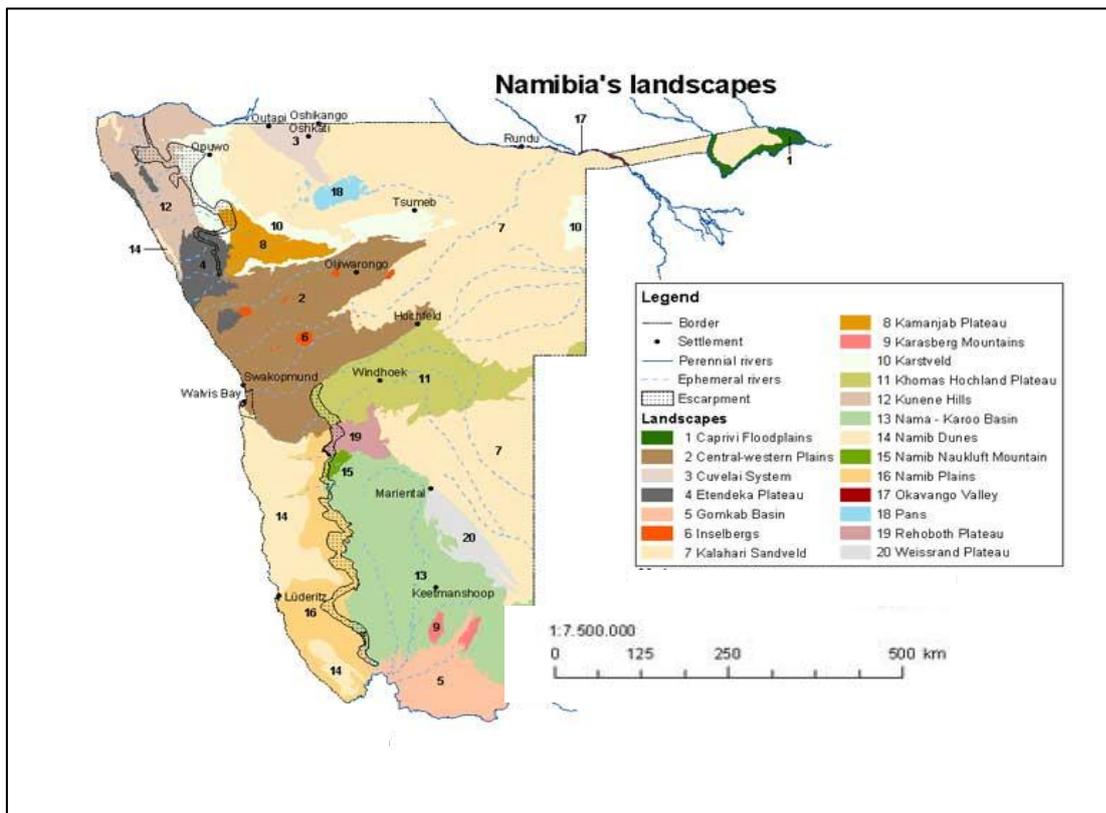


Figure 13. Demarcated landscapes of Namibia.

Based on elevation only, these lowland areas, offering the best potential for high water temperatures could be deemed most suitable for inland aquaculture. The suitability of these areas, however, may be moderated by climate, in particular, solar radiation which principally influences temperature, and rainfall. The influences of these factors, together with their interactions with air currents and rainfall, on potential regions for freshwater aquaculture development are considered next.

4.3 The Climate and Implications for Aquaculture Development

Actual water temperature records for Namibian waters could not be obtained, therefore air temperatures are used as there is a strong correlation between air and water temperature ($r = 0.96$). Air temperature can therefore serve as an indicator to identify suitable areas for freshwater aquaculture development in the first instance.

Solar radiation and temperature

Although Namibia is reported to have over 300 days of sunshine per year, the actual temperatures realized will depend on ameliorating factors such as sea currents and

in particular solar intensity which heats the earth. Along the coast, the cold Benguela current modulates and suppresses air temperature to an average of 23 °C in summer and 13 °C in winter. Inland, the temperatures are higher, but these are checked by altitude, typically between 1 000-1 500 m. This scenario is primarily a result of three main factors: elevation (considered above), solar radiation and interference of radiation. These factors are considered below to deliberate on suitable areas for freshwater aquaculture production.

4.3.1 Sunshine hours and solar radiation

Sunshine hours

Namibia enjoys over 300 sunny days throughout the year. The duration of sunshine in any day, and therefore the sun’s accumulated radiation striking earth, however, varies across Namibia. The number of hours of sunshine per day across Namibia is illustrated in Figure 14.

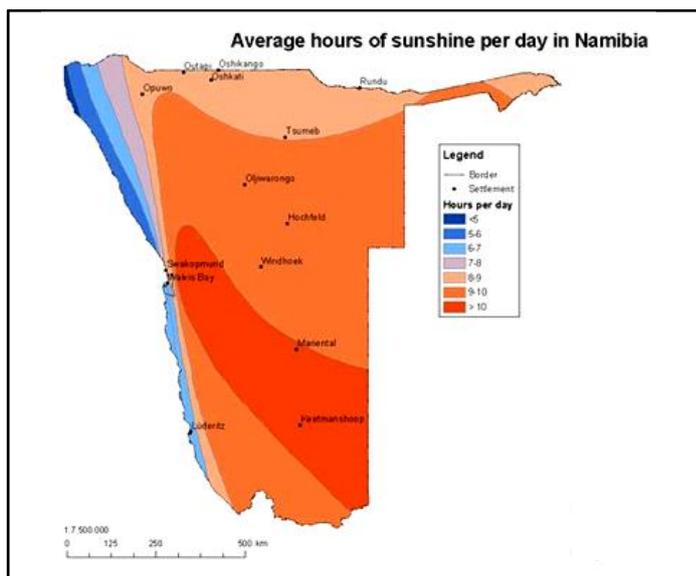


Figure 14. Pattern of average sunshine /day in Namibia

Sunshine hours are lowest along the low-lying coast; on average only up to 5 hours per day. Sunshine hours increase eastwards with a zone stretching from the central Namib Desert south-eastwards receiving between 10 and 11 hours of sunshine per day. The central and northern parts of the country enjoy fewer sunshine hours (between 8 and 10 hours) due to cloud-cover during the summer months.

Solar irradiation

During sunshine hours (clear skies) maximal solar radiation strikes the land or water mass. On reaching earth, the suns energy or radiation is converted to heat which in turn warms the land, water and atmosphere. Therefore, the amount of heat generated is a function of sun radiance as well as sunshine hours. This heat,

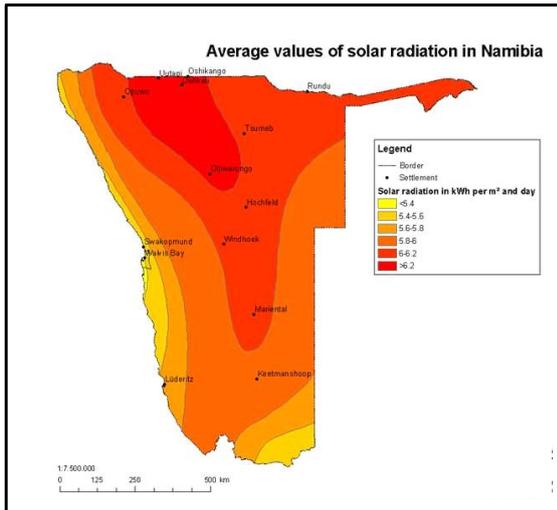


Figure 15. Distribution of average solar radiation in Namibia

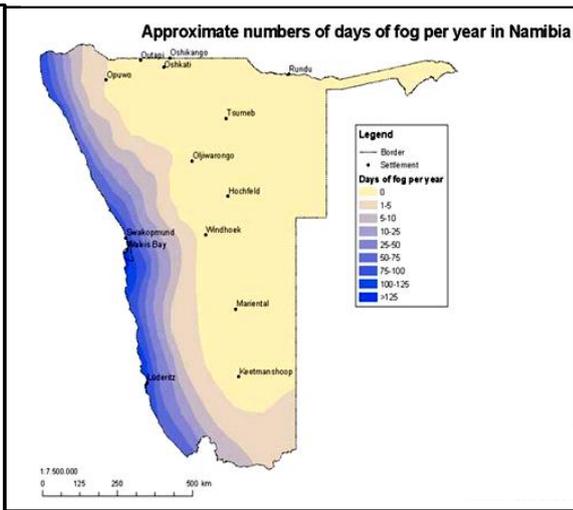


Figure 16 Occurrence and frequency of fog in Namibia

measured as sun irradiance (kWh/m^2), is a measure of the intensity of the radiation and determines the temperature. The average values for solar radiation across Namibia are illustrated in Figure 15. The intensity of solar radiation is lowest along the coast at up to $5.2 \text{ kWh}/\text{m}^2$. This low intensity is due to frequent cloud and fog cover which deflects the sun's radiation thus reducing the total solar radiation reaching the ground. As seen in Figure 16, the coastal zone is subjected to over 125 days of fog per year thus reducing the radiation reaching land or sea for prolonged periods and thus resulting in cooler temperatures (Figure 17).

The intensity of solar radiation gradually increases inland to about $5.8 \text{ kWh}/\text{m}^2$. The highest total radiation values are recorded on the plateau in central northern Namibia with values of between 6.2 and $6.4 \text{ kWh}/\text{m}^2$ as a result of no fog interference (Figure 15) and higher sun elevations. The southern regions have lower radiation values due to lower sun elevations in the sky on average, while in the north eastern regions more cloud cover, rather than fog, accounts for the lower radiation levels. The net result of these factors determines the temperature. The resulting temperature isotherms for Namibia are presented in Figure 17. Based on ambient air temperature alone, the areas enclosed within the

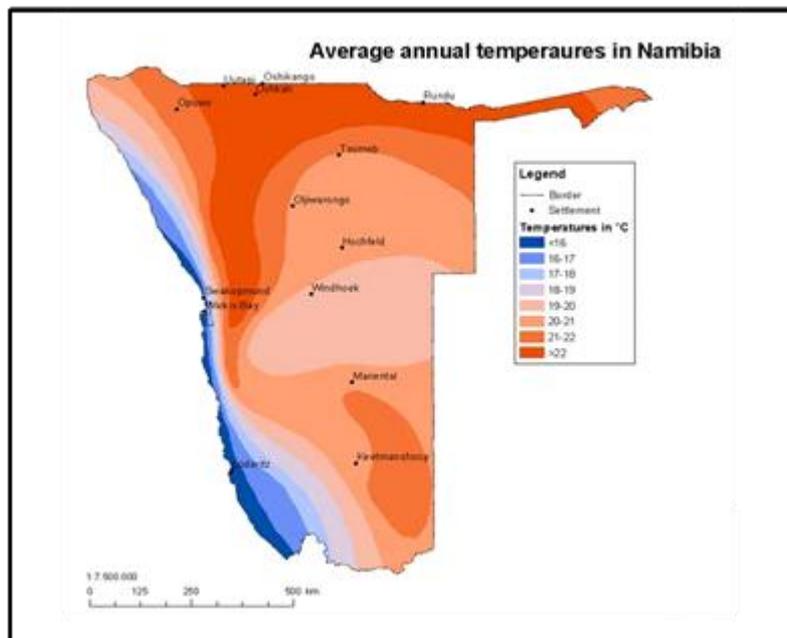


Figure 17. Isotherms showing average temperature profile across Namibia

Figure 17. Isotherms showing average temperature profile across Namibia

isotherm $>20\text{ }^{\circ}\text{C}$ could have the highest temperatures for farming warmwater fish. These regions include the north western regions, Kavango and Caprivi in the north and the eastern Karas region (Figure 17). These isotherms represent the average temperature.

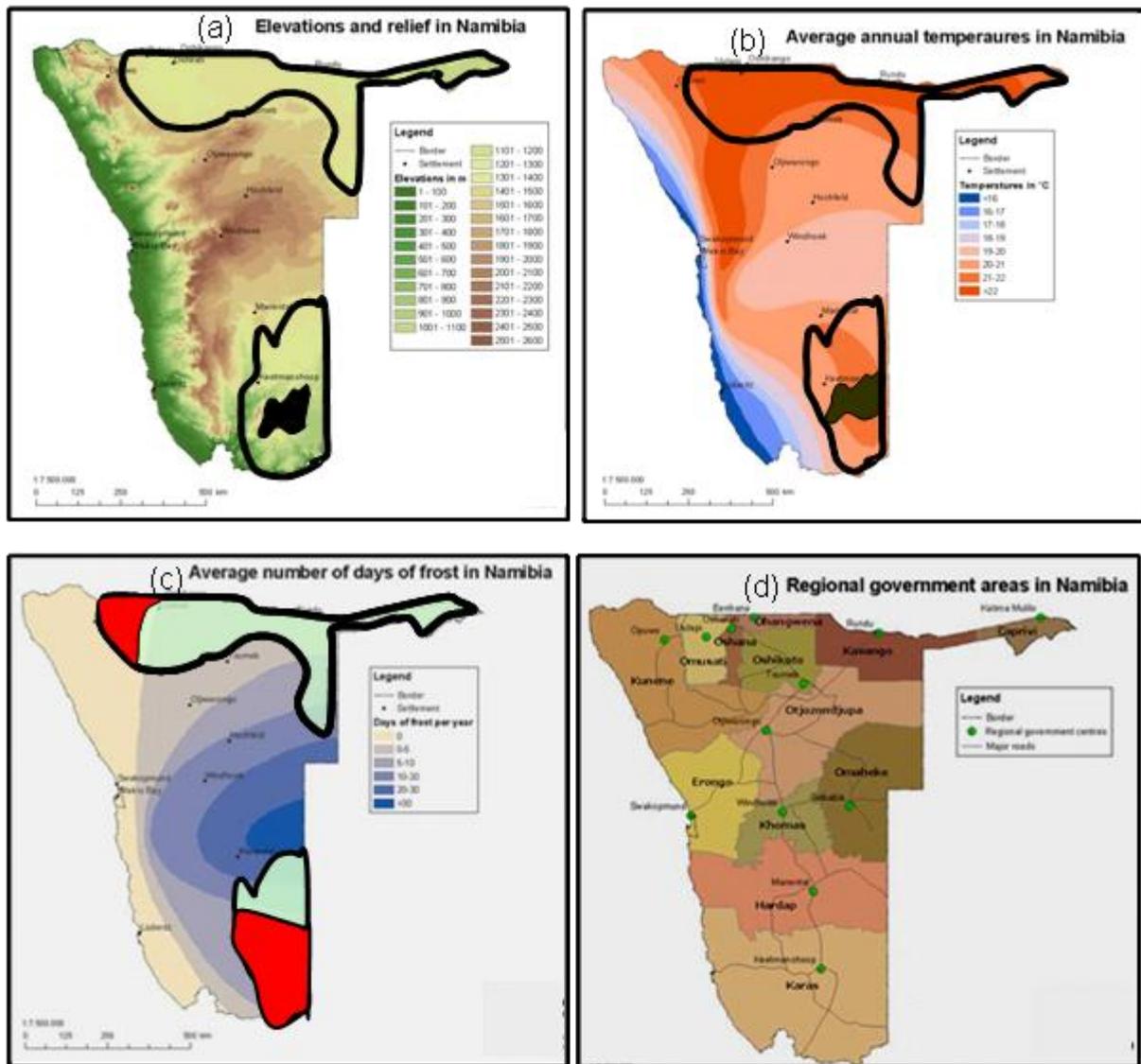


Figure 18. Identification of most suitable areas based on layers (a) Elevation, (b) Temperature, and (c) Frost. Most suitable areas for outdoor aquaculture in relation to regions (d).

In addition to elevation and temperature, diurnal fluctuation will influence average water temperatures and hence fish growth. Therefore for this report the number of days of frost in a year is used as an indicator of extreme diurnal temperatures across Namibia. Suitable areas based on the first layer i.e. elevation, are shown in Figure 18a. When considered together with average temperature isotherms the suitable areas are reduced in the south (Figure 18b). Since the growth and survival of proposed freshwater fish species will be affected by low temperatures, areas subject to frost were considered. Larger areas within the suitable average temperature zones area are prone to 0-5 days of frost (Figure 18c – green areas).

Two small areas, west of Opuwo in the north and south of Keetmanshoop in the south are free from frost (red areas in Figure 18c).

4.3.2 Rainfall

Namibia is a semi-arid country and so water is in short supply. Therefore, loss of water through evaporation will be a significant additional factor to be considered for outdoor fish farming.

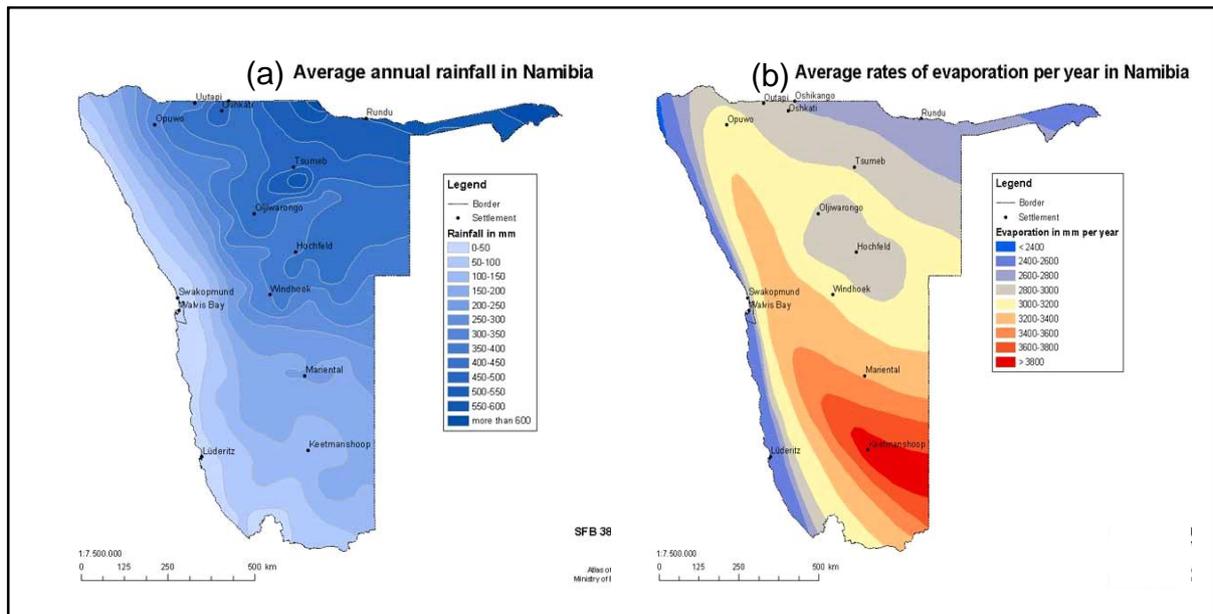


Figure 19. Distribution of rainfall pattern (a) and water loss through evaporation (b)

As seen in Figure 19a, the north receives 500-600 mm rainfall annually in contrast with just 0-100 mm south of Keetmanshoop, an area deemed suitable based on temperature. The low precipitation and resulting low humidity, however, results in this area having the highest trans-evaporation rate, in excess of 3 600 mm/yr (Figure 19b). Consequently, whilst suitable from a temperature point of view, it is unsuitable for **outdoor** aquaculture and therefore aquaculture in these regions will have to be conducted indoors e.g. under greenhouses.

Overall, the areas most suitable for outdoor aquaculture in Namibia are limited. Best opportunities exist in the northern regions but low winter temperatures will have to be considered carefully in the design of production systems. The south is not suitable for outdoor aquaculture but aquaculture could be developed under cover.

The above macro parameters of elevation, solar radiance, ambient air temperature and evaporation rates identify areas within the northern regions as having potential for outdoor freshwater aquaculture development. However, it is also recognized that

the major flood plains are also located in these regions and that large tracts of land are flooded annually with increasing severity and frequency in recent years.

The satellite image illustrates the severity of flooding in the regions of Omusati and Oshana (Figure 20) and Ohangwena (Figure 21). Clearly, more accurate surveys will need to be conducted to establish suitable elevations within these regions to establish aquafarms. Whilst it is appreciated that vast areas of these areas flood, opportunities exist to integrate fish farming with agriculture along areas of the Ruccana canal.

The above areas refer to potential areas for farming under outdoor conditions where farmers will be reliant on ambient water temperatures. However, Namibia presents the opportunity for aquaculture development using underground water. In this regard, most suitable areas will include those areas yielding warm water via springs under pressure. Such locations will facilitate the development of simple, relatively low-cost systems which can be integrated with vegetable farming. Examples of such locations were identified and presented under site visits.

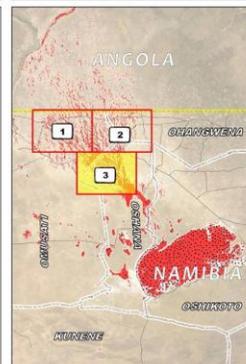
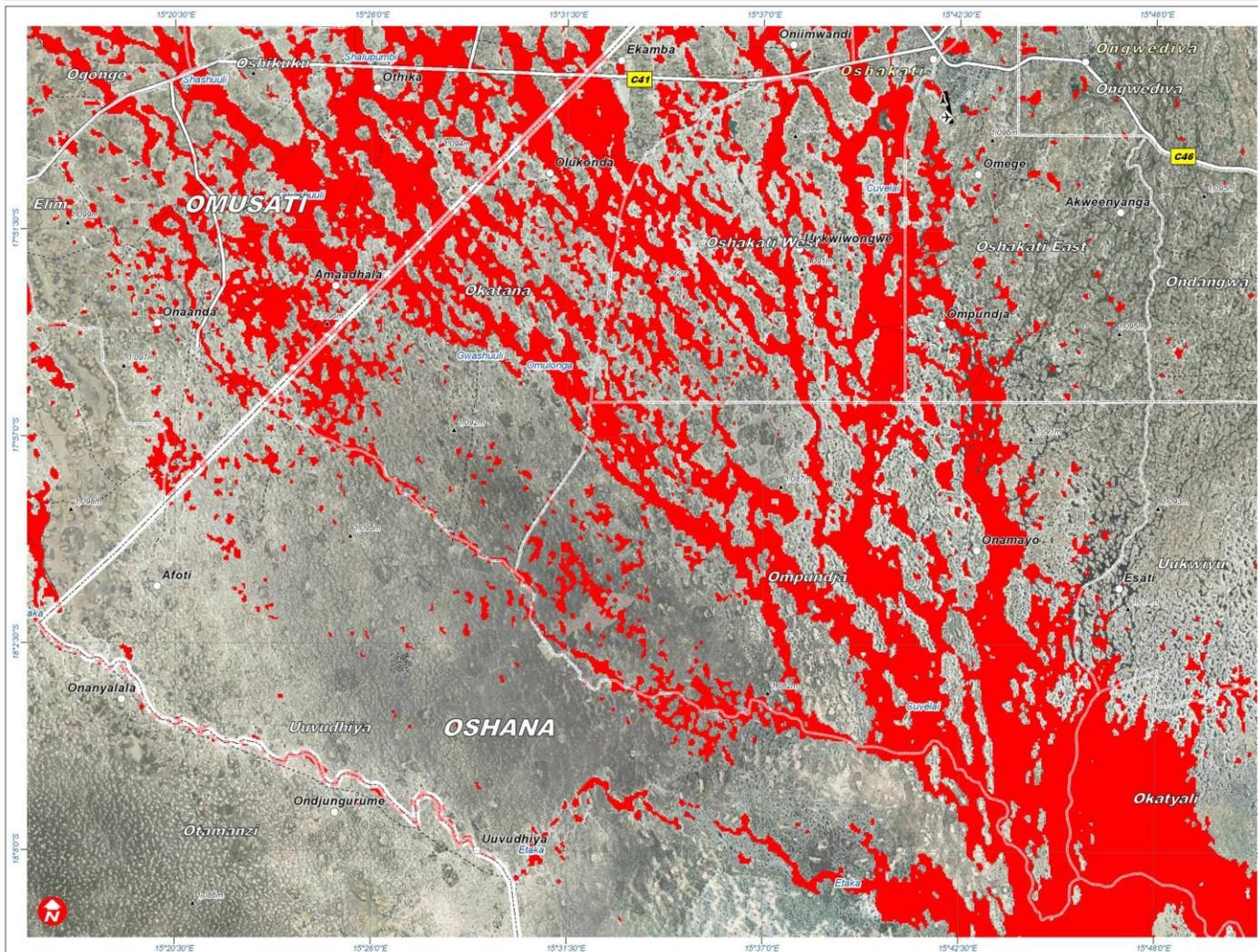
FLOOD WATERS OVER THE AFFECTED REGION OF OSHANA, NAMIBIA - 19 MARCH 2008

This map illustrates satellite-detected flood waters as of 19 March 2008 over the affected Region of Oshana, Namibia. Flooded areas have been sorted into 2 classes. Red areas represent standing flood waters identified with a high degree of confidence; and Blue areas represent pre-flood water levels in July-November 2007. Flood analysis was made using ENVISAT-ASAR data (WSM) recorded on 19 March 2008 at a spatial resolution of 150m, and MODIS recorded in November 2007 and March 2008. The flood detector is a preliminary analysis & has not yet been validated in the field.

Flood Analysis with ENVISAT-ASAR
WSM Data Recorded 19 March 2008



Heavy Rainfall & Flooding 20 March 2008
Version 1.0
Map Sheet: 3
Glide No: FL-2008-00004-NAM



Legend

- International Border
- Region Border
- Capital
- Village / Town
- Airfield
- Mine
- Spot Height (m)
- National Park
- Etosha Pan / Salt Lake
- Utility Line
- Constituency Border
- Main Road
- Track / Trail
- Railroad
- Park Border

FLOOD WATER ANALYSIS

Derived from ENVISAT-ASAR Recorded 19 March 2008

- Estimated Standing Flood Waters (4 March 2008)
- Pre-Flood Waters (July - November 2007)
- ENVISAT & MODIS

Map Scale for A3: 1:185,000

0 0.5 1 2 3 4 5 6 7 8 Kilometers

Radar Data ENVISAT ASAR (WSM)
Radar Resolution 150m
Radar Dates 19 March 2008 & 20 July 2007
Copyright ESA
Road Data Namibia Directorate Survey & Mapping
Flood Analysis UNOSAT
GIS Data USGS, NSA, UNILC, SALB
Landsat Image MDA-ESRI-NASA
Map Production UNOSAT (20 March 2008)
Projection UTM Zone 33 South
Datum WGS 1984

The depiction and use of boundaries, geographic names and related data shown here are not warranted to be accurate nor do they imply official endorsement or acceptance by the United Nations. This map was produced by the United Nations Institute for Training and Research (UNITAR) Operational Satellite Applications Programme (UNOSAT). UNOSAT provides satellite imagery & related geographic information to UN humanitarian & development agencies & their implementing partners.

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Figure 20. Recent flooding in Oshana

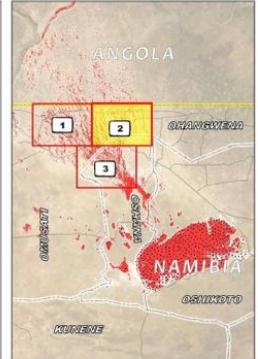
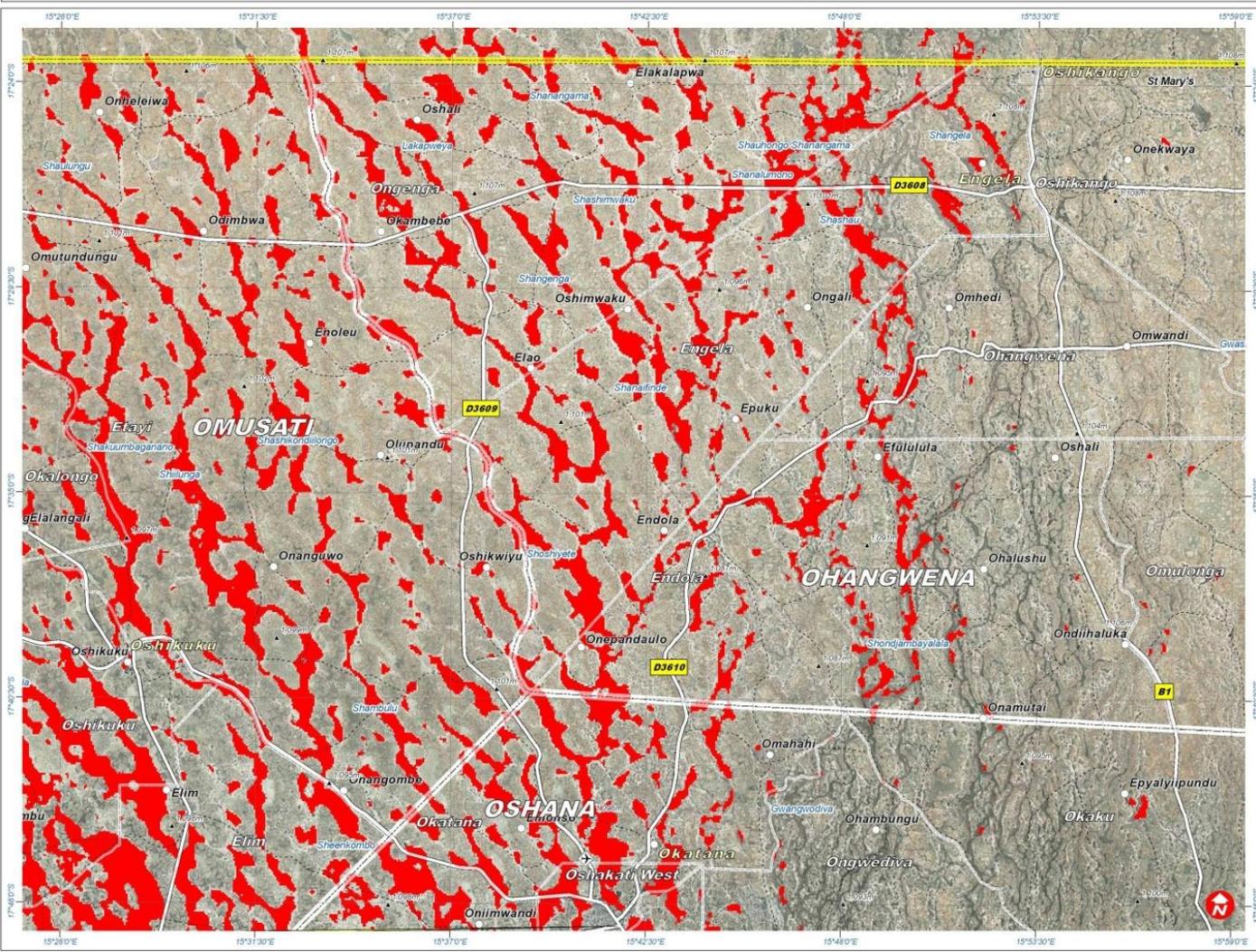
FLOOD WATERS OVER THE AFFECTED REGION OF OHANGWENA, NAMIBIA - 19 MARCH 2008

This map illustrates satellite-detected flood waters as of 19 March 2008 over the affected Region of Ohangwena, Namibia. Flooded areas have been sorted into 2 classes. Red areas represent standing flood waters identified with a high degree of confidence and Blue areas represent pre-flood water levels in July-November 2007. Flood analysis was made using ENVISAT-ASAR data (WSM) recorded on 19 March 2008 at a spatial resolution of 150m, and MODIS recorded in November 2007 and March 2008. This flood detection is a preliminary analysis & has not yet been validated in the field.

Flood Analysis with ENVISAT-ASAR WSM Data Recorded 19 March 2008



Heavy Rainfall & Flooding 20 March 2008
Version 1.0
Map Sheet: 2
 Grid No: FL-2008-000004-NAM



Legend

- International Border (dashed line)
- Region Border (dotted line)
- Constituency Border (dotted line)
- Main Road (solid line)
- Track / Trail (dashed line)
- Railroad (line with cross-ticks)
- Park Border (dotted line)
- Utility Line (line with cross-ticks)

FLOOD WATER ANALYSIS

Derived from ENVISAT-ASAR Recorded 19 March 2008

- Estimated Standing Flood Waters (4 March 2008) (Red area)
- Pre-Flood Waters (July - November 2007) (Blue area)
- (ENVISAT & MODIS)

Map Scale for A3: 1:185,000

0 0.5 1 2 3 4 5 6 7 8 Kilometers

Radar Data: ENVISAT ASAR (WSM)
 Radar Resolution: 150m
 Radar Dates: 19 March 2008 & 20 July 2007
 Copyright: ESA
 Road Data: Namibia Directorate Survey & Mapping
 Flood Analysis: UNOSAT
 GIS Data: USGS, NGA, UNALC, SALB
 Landsat Image: MODIS-ANSA
 Map Production: UNOSAT (20 March 2008)
 Projection: UTM Zone 33 South
 Datum: WGS 1984

The depiction and use of boundaries, geographic names and related data shown here are not warranted to be error-free nor do they imply official endorsement or acceptance by the United Nations. This map was produced by the United Nations Institute for Training and Research (UNITR) Operational Satellite Applications Program (UNOSAT). UNOSAT provides satellite imagery & related geographic information to UN humanitarian & development agencies & their implementing partners.

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Figure 21. Recent flooding in Ohangwena Region

5 SITUATION ANALYSIS OF FRESHWATER AQUACULTURE IN NAMIBIA: Assessment of Individual Private Aquaculture Initiatives

Preamble

As part of data and information gathering to contribute to a freshwater component of an aquaculture master plan for the country, three private freshwater fish culture initiatives were visited for rapid assessment. These were initiatives at Uis, Omandongo and Okapanda.

Assessments of the initiatives together with recommendations are presented below:

5.1 Farm No. 1

Name of farm: Uis Aquaculture Farm

Owner of activity: Johan van der Westuzien , P.O. Box 2, Uis, Namibia

Location: Uis

Person communicated with: Mr and Mrs Johan van der Westuizen

Rapid assessment:

- Operation of the farm consisted of two parts. Both intended to be commercial enterprises.
- An indoor 'flow-through' hatchery.
- Rearing containers were movable circular fibreglass, extruded plastic and concrete tanks.
- The concrete tanks were mainly intended for holding and management of broodstock, while the fibreglass and extruded plastic tanks were for nursing and management of fry until fingerling stages.
- Water source to hatchery was an old mine hole whose water was contributed to by aquifer and surface run-offs.
- Fish spawned in hatchery native *O. mossambicus* and red *O. mossambicus* obtained from Stellenbosch University in South Africa.
- Hatchery had a solar system facility to maintain temperature at desired levels especially during cold months of year.
- Owners exhibited sufficient knowledge, understanding and interest to support intended operation to appreciable extent.

A second component of Uis fish farm was an outdoor caged fish culture set-up in a former tin mine 'pit' where mining stopped in 1980.

Water area of the mine pit covered an area of about 1 ha:

- There were 15 cages.
- Each cage measured 2 x 3 x 2 m.
- Fish cultured in cages were the *O. mossambicus* and its red variety from Stellenbosch University in South Africa.
- Water temperatures were estimated to be lower than that required by tilapia to function and grow at rates that would support commercial operations.

5.1.1 Deductions

- Hatchery operations were considered very likely to achieve intended objective.
- It was, however, known to the operator that there were presently no fish farmers close by to be targeted as a local market for fish seed to be produced. The hatchery could develop to serve future fish farmers in the area.
- Water temperatures at the mine pit environment were below levels that would support optimal fish growth rates for a commercial enterprise.
- Most fingerlings generated from the hatchery would have to be grown in the same farm's on-growing system. Currently there are no local farmers to purchase them as intended and also with public sector hatcheries providing fingerlings at subsidized cost.

5.1.2 Recommendations and way forward

- i. Operators of farm should seriously consider establishing an indoor on-growing system to produce table size fish.
- ii. If cages are used the stocking size of fish be raised to 30-50g
- iii. Cover current fingerling facility with greenhouse grade polythene.
- iv. Produce and on-grow sex-reversed fish.
- v. Consider changing species to *O. niloticus* or its hybrids, if fish can tolerate temperatures at site.
- vi. Seek advice on design of production systems **prior** to building to ensure best value

Uis - Private farmer currently farming red mossambicus – The farmer is a good candidate for concerted support by MFMR



Farmer has understanding and appreciation of the need to monitor and record information



Has a simple but functional hatchery for his seed which needs upgrading and improved management



He produces fingerlings of a poor species under cover which need to be improved to conserve heat



He is building broodstock tanks that can be better designed and be more practical



He on-grows his fingerlings in cages in an ex-mining pit that are too small and inadequately designed



He farms red mossambicus which is a poor grower. He should consider other tilapia species. Needs to be aware of oxvaen debt

Farm No. 2

Name of farm: Pastor Shikuma Aquaculture Farm

Location: Okapanda

Person communicated with: Daughter of Pastor Shikuma aged about 12-15 years

Background: Pastor Shikuma had indicated interest to set up a commercial fish farm. He was said to have applied to AgriBank, Namibia, for support.

Rapid assessment:

- Area of intended farm ponds was a flood plain.
- Soil of site was not likely to have sufficient clay to hold water.
- Two uncompleted and completely dry ponds at the site indicated assessments of soil and elevation.
- Dryness of ponds suggested high seepage at site.

5.1.3 Deductions

- The site is most likely not suitable for fish pond construction due to poor elevation and insufficient clay content of soil.

5.1.4 Recommendations and way forward

- i. It is recommended that a detailed comprehensive assessment of the site be undertaken prior to any investment at the site.
- ii. Owners should seek professional advice at very beginning of intended activity.



Shallow ponds excavated by roadside. This site is unsuitable, soils are sandy and water seepage substantial.

5.2 Farm No. 3

Name of farm: Dr Hambo Indongo

Owner of activity: Dr Hambo Indongo

Location: Omandonga, near Grootfontein

Person communicated with: Daughter of owner

Background: A multi-crop farm with fish component just initiated

Rapid assessment:

- One cement tank in place filled with water.
- Depth of pond only about 0.4 m.
- Area of farm earmarked for fish had parched and compacted soil.
- The area for fish was less than 1 ha.
- There was apparently sufficient water to undertake a fish culture activity.
- Fish feed currently supplied by government feed mill.

5.2.1 Deductions

- Depth of tank about 0.4 m
- Owners have limited knowledge of fish farming.
- Earthen ponds would not be appropriate at the site.
- All fish cultivation would have to be in cement/concrete tanks.
- It was possible to fit two 400 m² on-growing ponds into the area presently being considered for fish on the farm.
- The owner recognized his need for technical advice and support.

5.2.2 Recommendations and way forward

- i. Given background of owners and farm activities, fish farming pecially should be investigated further.
- ii. Farm must keep records, especially temperature.
- iii. Design and construction of other tanks should be discussed with appropriate technicians **prior** to construction.



Private farmer with potential to understand concepts of aquaculture. Currently has one concrete tank. Tank design should be improved with better information on design. Water quality data should be monitored as discussed on farm.

5.3 Overview of Individual Private Freshwater Aquaculture Initiatives

Individual freshwater aquaculture initiatives assessed during the field exercise were considered indicative of the approach to and activity of freshwater aquaculture among the general population. The initiatives included three attempts at developing commercial fish farms commented on above and a site inspection of the 'Rainbow' aquaculture site evaluated (Subsection 8). Major issues generated from observations of the initiatives that need consideration and responses to the NAMP-FW, were mainly the following:

- i. The infancy of freshwater aquaculture in Namibia.
- ii. Sources of information and their apparent impacts on attitudes towards aquaculture enterprise.
- iii. Completeness of expectations and challenges of aquaculture to the public.

i. *Infancy of freshwater aquaculture in Namibia*

Assessments of the initiatives and the 'Rainbow' site as well as feedback from individuals on aquaculture during the field trips confirmed the infancy of freshwater aquaculture in Namibia. Knowledge on aquaculture production was clearly limited. The

MFMR had indicated that the concept of aquaculture and advocacy for practice had been initiated only in the past five years.

Within this period, MFMR had obviously been able to promote uptake and some practice of freshwater aquaculture in the country, bringing other potential beneficiary Ministries of Youth, National Service, Sport and Culture and Gender Affairs to partake in aquaculture development. The MFMR had also reached out to non-governmental organizations (NGOs), traditional authorities and private citizens with knowledge of freshwater aquaculture. The situation was considered an achievement for the MFMR for which they should be commended. The co-ordination of these interested groups, however, needs to be formalized.

ii. *Sources of aquaculture information to public and apparent impacts*

Interaction with members of civil society intending to engage in freshwater aquaculture revealed that the public were divided into two with regard to their sources of information as follows:

- a. Those whose information on aquaculture was obtained locally, presumably from staff of MFMR.
- b. Individuals whose information on aquaculture was obtained from local and external sources.

iii. *Completeness of expectations and challenges of aquaculture to the public*

It was apparent from public feedback that their expectation from aquaculture is unrealistic. We were informed that these expectations had arisen from MFMR. It is important that promotion of aquaculture is realistic and achievable. The economic returns that the public believe are possible are unrealistic and the challenges associated with aquaculture requiring full-time and continuous care of stock need to be stressed.

6 SITUATION ANALYSIS OF FRESHWATER AQUACULTURE IN NAMIBIA: Government Inland Fisheries and Aquaculture Centres

6.1 Preamble

The public sector of Namibia has established a number of institutions as centres or lead institutions for inland fisheries and aquaculture. As lead institutions, they were expected to function as research and development centres, addressing issues to promote growth and development of freshwater aquaculture and capture fisheries. Four such centres were visited during a survey undertaken to assess aquaculture facilities and activities in the country to inform NAMP-FW. The four centres visited were the:

- a) Epalela Fish Farm
- b) Onavivi Inland Aquaculture Centre
- c) Kamutjonga Inland Fisheries Institute (KIFI)
- d) Hardap Inland Aquaculture Centre Dam Station

The stations were visited to rapidly assess the following:

- i. on-going activities;
- ii. existing plans for adaptive research and development;
- iii. facilities;
- iv. indicative capacities of staff for inland aquaculture research and development activities; and
- v. to make appropriate recommendations for the centres' use as inland aquaculture research and development centres.

6.2 Common Strategic Observations and Assessments

- 1) All stations were engaged in some activities but there was no activity with specific national aquaculture growth and/or development objective.
- 2) There were no documented national plans for aquaculture research or development.
- 3) Facilities at three centres (i.e. Epalela Fish Farm, Onavivi Aquaculture Centre and Hardap) were sufficient for activities taking place and to take on targeted adaptive research and studies to benefit national aquaculture growth and development.
- 4) Staffs' capacities in aquaculture at all centres were below those of senior staff.

- 5) All stations seemed to have a unclear clear distinction between inland capture fisheries and aquaculture.

6.3 Government Facilities

6.3.1 Epalela Fish Farm

Person mainly communicated with: Dr Eldys Fernandez Nesa and Eng. Ernesto Estada Nican (Cuban experts to Namibia) and Oliver (Officer-in-Charge of Station).

Purpose of visit: To assess current and potential contribution to aquaculture growth and development in Namibia.

Background to farm: Station started operating in 2005/6 cultivating tilapia, (*O. mossambicus*) mainly, and the African catfish (*Clarias gariepinus*) in ponds. There are 12 ponds on the farm with individual sizes varying around 2 400 m². Previous major problems of farm were water seepage and predation on fish in ponds by birds.

The Cuban technical assistance through SSC (South-South Cooperation) to the station started about ten months prior to visit.

Current aquaculture activities and plans:

Activities: Recent major aquaculture activities of station have included:

- Lining of all (12) ponds to stop seepage.
- Change of stocking rates in ponds from 2-4 fish/m² to 6-10 fish/m².
- Feed ration currently put at between 1.9% to 15% body weight / day and fed 3-4 times.
- Bird predation controlled by protective netting.
- Considering adopting partial harvesting approach instead of total harvesting practised currently.

Current plans: No specific plans were stated. However, the Cuban experts seemed to be evaluating a number of culture strategies or parameters with the objective to maximize pond fish production. The parameters included:

- a) Influence of pond lining on water temperatures in ponds.
- b) Stocking densities for maximum fish production within six months and a targeted harvest size of 250 g fish.
- c) Fine tuning of ration and feeding frequency
- d) Multiple harvesting as an approach to increase production

Recommendations and way forward:

- i. Aquaculture issues being investigated at the station be reviewed and structured and clearly documented in order to disseminate outcomes to other government fish culture stations and to contribute to national information generation to support the emerging industry.
- ii. The station should also be considered as a demonstration and training centre for the northern regions.
- iii. Water temperature records must be kept and used to plan feeding strategy.



Epalela farm: Circular tanks used to rear catfish. High tanks are difficult to manage but have a larger water volume for increased production.



Plastic-lined ponds for on-growing *O. andersonii* at Epalela farm. Note anti-bird predation nets used over ponds. Structures and netting can be improved to ensure better protection against predation and better access.

6.3.2 Onavivi Inland Aquaculture Centre (Onavivi-IAC)

Location: Onavivi.

Person mainly communicated with: Ms Elizabeth Ndivaye (Officer-in-charge of station) and Teodor Simon.

Background to farm: The Onavivi-IAC was the first of a few IACs in Namibia. It was used to introduce the subject of aquaculture to Namibia and to inform outsiders that the country was getting involved in freshwater aquaculture.

Functions at inception of station:

- Fingerlings production
- Training of technicians and small-scale farmers
- Fish production at pilot scale
- Production of fish seed

The Government of Spain assisted Namibia to rebuild the centre during 2003 to 2006. At the end of the assistance the centre consisted mainly of a hatchery, a feed plant and a number of earthen ponds to undertake fish production at a 'medium scale'.

Current aquaculture activities and plans:

- Fish seed production (of tilapia, *O. andersonii* and African catfish, *C. gariepinus*). However, have problems with the catfish seed production.
- Formulated fish feed production (feed produced in sinking pellets form).
- Fish production at small-medium-scale level.

Current plans:

- Current plans associated with producing floating feed pellets.

Recommendations and way forward:

- i. Centre should develop a research agenda linked to a national R&D strategy to contribute to aquaculture growth and development.
- ii. Fish seed production and fish production; the current problems related to poor catfish fingerling survival and production must be defined, documented and a **plan made to resolve them.**

- iii. Co-ordinate with other centres to develop a broodstock management and development programme.
- iv. Streamline facilities and acquire relevant equipment for delivering on an agreed time bound action plan.

6.3.3 Kamutjonga Inland Fisheries Institute (KIFI)

Location: Kamutjonga.

Person mainly communicated with: Sililo Sitengu (Chief Fisheries Biologist), Hermes Mataya (Fisheries Research), Sy Van Ngo (Vietnamese Expert), Elizabeth Sinvula and Thadeus Mushambe.

Background to institute: A national flagship Institute inaugurated on 3rd October, 2008.

Current activities:

- Capture fisheries data and information gathering and storage
 - Fish surveys
 - Fish collection
 - Growth and ageing
 - Fish parasites and diseases study
 - Water quality in ponds and rivers
- Fingerling production
- Fish processing
- Aquaculture extension

Current plans: To continue with current activities.

Comment: There is an urgent need to conduct an in-depth technical audit of KIFI to strengthen the current leadership of KIFI and provide unified direction. The institute seems to have a limited **visible** aquaculture agenda but may be kept so if KIFI's main focus is deemed exclusively inland **capture** fisheries. The only indoor fingerling production facility may not work optimally due to the limited training of aquaculture personnel in post.

The indoor facilities are inadequately designed for purpose and constructed, making most of the facilities difficult to use, at best. Despite being new, it has acquired obsolete laboratory equipment and chemicals which were out of date prior to the building construction date. These chemicals are also of limited relevance to aquaculture in Namibia and much of the equipment is not fit for purpose. Similarly, the ponds have serious inherent design faults making their use problematic.

Recommendations and way forward:

- i. Develop a time bound nationally coordinated R&D agenda.
- ii. The centre should focus on monitoring and managing inland capture fisheries.
- iii. The GRN should strengthen the leadership at KIFI.
- iv. Conduct a detailed audit of facilities and invoke remedial measures to optimize its facilities (see photographs below).
- v. Fisheries data and information collection must be made prominent and build modern linkages with other fisheries information centres and related libraries.
- vi. Institute must take time to set justified agenda of work.



KIFI station opened in 2009. This facility should principally focus on inland capture fisheries and as a national repository for information. Currently lines of duty are mixed leading to poor productivity.



Display facilities at KIFI. Space could be better utilized. Systems are over specked and space poorly used. Suggest KIFI reconsider the value of this facility.



Fingerling production units: materials used adequate but as in other systems, management considerations not well considered. Tanks are far too high and cannot be easily managed for feeding, cleaning and harvesting. The pipework is also suboptimal (see photographs on right) as pipe dimensions ignore basic principles of recirculation systems and repeated in new raceways being built.





Breeding systems: materials adequate but inadequate design considerations. Tanks are far too high making them impractical for managing as intended spawning tanks. Limited consideration to passageway, making operation of systems problematic. Note space for walkway only two pens (approximately 40 cm) wide.



New fingerling raceways under construction at KIFI: materials adequate but same design faults as in broodstock systems. Suboptimal pipework sizings are repeated here and suggest a lack of understanding of the basic principles of recirculation systems.

Note, as in other systems, inflow and outflow are similar dimensions.





KIFI has a microbiology lab and houses chemicals of no real value. Moreover, the entire store of chemicals acquired is inappropriate for aquaculture, well out of date (2007) and **should be discarded**.



Despite being brand new, the internal infrastructure is showing signs of water ingress and should be rectified immediately to prevent further deterioration.



The station is new but is poorly designed and fitted. The station has acquired several pieces of obsolete equipment of no relevance to needs. Examples shown here are a cryostat and microtome. Such equipment should be discarded or perhaps given to a university and labs fitted based on a clear, planned and supervised inland capture fisheries research agenda.

6.3.4 Hardap Inland Aquaculture Centre

Location: Hardap dam site.

Person mainly communicated with: Lesley Kikuri.

Background to institute: Centre was established in 1968 and operated as a public sector institution until 2003. During this period, the centre emphasized freshwater biological research and some aquaculture studies. In 2003, a private aquaculture company, Eco-Fish, joined the public sector in a PPP. In the partnership Eco-Fish operates the fish culture component of the centre on a commercial basis while the public sector is expected to continue with freshwater biological research which could include aspects of aquaculture.

Current activities:

- Private sector (PS) component running indoor greenhouse recirculation system in concrete tanks to farm the Nile tilapia, *O. niloticus*.
- PS component also running an indoor hatchery which could produce more fish seed than needed on the farm.
- Government sector (GS) component of station continues inland fisheries studies.

Current plans:

- The GS component to try to attain better sex reversal results at station to attain 100% success.
- The GS component to resolve seepage problem of four earthen ponds at station.

Current issues:

- No properly trained aquaculture personnel at station.
- The PPP at Hardap is ineffective and should be dissolved and a management buyout considered with government partnership.

Recommendations and way forward:

- i. MFMR should have a clear aquaculture agenda for the station.
- ii. Evaluate purpose of inland capture fisheries monitoring.
- iii. Ensure a programme of effective record keeping.
- iv. Train appropriate aquaculture personnel for meet stations main agenda.
- v. Import new strains of *O. niloticus*, a species that already exists in Namibia.
- vi. Produce 30-80 g sex-reversed fingerlings for on-growing.

7 SITUATION ANALYSIS OF FRESHWATER AQUACULTURE IN NAMIBIA - INSTITUTIONAL INITIATIVES: Ministry of Fisheries and Marine Resources Assisted 'Cooperative' Fish Farms

In total, four of the six cooperative farms were visited; Mpungu Fish Farm, Likunganelo Fish Farm, Kalimbeza Farm, and Kalovo Fish Farm. The information gained was derived through informal interviews with stakeholders present at meetings.

7.1 Mpungu Fish Farm

Location: Nkurenkuru (under Rundu regional office)

Persons mainly communicated with: Mr Cyprian Mutelo and Mr Vallentinus Shindimba.

Purpose of visit: To assess situation of farm and make recommendations towards making it functional, productive and profitable.

Background to farm: The farm was established in 2003, as a community cooperative venture by MTI prior to the institutionalisation by MFMR in Namibia. The cooperative lacked persons with knowledge of fish culture. However, ownership by the area cooperative was and is still in place but the nature of ownership and related responsibilities remain unclear.

Rapid assessment:

- The two people talked to were staff of MFMR, based at Rundu, a town 140 km from the farm.
- The farm initially had grave seepage problems.
- Since the handover of the farm to MFMR, it has been run and managed from Rundu.
- Frequency of personnel visits from Rundu to farm was not fixed.
- The farm has six on-growing ponds of 2 000 m² each, four spawning/breeding ponds of 500 m² each and four 1 000 m² nursery ponds.
- Water temperatures in summer ranged from 22 to 26 °C and from 17 to 23 °C during winter.
- The seepage problems had been largely resolved by lining of the production ponds. However, the other ponds, all below the production ponds, seemed to hold water.

Current major challenges (as indicated by MFMR staff at hand):

- Ponds were originally stocked with mixed-sex wild three spotted tilapia, *Oreochromis andersonii*. Subsequently, progeny of these fish, periodically collected from all ponds, have been used to restock harvested ponds.
- Great mortalities of fingerlings (10-29 g fish) have been experienced within about six days of all stocking activities.
- Issues related to feed rations and feed were discussed.

Deductions / Conclusions:

- The station had sufficient basic infrastructure to make the farm run as an entity.
- The economics of the farm will require further evaluation following detailed technical audit.
- All current 'problems' were issues of management which could be resolved by permanent and competent staff.
- Ownership and responsibility positions are at best confused.

Recommendations and way forward:

- i. An on-site effort must be made to give basic training to selected youth nominated by the communities considered as owners/employers of the fish farm to run the farm on behalf of the community under some agreed arrangement.
- ii. The farm be rented or leased as a PPP (community-government) concern for a period of time that would facilitate the government recovering the cost of most of its capital. The period may also serve to give evidence to the community that the farm could make some money with sufficient effort. Thereafter, the government may, in collaboration with the area cooperative, release its share. If the farm is to be returned to the cooperative, it is further recommended that there should be a condition for the cooperative to hire competent team(s) to run the farm.

7.2 Likunganelo Fish Farm

Location: Katima area of Caprivi Region.

Purpose of visit: To assess farm in order to suggest actions that could make the farm function better, be productive and aim at profitability.

Persons mainly communicated with: Mr Cosmos Imukusi, farm manager and Mr Calvin Mwiya, a Chief Fisheries Research Technician. Both were staff of MFMR assigned to the farm but based in Katima.

Rapid assessment:

- The farm had six production ponds of 2 000 m² each, four spawning/breeding ponds of 500 m² each and four 1 000 m² nursery ponds.
- Flooding was a major issue. Floodwaters come from the Lisikili Lake and the Zambezi River, on different sides of the ponds.
- Pond areas have been fenced with 10 mm mesh chicken wire, to trap fingerlings and prevent escape with flood waters.
- Flood period was said to start in March/April until about June/July.
- Floods also usually bring unknown types and quantity of fish into the ponds; a situation collaborated by one of the technicians on hand.
- Usual intended harvest size of fish on the farm was 350 g during a period of six months.
- The last harvest in April, 2011 produced a total of about 10 tonnes of fish of various sizes. Harvest from one pond was 1 tonne.
- The fish were sold in nearby community market and unsold fish were to the Katima market, where it took almost a week to dispose due to excess fish from capture fisheries.
- Predation by birds was an issue.
- The farm also experiences high evaporation rates.

Deductions:

- The farm had sufficient basic infrastructure to make the farm run as a commercial entity.
- Most significant and determining challenge of the farm was its flood-prone physical position.
- The flooding position currently makes new investments to improve the farm unrealistic.
- Ownership and responsibility positions are at best confused and seriously adversely affect functioning of the farm.

- Sale of farmed fish on markets near the farm could be affected by availability of capture fisheries products.

Recommendations and way forward:

- i. Farm should be considered as a seasonal farm, where fish are cultured and harvested during low water and dry season periods of year.
- ii. On basis of the above a detailed scheduling of activities on the farm has to be drawn together with MFMR. These would include, for example, where and how to hold fingerlings and broodstock during flood periods.
- iii. Direct effort must be made to give basic training to **dedicated** youth nominated by the community considered as owners of the fish farm to run the farm on behalf of the community under some arrangement between the youth and individual community.
- iv. Investment into using bird nets to protect fish in ponds should be considered when planning for seasonal fish farming at the site.
- v. The farm is rented or leased as a PPP (community-government) concern for a period of time that would facilitate the government recovering the cost of most of its capital. The period may also serve to give evidence to the community that the farm could make some money with sufficient effort. Thereafter, the government may, in collaboration with the area cooperative, release its share.
- vi. If the farm is to be returned to the cooperative, it is further recommended that there should be a condition for the cooperative to hire competent team(s) to run the farm.

7.3 Kalimbeza Farm

Location: At Kalimbeza near Katima.

Persons communicated with: Mr Cosmos Imukusi, as farm manager and Mr Calvin Mwi. Both staff of MFMR based at Katima.

Background to farm: Farm presented as one of six fish farms built by MTI and given to community cooperatives to operate prior to being managed by MFMR. Farm area under current consideration for a conservation project area, where e.g. fish would be stocked and maintained for sport fishing and crocodiles farmed. It was indicated to us that fish farming at the farm was under consideration to be abandoned.

Current major challenge: Extreme flooding.

Rapid assessment:

- Farm has six production ponds of 2 000 m² each, four nursery ponds of 1 000 m² each and four spawning ponds of 500 m² each.
- Ponds were all completely dry.
- Farm appeared abandoned.

Deductions:

- The farm was within a few kilometres of the Likunganelo farm where ponds had water in them. With all ponds totally dry at Kalimbeza there could be seepage problems.
- The farm could have suffered from bird predation.
- Water marks on farm structures suggest extensive flooding during wet season.

Recommendations and way forward:

Proposal to convert farm area to a recreational-cum-conservation area be thoroughly investigated for possible implementation.

7.4 Kalovo Fish Farm

Persons communicated with: Dominic Mwanamwali, KIFI.

Background to farm: Farm presented as one of six fish farms built by MTI and given to community cooperatives to operate prior to the institution of MFMR.

Current major challenges:

- Flooding of part of farm (mainly the spawning and nursery ponds) during December to March.
- Labour from community cooperative members expected to provide labour are virtually not available.
- Fish available for stocking of ponds highly inbred.
- Pond drainage system faulty; ponds can't be completely drained.
- Birds and otter predation.
- Some farm equipment needs replacement.

Rapid assessment:

- The farm could be operated reasonably well.
- Farm operations should be scheduled on a seasonal basis outside the flood period.
- Vegetable production component on the farm was assessed to contribute significantly to current farm output.

Recommendations and way forward:

- i. The farm be rented or leased as a PPP (community-government) concern for a period of time that would facilitate the government recovering the cost of most of its capital. The period may also serve to give evidence to the community that the farm could make some money with sufficient effort. Thereafter, the government may, in collaboration with the area cooperative, release its share. If the farm is to be returned to the cooperative, it is further recommended that there should be a condition for the cooperative to hire competent team(s) to run the farm.
- ii. Repairs and replacement of equipment on the farm should be a part of practical ownership change.
- iii. Broodstock material on farm must be renewed with a plan put in place for broodstock management.
- iv. Ponds need to be provided with bird netting.

7.5 General Comments and Recommendations on “Cooperative” Fish Farms (Especially the Mpungu, Likunganelo and Kalovo Fish Farms)

Four ‘cooperative’ fish farms were visited with the same objective of assessing their situations and make key recommendations on how each farm may attain maximum production. One of the farms, the Kalimbeze fish farm, was considered to require too many resources for a possible recovery which might not be worth the investment. Thus it was recommended that the Kalimbeze fish farm area be reviewed for other purposes. The Mpungu, Likunganelo and Kalovo fish farms could be made to function better as fish farms. These farms had similar administrative, operational and technical issues and challenges:

Major administrative challenges:

- a) **Ownership of cooperatives:** Present ownership situation clearly identifies beneficiaries of the farms but does not seem to make it clear as to who should ensure that necessary activities are carried out.

Recommendations:

The farms be rented or leased as a PPP (community-government) concern for a period of time that would facilitate the government recovering the cost of most of its capital. The period may also serve to give evidence to the community that the farm could make some money with sufficient effort. Thereafter, the government may, in collaboration with the area cooperative, release its share. If the farm is to be returned to the cooperative, it is further recommended that there should be a condition for the cooperative to hire competent team(s) to run the farm.

In arriving at the recommendations we emphasize local community ownership of private company to keep the farms for locals as apparently originally intended, but this can only be successful if communities embrace a paradigm shift on required dedicated work ethic. The MFMR acts as the local technical partners.

b) Technical competence

Cooperative members have limited knowledge on fish farming and lack of appreciation of discipline required to farm fish

Recommendations:

- i) Technical personnel currently in charge of farms need to have periodic on-the-job orientations to enrich their aquaculture experience. Special orientation on feed, feeding and feed rations for fish would be appropriate.
- ii) The farms need to be recognized as low water and dry season farms for them to be planned for and operated as such.
- iii) Farms be equipped with essential monitoring equipment.
- iv) New broodstock are needed on the farms on condition that they would be managed otherwise all farms should obtain their fingerlings from identified fingerling sources.

8 SITUATION ANALYSIS OF FRESHWATER AQUACULTURE IN NAMIBIA: Evaluation of Potential Aquaculture Sites

8.1 Preamble

The team, amongst other activities, was requested to assess a number of potential and earmarked freshwater aquaculture sites in several parts the country. Seventeen sites were evaluated. Summary briefs of the site assessments are provided below. However, six sites, ranked 1 and 2 in terms of general suitability, showed most promise although each, as all other sites with potential, would require specific detailed assessments prior to their utilization.

The most suitable sites were those inspected at Kaoko Otavi, Oruvandjei, Warmquelle, and Bernafay i.e sites 1, 2, 8 and 11, respectively. All the sites have, however, been ranked with reference to their suitability in Table 9 below. This ranking was based on onsite observations but could change if greater volumes of ground water can be found. For example a borehole at Warmbad may yield adequate volumes of heated water for larger scale aquaculture

Table 9. Locations ranked by priority of suitability for aquaculture

Site No.	Location	Ranked Priority No.
1	Kaoko Otavi	1
2	Oruvandjei	1
8	Warmquelle	1
11	Bernafay	1
6	Fransfontein	2
10	Witkrans	2
5	Etunda irrigation area	3
14	Keetmanshoop	4
7	Sesfontein	5
3	Rainbow site	5
17	Naute reservoir/dam	6
15	Noordoewer and Aussenkehr	6
4	NamWater borehole site at Kamanjab	7
9	Voighgrund reservoir/dam	8
12	Gibeon	8
13	Berseba	8
16	Warmbad	8

8.2 Site 1: Kaoko Otavi Pool Site

Nearest Community: Kaoko Otavi via Opuwo.

Purpose of visit: To assess the sufficiency of water volume from a spring fed pool to support a fish culture activity.

Background to visit: Community elders had previously requested MFMR officials to investigate potential of their water resource in supporting an aquaculture activity.

Rapid assessment of site:

- Site indicated by community representative was a pool which the team eventually considered to be contributed to by several springs.
- Pool of water was about 30 m long and 20 m wide and held behind an old stone dam. At the dam end the pool the water was more than one meter deep.
- Water of pool was clear with estimated temperature of between 25 and 27 °C.
- Recharge of pool was sufficient to keep pool overflowing flowing through the dam (through an opening about 0.5 m below the top) consistently, apparently since the community could remember and on date of visit.
- The date of visit, (September 2011), was during the end of the dry period of the year. However, water flowing from the pool was considered sufficient to support agricultural activity including fish culture.
- The water was only one of two similar sources of potable water to the community of Kaoko Otavi, as indicated by the community member with visiting team.

Conclusion of assessment: The team considered that this site generated sufficient water to support a small aquaculture activity. Prior to this, however, some actions are recommended, including:

- dredging of pool carefully;
- estimation of water recharge rate from the springs to establish possible size of farm; and
- protection of the pool.

Recommendations and way forward:

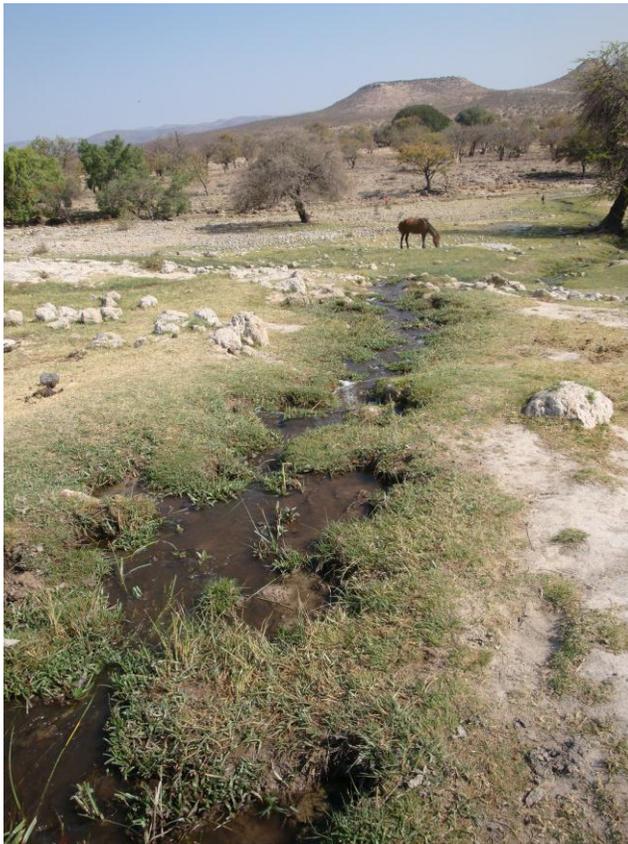
- i. A small flow-through system of tanks for the growing of finfish (tilapia and catfish), which the country's Aquaculture Strategic Plan encourages.
- ii. Integrate farming of vegetables of high preference in area including Opuwo using fish farm effluent water for year-round cultivation below fish growing areas.



Free-flowing springs with good water at decent flow rate. Conducive to simple, yet productive, agri-aqua farming system. We suggest follow-up evaluations.



Good flow but requires more detailed studies. This site will lend well to agri-aqua integration if community is committed.



Good location and site for simple farm between water source and gardens.

8.3 Site 2: Oruvanjei Pond Site

Nearest or associated community: Oruvandjei.

Purpose of visit: Elders of Oruvandjei community had previously requested the MFMR to confirm possibility of the pond water being sufficient to support a freshwater aquaculture activity.

Person communicated with: The team had to assess the situation virtually on their own because the whole community had gone to another nearby community for a ceremony. However, two young girls, not more than six years old, appeared at the site as the team was departing but they answered a few questions, which confirmed some deductions made by the team.

Background to visit: Community elders had previously requested MFMR officials to investigate the potential of their water resource supporting an aquaculture activity.

Rapid assessment of site:

- What had appeared as a dug-out was eventually identified as an excavation to contain water of several springs.
- Springs were evident at very clear spots at the bottom of the water area.
- Water area was estimated to measure 15 x 15 m with a depth of about 1.5 m.
- Dug-out was considered to have silted over the years.
- Water was very clear, considered to indicate that the water did not stay in confinement long enough to grow algae. Water temperature was estimated to be between 26 and 28 °C.
- Water flowed from the pond through five outlet pipes.
- It was apparent that the outflows went to satisfy different demands in the community, e.g. household water, cattle watering and perhaps gardening.

Conclusion of assessment: It was concluded that sufficient water was generated at the Oruvandjei pond to support present activities as well as a small aquaculture activity.

Recommendations and way forward:

Considering the proximity of Oruvandjei to Kaoko Otavi (about 8 km apart) where a small to medium-scale fish on-growing operation has been proposed with vegetable cultivation, a simple flow-through hatchery system for the production of fish seed or fingerlings (catfish and tilapia) is proposed for the Oruvandjei site to service the Opuwo region



Fast flowing springs with good water suitable for simple integrated aquaculture. Further evaluations required.



Adequate flow currently not well used. Suggest follow-up.

8.4 Site 3: Rainbow Fish Farming Proposed Fish Farm Site

Nearest community: Etunda Irrigation Scheme area communities.

Purpose of visit: To rapidly assess suitability of the site for fish farming.

Person communicated with: Official of MFMR, who communicated the desire of would be proprietor of Rainbow Fish Farming.

Background to visit: Rainbow Fish Farming had indicated to MFMR that the company was interested in developing a freshwater fish farm at the site and requested support of the ministry in the assessment of the location.

Rapid assessment of site:

- Due to absence of the would-be developers, no specific location of a bank of the Etaka reservoir was indicated for evaluation.
- The Etaka reservoir ensured that sufficient suitable water would be available to any segment of the bank area where an aquaculture activity would be developed.
- It was also considered that much of area indicated would be within flood limits of the reservoir
- A previous dig in the area allowed estimation of soil in the area to be assessed as sandy up to about 1 m deep, with no indication of soil nature further down.

Recommendations and way forward:

Aquaculture in some parts of the area shown is recommended subject to confirming at least the following:

- i. Site selected must be beyond flood lines of the reservoir from all angles of influence; the specific area must be determined.
- ii. Clay content of soil beyond 1 m deep must be determined to ensure that it is above 30 to 35% in the area to be used for the development of ponds.
- iii. In going beyond flood lines, the cost of getting water to the facility is likely to increase and consideration for that must be kept in mind.

8.5 Site 4: NamWater Borehole Site

Nearest Community: Kamanjab.

Purpose of visit:

- To investigate the possibility of a nearby reservoir as a source of fish for the community or developing it through stocking.
- To find information on water volumes at the borehole for potential aquaculture development.

Background to visit: The visit had not been a scheduled one. It came out of an attraction to a small reservoir in an area of apparently no such resource and also a borehole facility.

Person communicated with: Head of the NamWater water purification station at Kamanjab.

Rapid assessment of site:

- The NamWater station was the centre for 11 boreholes from which water was abstracted for domestic use.
- Depth of borehole nearest to the station (which had attracted the team's attention) was 65 m and produced 4.5 m³/hr.
- Water from the 11 boreholes was purified and distributed to the community of 5 000 around Kamanjab.
- The team's enquiry as to the potential capability of such boreholes producing significantly more water for the extra required to produce fish was advised to be sent to NamWater headquarters.
- The reservoir observed from the road was about 0.4 ha in size and was estimated, at the time of the visit in September, to contain sufficient water to accommodate some fish for recreational purposes.
- The reservoir was said to contain some catfish.

Conclusion and recommendations on way forward:

The request for information on water recharge rates from boreholes should be followed up at NamWater for the possibility of identifying any boreholes with sufficient water to spare for freshwater aquaculture. The reservoir was considered to have potential for use as a resource for fish production for the local community and would be controlled by the NamWater staff at the station.



Reservoir fed by spring. Site has a borehole which could be investigated further.

8.6 Site 5: Etunda Irrigation Scheme

Purpose of visit: To obtain an overview of an established irrigation project activity and to consider the technical possibility of fish culture as one of the activities under the scheme.

Background to visit: Fish had not been considered among the commodities farmed under the scheme.

Rapid assessment:

- The project covers a total area of 600 ha.
- Primary water source of irrigation was the Surcana River.
- Operators under the scheme include private farmer groups.
- Crops cultivated included maize, wheat and several vegetables.
- Water systems to areas under cropping were all functional and new areas under development.
- Farmers were obtaining water at an agricultural rate, which was only a token.
- The scheme processes wheat and maize and already provides wheat bran as an ingredient for formulated fish feed to a fish feed plant elsewhere in the country.

Conclusions and recommendations on way forward:

The scheme, with reference to water availability and operations, could accommodate fish as another crop under cultivation within the scheme. In addition, fish can be raised along and in the Ruacana-Ongadewa canal.



This irrigation scheme is served by the Ruacana canal



8.7 Site 6: Fransfontein

Nearest Community: Fransfontein.

Purpose of visit:

- To determine the source of water of the 'known fountain' providing the community with water.
- To assess the flow rate of water of 'the fountain' to determine if it could additionally support some aquaculture activity.

Background to visit: The site had been suggested for assessment by MFMR with reference to potential rural fish farming activity.

Rapid assessment:

- The location had two sources of water, both springs and multiples of springs not far from each other.
- The bigger source of water was pumped from its source to a reservoir and is then distributed by gravity to communities for potable water.
- Communities size receiving water indicated to be about 4 000 people
- The second source, which apparently produced less volume of water compared to the first, consisted of a number of springs closely positioned.
- Water generated by the group of springs was channelled through a small cement gutter, earthen channel and rubber tube at deferent segments into a cement tank downstream. Flow into the tank was estimated at about 2 l/sec.
- From the cement tank water flowed down to be used to irrigate a garden of various vegetables and two fish ponds (each about 20 x 10 m with depth of approximately 1.3 m).

Conclusion of assessment:

- Water from the smaller source of water was capable of supporting a rural aquaculture activity and a larger scale gardening activity than observed.

Recommendations and way forward

- i. Water channel from the group of springs to the cement tank downstream needs to be contained within pipes.
- ii. Gardening advisory support should be provided to community for a reasonable length of time, and should include enhancing soil quality.
- iii. Extension support also required for fish culture component of activities.



Fransfontein: source of natural springs currently used for gardening and potential fish farming



Main pipe carrying water from tank to vegetable garden and fish ponds





Water from tank, feeding ponds and gardens. Water levels in ponds low. Pipes prone to blockage. Water supply to farm required remedial action. Site is fenced and shows good potential.



Vegetable garden supported by water from spring. Such communities require education and training in integrated farming to improve the value of water and increase production

8.8 Site 7: Zebra Campsite Area of Sesfontein

Nearest community: Sesfontein

Purpose of visit: The site had been proposed for assessment by MFMR as a potential site for aquaculture because of an apparently good water source.

Background to visit: Site was proposed by MFMR for assessment of its potential for aquaculture due to the generally known availability of water from several springs or natural fountains.

Rapid assessment:

- Area suggested had several springs close to each other.
- Springs apparently contained and secured under a concrete structure.
- Water from the springs was apparently substantial and used as source of water for a camp/public bathroom facility.
- The specific site did not immediately lend itself to the development of fish culture structures.

Conclusion from assessment:

The site was not an obvious one for an aquaculture facility.

Recommendations and way forward:

Further survey of areas around the township of Sesfontein as it is known to have several fountains.



One of the largest springs at Sesfontein. This site with fig trees has public amenities nearby and is not suitable for aquaculture. We were unable to assess water availability.

8.9 Site 8: Warmquelle Quarry and Gardening Area

Persons met: Mr Swanepoel

Nearest community: Warmquelle

Purpose of visit: To assess potential of water and other physical resources of area for fish culture activity.

Background to visit: Site was suggested to the team while in Sesfontein.

Rapid Assessment:

- Four springs each generating obviously sufficient amounts of water to support some fish culture activities were found within an area of about 500 m of each other.
- Two of the springs, within 20 m of each other, had previously been the source of water pumped into an elevated reservoir and used to irrigate a medium sized commercial garden enterprise.
- The temperature of water from springs was estimated to be between 27 and 30 °C. While visiting the site, a new spring, said to have been found within about 30 m of the two indicated above was being channelled to also provide water for the garden.
- Mr Swanepoel indicated he was leading the community to revive the gardening and extend it to a 100 ha operation.
- The garden site, which was below elevation of water sources, had sufficient area and appropriate soil for fish ponds.
- Community leaders already considering building a series of small dams to impound water from springs around area for bigger projects.

Conclusion from assessment:

Site considered to be the location with maximum potential for fish culture so far located within the Sesfontein area.

Recommendations and way forward:

- i. Detailed study of area recommended for a pilot activity for the area.
- ii. Community with their entrepreneurial leadership to be sensitized.



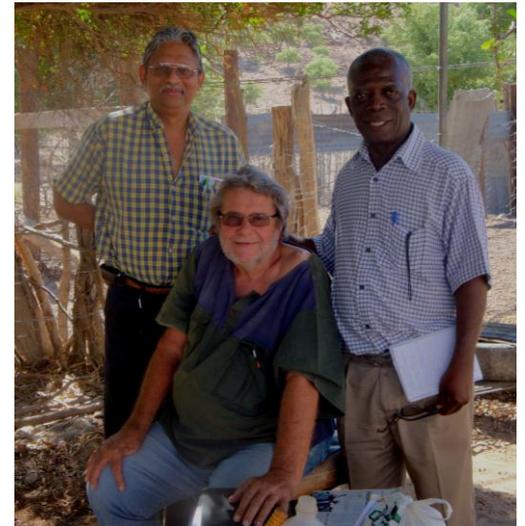
Natural warm water springs at Warmquelle. Source of spring protected by thorny vegetation (insert). Water is diverted via canal (left) into disused garden field. Water temperature estimated at 30 °C.



Local community taking the initiative to clean and divert water for gardening and consumption



Disused irrigated gardens below spring with now defunct canal system. This site shows best promise for an integrated pilot agri-aquaculture project



Local community leader with plans to resurrect vegetable gardens. He has a construction background and should make for a constructive PPP initiative

8.10 Site 9: Voighigrund Reservoir/ Dam

Nearest community: A resettled small farming community several kilometres away.

Purpose of visit: To assess suitability of the reservoir and its environment for aquaculture activity.

Rapid assessment:

- The reservoir was too far away from any habitation to be used for aquaculture activity.
- Much of the water area of reservoir was seasonal, with water receding significantly during dry season.

Conclusion from assessment:

The study team concluded that the site was not conducive for aquaculture activities. However, it is suggested that the reservoir could be developed for controlled capture recreational fisheries.

Recommendations and way forward - preliminary activities:

- i. Available information on fish species composition, available at Hardap should be analysed to direct development of fisheries in the reservoir.
- ii. Consider development of controlled capture fisheries on the Voighigrund reservoir, eco-tourism and recreational fisheries.



Reservoir - not ideal for aquaculture but suggest explore restocking programme. Consider tilapia species other than *O. mossambicus*. Suggest *O. niloticus*

8.11 Site 10: Catholic Church at Witkrans

Nearest Community: Witkrans, about 60 km from Mariental

Purpose of visit: To evaluate the possibility of supporting the church's programme to teach and look after about 100 children, including providing them with food during school days, by helping the church to grow some fish in a big concrete tank (50-60 m³). The reservoir, about 20 m in diameter and 2.5 m deep, is used to hold groundwater to irrigate a vegetable garden plot which helps to feed the children in the care of the church.

Person communicated with: Rev. Williem Christtians, coordinating priest of the Catholic church at Witkrans.

Background to visit: Mr Lesley Kikuri, staff of MFMR at Hardap led the team to the site. The Hardap MFMR station had tried to grow fish in the reservoir about two years earlier but had not been very successful.

Rapid assessment:

- Size of tank and volume of water were good.
- Flow of water was estimated at more than 60 l/min, which was considered more than sufficient.
- Flow of water was about constant all year round.
- Water temperature was estimated at 27-28 °C almost all year.

Conclusion from assessment:

Fish could be raised in the tank but fingerling stock must be 30-50g all-male *O. niloticus* from Hardap.

Recommendations and way forward:

- i. Tank to be drained, cleaned and refilled.
- ii. Hardap station to organize a batch of all-male *O. niloticus* for the tank.
- iii. Have an all-male fish population in the church tank to generate some fish for church, not only for food but also as teaching and learning material.
- iv. Integrate agri-aquafarming into school curriculum.
- v. Feasibility of additional ponds/tanks should be explored.
- vi. Integration of appropriate subjects into this activity as school clubs. Grow and harvest fish for the boarding school menu.



Large concrete reservoir is in fair condition. Currently has some *O. mossambicus*.



Water from pressure borehole supplying tank



Vegetable garden serviced by tank. Can be significantly improved.

8.12 Site 11: Bernafay

Nearest community: Gardening community (Bernafay about 60 km from Mariental).

Person communicated with: Mr Pienar Frederiks, foreman of settlement farm community.

Purpose of visit: To assess what could be done to enhance and extend fish culture component of gardening project.

Background to visit: Hardap station of MFMR had initiated incorporation of fish into gardening activity of settler community some two years earlier but had not made the desired impact. Mr Lesley Kukuri, of the Hardap station of MFMR therefore requested the visit of the Master Plan development team.

Rapid assessment:

- Gardening was at subsistence level, involving 12 households with 65 people.
- Water source was spring water with a flow rate estimated to be about 150 l/min.
- Water available for both vegetables and valuable for fish production.
- Tank containing fish was 25 m diameter and about 1.5 m deep.
- Fish in tank was mixed-sex *O. mossambicus*.
- Excessive reproduction of fish in tank.

Conclusion of assessment:

- Tank could produce reasonable harvest of fish if reproduction could be curtailed.
- Project advised to build new tanks for MFMR to support expansion of aquaculture activities.
- Fish and integrated gardening could fit into present activity of project especially because their water source is good.

Recommendations and way forward:

- i. The concrete tank be harvested, cleaned and restocked with 30-50 g sex-reversed *O. niloticus* fingerlings.
- ii. Water flow and bore recharge rates be established and the feasibility of a small aquaculture operation be undertaken.



Concrete tank previously used as a swimming pool. Should be cleaned and stocked with *O. niloticus/mossambicus* hybrids from Hardap.



Borehole under pressure. Good pressure and estimated volume of 100-150 l/min.

8.13 Site 12: Gibeon

Nearest community: Gibeon.

Purpose of visit: Inspection of a site for Youth Forum aquaculture project.

Background to visit: Youth Forum of community had requested MFMR, Hardap station to assist them in developing an aquaculture operation at an old sewerage pond site.

Rapid assessment:

- Spring intended to be source of water too far from site.
- Soil of site considered too sandy and stony.
- Old sewerage pond intended to be converted to fish ponds not suitable.

Conclusion and recommendation:

The site inspected is unsuitable and a more suitable site should be sought.



Disused sewage works. Water is only available some 3 km away. Below left: borehole at church flow from spring too low to justify any aquaculture activity.

8.14 Site 13: Berseba

Nearest community: Berseba village.

Purpose of visit: To evaluate a site and water source for a community fish farming project.

Background to visit: A visiting scientist from MFMR at Hardap IAC had previously visited this site for the same purpose. Although soil and water samples were taken for evaluation, results are still awaited.

Rapid assessment:

- The team suggested the local community to dig four 1 m deep pits to check for water table and establish how long it would take to evaporate as a measure of soil capacity to hold water.
- Results were to be reported by village to MFMR Hardap IAC for appropriate action.

Conclusion and recommendation:

No conclusion has been made as results are being awaited.



Springs will not supply adequate volumes of water. Site needs detailed evaluation. Hole on right showing high water table. Some areas are also prone to flooding.



8.15 Site 14: Keetmanshoop

Nearest community: Keetmanshoop community.

Person communicated with: Mr Simasiku

Purpose of visit: To evaluate community ownership status of an intended aquaculture project and to evaluate intended project.

Background to visit: The community expressed interest to have an aquaculture project. The GRN had commissioned a feasibility study for developing a commercial aquaculture project at this site. An evaluation of this study was made and given in Subsection 3.2.

Rapid Assessment: The team discussed aspects of intended project with its nominated technical assistant, Mr Simasiku. Outcomes of discussion with local communities were apparently not clear with respect to objectives and in particular what the community would contribute to have ownership of the project. These issues are yet to be resolved.

Recommendations and way forward:

The community would have to discuss their intentions for the project to consolidate their objectives as well as ownership strategies.



This site has a warmwater spring. The spring is under pressure but data on discharge volumes were unavailable. Site shows some promise due to warmwater but requires a more detailed site analysis. The feasibility study of this site may have overstated the capacity of this site.

8.16 Site 15: Noordoewer and Aussenkehr

Nearest Community: Noordoewer and Aussenkehr.

Purpose of visit: Assessment of an intended fish culture site as requested by community to MFMR, Hardap. The GRN had commissioned a feasibility study for developing a commercial aquaculture project at this site. An evaluation of this study was made and given in Subsection 3.2.

Persons interacted with: Personnel of village council.

Background to visit: Only a follow-up to village council request.

Rapid assessment:

- Site approximately 7 ha.
- Soils very sandy and rocky.
- Soil samples were taken by MFMR scientist for confirmation of characteristics in relation to suitability for fish pond construction but await results. Site evaluation, however suggests, unlikely to be suitable as soils were sandy.

Conclusion:

The immediate conclusion was that the site was not suitable for ponds. However, confirmation of soil analysis is awaited.



Orange River bordering SA from whence water is extracted to canals below to Aussenkehr.



Site visited near the banks of river. Soils not suitable for ponds. Water appears good and can be extracted from canals for aquafarming under cover. Low temperatures are the key challenge.



Canal system built to serve the table grape industry can be used to stock fish directly into canal.



8.17 Site 16: Warmbad

Nearest Community: Warmbad.

Purpose of visit: To assess if warm water at springs could support aquaculture.

Persons interacted with: Village council staff.

Background to visit: Village had expressed intention of developing fish culture structures at a site they wished to assess.

Rapid assessment:

- Site had several hot springs with small water volumes
- Site had lots of large stones.

Conclusion:

This Warmbad site has a geothermal spring but water discharge rates are low and insufficient for aquaculture. However, since this site is situated along a geothermal fault line, water prospecting may provide adequate quantities of heated water. If successful, a project could be feasible here

Recommendations and way forward:

The current site is recommended for development of eco-tourism.



Warmbad. Warmwater flow but volumes inadequate to be of value for aquaculture.



Rocky terrain around warm baths not suitable for building.

8.18 Site 17: Naute Dam

Nearest Community: Keetmanshoop, Karas Region.

Purpose of visit: To see if water from the reservoir can be used for aquaculture.

Background to visit: Reservoir behind Naute Dam is the second largest in Namibia after Hardap Dam. Hardap station of MFMR had considered the reservoir for possibilities of aquaculture activities and was seeking confirmation.

Rapid assessment:

- Dam has a pipeline to palm plantation which could be used to feed an aquaculture operation.
- Ground below dam appears suitable.
- Would require indoor facilities for rearing fish but if linked to palm plantations then could look at simple flow through subject to water temperature.

Conclusion, recommendations and way forward:

May be possible to farm fish here but a more substantive study is necessary. Fish could be farmed in dam but water temperature would need to be carefully studied to establish feasibility.



Palm plantation in background serviced by pipeline from dam.



Pipeline from dam to plantations offers the possibility of using this supply to farm fish. A potential farmer is exploring this site.

9 DEVELOPING THE NATIONAL AQUACULTURE MASTER PLAN FOR FRESHWATER AQUACULTURE: Stakeholder Consultation Outcomes and SWOT Analysis Identifying Areas of Immediate Concern for Freshwater Aquaculture Development in Namibia

9.1 Preamble

Given the infancy of Namibian freshwater aquaculture, it is imperative to have an understanding of expectations, and capacity of primary stakeholders to take up aquaculture as an economic activity. Therefore, as part of the situation analysis and to ensure a bottom-up approach, six stakeholder workshops were conducted in geographical locations to represent all Namibian regions except Omaheke. The purpose of these workshops was to assess resources, constraints, current activities and related information for the development and growth of freshwater aquaculture. Such collated information was used to inform the development of the Freshwater Aquaculture Master Plan for Freshwater Aquaculture (NAMP-FW).

9.2 Approach

The structure of and activities at each workshop was standardised. One key objective of these workshops was **to identify strengths, weaknesses, opportunities and threats (SWOT)** with reference to regional development and growth of freshwater aquaculture. These regional SWOT analyses were used to eventually identify and prioritize issues for the Master Plan.

At each of the six workshops, representative stakeholders from the regions were facilitated by MFMR to identify what they considered to be their strengths, weaknesses, opportunities and threats for the growth and development of freshwater aquaculture in their region. Items listed were briefly discussed and recorded. After the workshops, **each set of items** (i.e. items listed under SWOT) were grouped into items related to 'Natural Resources', 'Human Resources', 'Civil Society/Private Sector', 'Government or Public Sector', 'Inputs' and 'General'. These grouped items were then synthesized as a national SWOT to inform and develop the NAMP-FW.

9.3 Outcomes

The outcomes of grouped issues and their frequency across the regions are presented below as a **National SWOT Analysis** as four tables: 'strengths' (Table 10);

‘weaknesses’ (Table 11); ‘opportunities’ (Table 12); and ‘threats’ (Table 13). Each table comprises of the collated outcomes from the six regional workshops.

An analysis of Tables 10, 11, 12 and 13 suggests that at a national level, the following major ‘strengths’, ‘weaknesses’, ‘opportunities’ and ‘threats’ for freshwater aquaculture development and growth in Namibia and thus, where national resources should be invested and focused towards the subsector’s development and growth. At the national level, attributes across the regions which were considered significant and important were extracted and discussed.

9.3.1 National strengths

The overall major strengths considered significant by the stakeholders were:

- i. **Natural resources/attributes:**
 - Availability of water, including surface and groundwater
- ii. **Human resources:**
 - Presence of development partner SSC support personnel
- iii. **Civil society attributes:**
 - Availability and willingness of communities to participate
- iv. **Government/public sector related:**
 - Infrastructure (roads, electrical power and communication)
 - Financial assistance (in various forms)
- v. **General strengths:**
 - Availability of local and regional markets

9.3.2 Weaknesses

The overall major weaknesses considered significant by the stakeholders are represented below:

- i. **Natural resources and their attributes:**

- Non-uniform distribution of water for aquaculture across Namibia
- ii. **Human resources:**
 - Limited management skills in aquaculture
 - Generally low human capacities in number and quality in institutions
 - Limited technical capacity in freshwater aquaculture
 - iii. **Aquaculture inputs:**
 - Limited information on aquaculture
 - iv. **General challenges:**
 - Predation by birds

9.3.3 Threats

The overall major threats considered significant by the stakeholders are represented below:

- i. **Natural resources/attributes:**
 - Floods/droughts
- ii. **Human resources:**
 - Lack of skilled labour
 - Lack of technical capacity for proposed culture systems
- iii. **Civil society/private sector:**
 - Theft and poaching
- iv. **Government/public sector:**
 - Maintenance of cooperative model
- v. **General issues:**
 - Predation by birds

9.4 Overall Assessment

A discussion of the above SWOT for the development and growth of freshwater aquaculture reveals that the most critical issue to be attended to is the **situation of**

human resources/capacity. This is supported by the situation that among ‘strengths’, whilst capacity existed in the form of foreign experts (SSC), Namibian capacity was lacking. Among ‘weaknesses’, human resource weaknesses were listed in many regions. Among ‘opportunities’, development of the Master Plan was seen as a great opportunity to develop capacity for the subsector. And finally, among ‘threats’, the lack of human capacity was identified as a threat to the growth and development of the freshwater sector. Therefore plans to improve human resources/capacity for growth and development at various levels should be a major aspect of the Master Plan. Combining the human capacity constraints together with weaknesses in Table 11, examples of capacity building were advocated in:

- Aquaculture technology in institutions
- Extension services
- Farmer level of knowledge in aquaculture
- Management of aquaculture projects and on farm
- Proposal development and writing
- Business plan development and writing

The ‘**strengths**’ (Table 10) listed under government/public sector involvements encompassing advocacy, financial incentives, infrastructure, subsidized feed and seed and availability of technical support, have apparently brought freshwater aquaculture to its current gains. Plans should, therefore, be put in place to encourage and maintain public sector interest in supporting the growth and development of freshwater aquaculture. These plans should include, for example, establishing the monitoring of activities and progress of the various government-initiated aquaculture programmes to inform of and disseminate any progress.

The ‘threats’, from floods and predation by birds are the major issues generated by the SWOT analysis and therefore should be responded to in the Freshwater Aquaculture Master Plan. To mitigate against threats the following actions are suggested:

a. Floods

- In existing farms which currently flood, consider mitigation against the loss of fish during the flooding season through appropriate designs of rearing structures such as cages within the ponds.

- Exploit flooding zones through the use of pond designs and management to utilize flood waters as a means of fish farming.

b. Bird predation

- Assess the losses associated with bird predation to establish significance of problem.
- For existing farms, include the cost of bird cover nets as a constant feature of budget.
- For new facilities, consider fingerling and on-growing facilities under greenhouse or similar structures.
- Use of bird scares.

Several other issues were also indentified as being important, these included:

Among '**weaknesses**':

- Limited management skills.
- Limited technical capacity in fish culture locally.
- Limited human capacity in institutions leading aquaculture.

Among '**opportunities**':

- Capacity building.
- Increasing water productivity.

Among '**threats**':

- Lack of skilled labour.
- Lack of functional cooperative model.

9.5 National Collation of Regional SWOT Analysis

The tables below represent outcomes of stakeholder feedback across the regions.

Table 10. Regional **strengths** for aquaculture development and growth

At:		<i>Outapi</i>	<i>Ongwediva</i>	<i>Katima</i>	<i>Rundu</i>	<i>Grootfontein</i>	<i>Mariental</i>
For Regions:		<i>Omusati and Kunene</i>	<i>Oshana, Omusati Kunene, Ohangwena and Oshikoto</i>	<i>Caprivi</i>	<i>Okavango</i>	<i>Otjozondjupa</i>	<i>Hardap and Karas</i>
ISSUES							
No.	NATURAL RESOURCES						
1	Availability of land	+		+	+		+
2	Availability of water (surface and/or ground)	+	+	+	+		
3	Suitable climate		+				
4	Good water quality				+		
HUMAN CAPACITIES/ RESOURCES							
1	Existence of international personnel in South-South cooperation to advance freshwater aquaculture				+		
CIVIL SOCIETY INVOLVEMENTS							
1	Fish eating habit in region and thus demand		+		+		
2	Communities available and willing to participate			+		+	+

Table 10. Regional **strengths** for aquaculture development and growth

At:		<i>Outapi</i>	<i>Ongwediva</i>	<i>Katima</i>	<i>Rundu</i>	<i>Grootfontein</i>	<i>Mariental</i>
For Regions:		<i>Omusati and Kunene</i>	<i>Oshana, Omusati Kunene, Ohangwena and Oshikoto</i>	<i>Caprivi</i>	<i>Okavango</i>	<i>Otjozondjupa</i>	<i>Hardap and Karas</i>
ISSUES							
3	Training institutions preparing to offer 3-month aquaculture training programme					+	
4	Some private farmers prepared to invest to succeed					+	
GOVERNMENT/PUBLIC SECTOR INVOLVEMENTS							
1	Existence of legal and policy framework	+		+			
2	Sector technical support available to some extent	+	+	+	+		+
3	Government tax incentive through AgriBank and other actions	+		+	+	+	+
4	Wide availability of AgriBank branches	+	+		+	+	
5	Availability of infrastructure (roads, electric power, telecommunications etc.)		+	+	+		+
6	Political stability	+	+				+
7	Political will and support	+	+	+		+	+

Table 10. Regional **strengths** for aquaculture development and growth

At:		<i>Outapi</i>	<i>Ongwediva</i>	<i>Katima</i>	<i>Rundu</i>	<i>Grootfontein</i>	<i>Mariental</i>
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ISSUES							
	GENERAL STRENGTHS						
1	Good local and regional markets			+	+		
2	Availability of local security			+			
3	'Fish culture' introduced as a study subject in second cycle institutions				+		

Table 11. Regional **weaknesses** for aquaculture development and growth

At:		<i>Outapi</i>	<i>Ongwediva</i>	<i>Katima</i>	<i>Rundu</i>	<i>Grootfontein</i>	<i>Mariental</i>
For Regions:		<i>Omusati and Kunene</i>	<i>Oshana, Omusati Kunene, Ohangwena and Oshikoto</i>	<i>Caprivi</i>	<i>Okavango</i>	<i>Otjozondjupa</i>	<i>Hardap and Karas</i>
ISSUES							
	NATURAL RESOURCES						
1	Lack of suitable land		+				

Table 11. Regional **weaknesses** for aquaculture development and growth

At:	<i>Outapi</i>	<i>Ongwediva</i>	<i>Katima</i>	<i>Rundu</i>	<i>Grootfontein</i>	<i>Mariental</i>
For Regions:	<i>Omusati and Kunene</i>	<i>Oshana, Omusati Kunene, Ohangwena and Oshikoto</i>	<i>Caprivi</i>	<i>Okavango</i>	<i>Otjozondjupa</i>	<i>Hardap and Karas</i>
ISSUES						
2	Access to suitable land for commercial agriculture				+	
3	Lack of sufficient water for agriculture	+		+	+	
4	Cost of accessing ground water					
5	Distribution of freshwater		+			
6	Unfavourable weather patterns					+
HUMAN CAPACITIES						
1	Limited management skills	+			+	+
2	Limited knowledge of aquaculture in financial institutions	+			+	
3	Lack of expertise in developing business plan		+	+		
4	Limited technical capacity in fish culture locally	+		+	+	+
5	Limited aquaculture education at all levels				+	
6	Generally low human resources in numbers and capacity in institutions	+	+	+		
7	Limited knowledge of farmers		+			
AQUACULTURE INPUTS						
1	Feed quality (physical)		+		+	+

Table 11. Regional **weaknesses** for aquaculture development and growth

At:	<i>Outapi</i>	<i>Ongwediva</i>	<i>Katima</i>	<i>Rundu</i>	<i>Grootfontein</i>	<i>Mariental</i>
For Regions:	<i>Omusati and Kunene</i>	<i>Oshana, Omusati Kunene, Ohangwena and Oshikoto</i>	<i>Caprivi</i>	<i>Okavango</i>	<i>Otjozondjupa</i>	<i>Hardap and Karas</i>
ISSUES						
2	High cost of feed					+
3	Lack of fish feed variety			+		
4	Fish seed quality	+				
5	Mixed-sex fingerling production					+
6	Lack of domesticated fish and seed/fingerlings			+		+
7	Limited availability of simple aquaculture equipment e.g. hand nets				+	
8	Lack of information on aquaculture	+	+			+
9	Limited extension services and support		+	+		+
10	Limited number of fish species in culture					+
11	High cost of capital					+
12	Limited knowledge of farmers					+
13	Lack of awareness of freshwater fish culture	+	+		+	
14	Limited community awareness of new fish culture activities	+		+		
15	Lack of initiatives from community	+			+	

Table 11. Regional **weaknesses** for aquaculture development and growth

At:	<i>Outapi</i>	<i>Ongwediva</i>	<i>Katima</i>	<i>Rundu</i>	<i>Grootfontein</i>	<i>Mariental</i>
For Regions:	<i>Omusati and Kunene</i>	<i>Oshana, Omusati Kunene, Ohangwena and Oshikoto</i>	<i>Caprivi</i>	<i>Okavango</i>	<i>Otjozondjupa</i>	<i>Hardap and Karas</i>
ISSUES						
16	Lack of motivation of farmers to become involved	+				
17	Public understanding of aquaculture			+		
18	Lack of an aquaculture success story as wealth creator		+		+	
19	Unrealistic expectations of general civic society from aquaculture				+	
20	Lack of community participation in cooperative projects					+
21	Gender balance		+			
GOVERNMENT/PUBLIC SECTOR INVOLVEMENTS						
1	Nature of cooperatives		+			
2	Ownership issues of public sector built farms for cooperatives		+			
3	Lack of involvement of local authorities	+				
4	Donors pushing for weak unsustainable models		+			

Table 11. Regional **weaknesses** for aquaculture development and growth

At:	<i>Outapi</i>	<i>Ongwediva</i>	<i>Katima</i>	<i>Rundu</i>	<i>Grootfontein</i>	<i>Mariental</i>
For Regions:	<i>Omusati and Kunene</i>	<i>Oshana, Omusati Kunene, Ohangwena and Oshikoto</i>	<i>Caprivi</i>	<i>Okavango</i>	<i>Otjozondjupa</i>	<i>Hardap and Karas</i>
ISSUES						
5	Government bureaucracy and regulations	+	+		+	+
6	Inadequate communication between Ministry promoting aquaculture and other stakeholders				+	
7	South-South cooperation on aquaculture limited by language and apparent 'relaxed' management				+	
GENERAL CHALLENGES						
1	Predation by birds	+			+	
2	Lack of cold storage facilities					
2	Limited research				+	+
3	Generally low human resources, in numbers and capacity, in institutions (e.g. extension staff)	+	+	+		
4	Lack of local market					+

Table 12. Regional **opportunities** for aquaculture development and growth

At:	<i>Outapi</i>	<i>Ongwediva</i>	<i>Katima</i>	<i>Rundu</i>	<i>Grootfontein</i>	<i>Mariental</i>
For Regions:	<i>Omusati and Kunene</i>	<i>Oshana, Omusati Kunene, Ohangwena and Oshikoto</i>	<i>Caprivi</i>	<i>Okavango</i>	<i>Otjozondjupa</i>	<i>Hardap and Karas</i>
ISSUES						
NATURAL RESOURCES						
1	Increased water productivity	+				+
2	Utilization of ground water	+				
3	Opportunity to reduce human pressure on wild fish stocks			+		
4	Value addition to agricultural products			+		
HUMAN CAPACITIES/RESOURCES						
1	Capacity building opportunities in various vocations (e.g. fish culture, handling, processing, trade and utilization)	+	+		+	+
2	Exchange of technical personnel programme with other countries		+			+
AQUACULTURE INPUTS						
1	Availability of fingerlings					+
2	Grants and soft loans from AgriBank	+			+	+
CIVIL SOCIETY INVOLVEMENTS						
1	Support to increase fish eating habit	+				+

Table 12. Regional **opportunities** for aquaculture development and growth

At:	<i>Outapi</i>	<i>Ongwediva</i>	<i>Katima</i>	<i>Rundu</i>	<i>Grootfontein</i>	<i>Mariental</i>
For Regions:	<i>Omusati and Kunene</i>	<i>Oshana, Omusati Kunene, Ohangwena and Oshikoto</i>	<i>Caprivi</i>	<i>Okavango</i>	<i>Otjozondjupa</i>	<i>Hardap and Karas</i>
ISSUES						
	in regions					
2	Enhancement of food and nutritional security	+		+	+	+
3	Job creation	+	+		+	
4	Creating career opportunities	+			+	
5	Urbanization opportunity to utilize aquaculture products			+		
6	Financial institutions opportunity to initiate a new line of business				+	
7	General poverty reduction	+			+	+
GOVERNMENT/PUBLIC SECTOR INVOLVEMENTS						
1	Availability of finance by government through AgriBank					+
2	Government incentives (e.g. soft loans and grants)	+			+	+
3	Support to Namibian Fish Promotion Trust	+				
4	NamWater canal in region provides an opportunity	+				
5	Government support in provision of fish seed and feed at subsidized		+			

Table 12. Regional **opportunities** for aquaculture development and growth

At:	<i>Outapi</i>	<i>Ongwediva</i>	<i>Katima</i>	<i>Rundu</i>	<i>Grootfontein</i>	<i>Mariental</i>
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ISSUES						
	prices presently					
6	Political will to promote aquaculture	+	+	+	+	+
GENERAL OPPORTUNITIES						
1	Growing local and regional markets offering opportunities	+	+		+	+
2	Opportunity to farm organisms other than fish	+				+
3	Improving local economies	+	+		+	
4	Opportunity for wealth creation	+	+			+
5	To market fish during closed season of capture fisheries			+	+	

Table13. Regional **threats** against aquaculture development and growth

At:	<i>Outapi</i>	<i>Ongwediva</i>	<i>Katima</i>	<i>Rundu</i>	<i>Grootfontein</i>	<i>Mariental</i>
For Regions:	<i>Omusati and Kunene</i>	<i>Oshana, Omusati, Kunene, Ohangwena and Oshikoto</i>	<i>Caprivi</i>	<i>Okavango</i>	<i>Otjozondjupa</i>	<i>Hardap and Karas</i>
ISSUES						
	NATURAL RESOURCES					
1	Climate change impacts and variability	+	+	+	+	+
2	Floods		+	+	+	+
3	Drought		+	+	+	+
4	Current abundance of capture fisheries which can be cheaper than culture products			+	+	
5	High marine capture fisheries production		+			
	HUMAN CAPACITIES/RESOURCES					
1	Lack of fish vets	+				
2	Lack of skilled labour			+	+	
3	Lack of tradition of fish culture/farming			+		
4	Poor management skills				+	
5	High staff turnover at MFMR				+	
6	Mushrooming of unaccredited aquaculture training activities					+

Table13. Regional **threats** against aquaculture development and growth

At:	<i>Outapi</i>	<i>Ongwediva</i>	<i>Katima</i>	<i>Rundu</i>	<i>Grootfontein</i>	<i>Mariental</i>
For Regions:	<i>Omusati and Kunene</i>	<i>Oshana, Omusati, Kunene, Ohangwena and Oshikoto</i>	<i>Caprivi</i>	<i>Okavango</i>	<i>Otjozondjupa</i>	<i>Hardap and Karas</i>
ISSUES						
	AQUACULTURE INPUTS					
1	Rising cost of inputs				+	
	CIVIL SOCIETY INVOLVEMENTS					
1	Lack of commitment in communities	+				
2	Land and water use conflicts				+	+
3	Theft and poaching		+	+		+
4	High turnover of community participants due to considered low benefits			+		
5	Competition from other parts of country and neighbouring countries				+	
6	High expectations from aquaculture apparently without much input of time and work					+
7	Apparent lack of motivation of farmers					+
	GOVERNMENT / PUBLIC SECTOR INVOLVEMENTS					
1	Political will changes				+	

Table13. Regional **threats** against aquaculture development and growth

At:	<i>Outapi</i>	<i>Ongwediva</i>	<i>Katima</i>	<i>Rundu</i>	<i>Grootfontein</i>	<i>Mariental</i>
For Regions:	<i>Omusati and Kunene</i>	<i>Oshana, Omusati, Kunene, Ohangwena and Oshikoto</i>	<i>Caprivi</i>	<i>Okavango</i>	<i>Otjozondjupa</i>	<i>Hardap and Karas</i>
ISSUES						
2	Maintenance of “cooperative” model of operating a fish farm				+	
3	Anticipated withdrawal of government support					+
4	Changes in local government administrations					+
GENERAL CHALLENGES						
1	Predation by birds		+	+	+	+
2	Bio-security		+		+	+
3	Introduction of fish diseases			+		

10 CHALLENGES AND CONSIDERATIONS FOR PROMOTING THE NATIONAL AQUACULTURE MASTER PLAN FOR FRESHWATER AQUACULTURE: Assessment of Market Demand for Namibian Farmed Freshwater Fish

The potential markets for Namibian freshwater fish have been recently reviewed by INFOSA for MFMR (Hempel et al., 2007). The demographics and buying power of the population will also influence and shape aquaculture development and marketing efforts. These together with additional assessments are reviewed below. Further, in this synthesis we exclude non-African international markets since we believe Namibian freshwater fish will not be competitive. Emphasis is therefore placed on domestic and regional markets.

10.1 Potential Influence of Demographics on Aquaculture Market and Development

The demographics of Namibia is explored in order to assess how best to consider regional aquaculture development and explores the suggestion that females are the majority household heads. The regional structure of the population and income distribution with a gender perspective was assessed and aquaculture opportunities of female households discussed were considered relevant.

10.1.1 Demographics and economic development

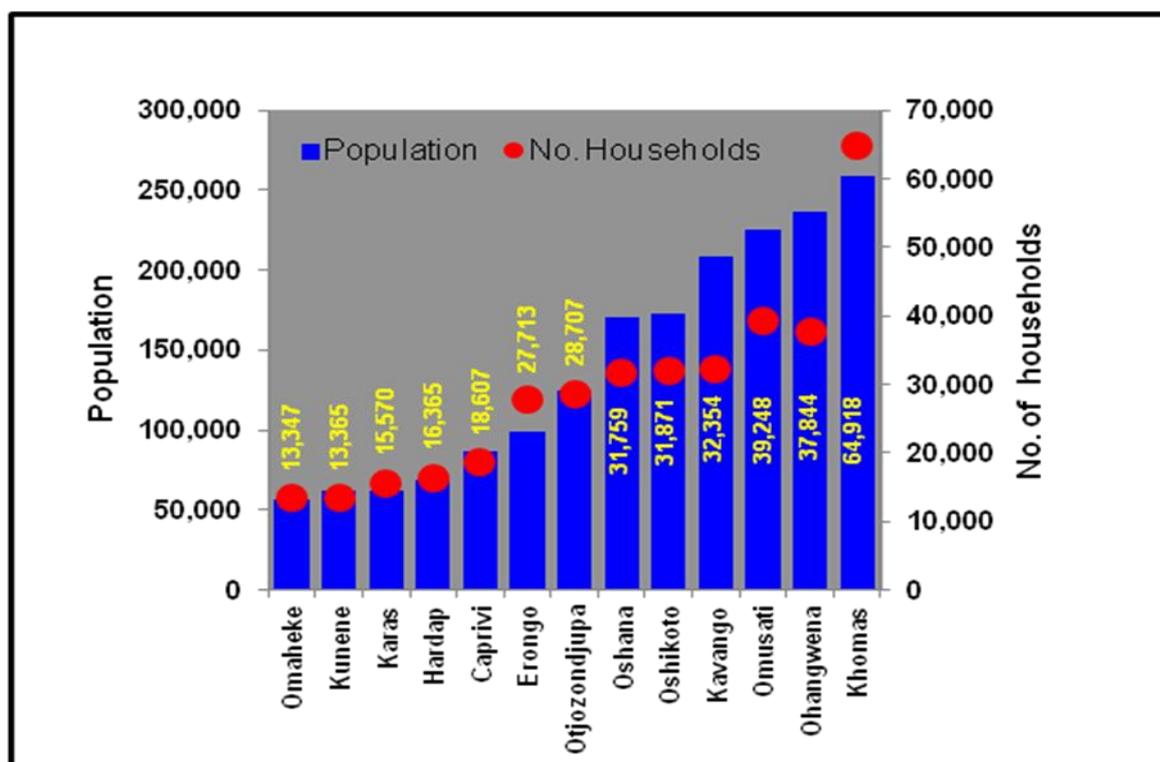


Figure 22. Regional demographics in Namibia ranked to show population and related number of household

The demographics of Namibia are helpful in understanding how the population is distributed to assist with planning in relation to local markets and human resources.

Namibia is the second least populated country in the world with an estimated population of around 2 million people living in a semi-arid to arid country.

Consequently, the population is clustered around water resources, especially in the north along the major river systems and associated canals. Around 60% of the population lives in the north east and west provinces,

with Ohangwena having the largest populations (Figure 22). The Khomas region is the most populated region accounting for 14% of the Namibian population,

while Omaheke is the least populated with only 3% of the total population. The majority of Namibians live in rural (65%) rather than in urban (35%) areas. The capital, Windhoek, is situated in the Khomas Region, which has a population of around 260 000.

The household survey of 2003-2004 indicates that the Namibian population is composed of more females than males at every age group, with an overall sex ratio of 91, i.e. for every 100 females there are only 91 males (Table 14). Erongo and Omaheke, however, reported more males than females while Oshana, Oshikoto, and Omasati reported the lowest proportion of males.

The conclusion in the household survey of 2003-2004 that there are more females than males is probably marginal, given that the actual sample size was only 9 800 households (2.6%). Statistically, given a 5-10% error due to sample size this difference is unlikely to be significant. The recent census of 2011 may shed more accurate data on the sex ratio. A more detailed assessment of the data, however, suggest that age group has a notable bearing on sex ratio (Figure 23). As shown in Figure 23, the national sex ratio among the youth (age groups 1-14) is almost 1:1. A similar ratio is evident in the working adult age groups 30-34 and 55-60.

Bar a few anomalies, the biased sex ratio in favour of females is clearly evident in the oldest age-groups (non-working and pension group) thus skewing national average sex ratio. Older Namibian females have a significantly longer life span than males.

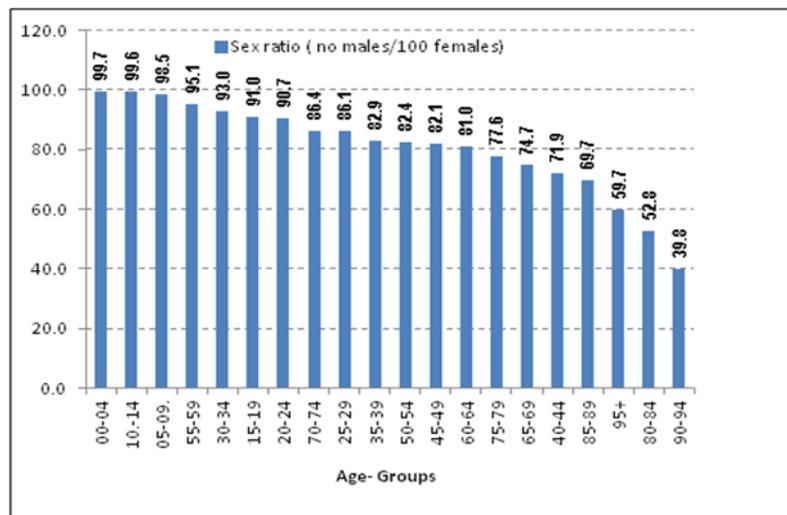


Figure 23 Ranked Sex ratio of Namibian population by age groups. Source: adapted from Namibia Household Income & Expenditure Survey 2003/2004

Table 14. Population by sex, region and urban/rural areas

Region	Female		Male		Both sexes		Sex ratio ¹
	Number	%	Number	%	Number	%	
Caprivi	45 918	4,8	40 520	4,7	86 437	4,7	88,2
Erongo	46 085	4,8	52 928	6,1	99 013	5,4	114,8
Hardap	34 414	3,6	33 780	3,9	68 194	3,7	98,2
Karas	31 351	3,3	31 114	3,6	62 465	3,4	99,2
Kavango	107 390	11,2	101 051	11,6	208 441	11,4	94,1
Khomas	131 692	13,7	126 812	14,6	258 504	14,1	96,3
Kunene	32 128	3,4	29 519	3,4	61 647	3,4	91,9
Oshana	95 015	9,9	75 175	8,6	170 190	9,3	79,1
Oshikoto	93 505	9,8	79 131	9,1	172 636	9,4	84,6
Otjozondjupa	64 660	6,7	59 623	6,8	124 283	6,8	92,2
Urban	330 258	34,4	304 065	34,9	634 322	34,7	92,1
Rural	628 488	65,6	567 218	65,1	1195 706	65,3	90,3
Namibia	958 745	100	871 283	100	1 830 028	100	90,9

Source: adapted from Namibia Household Income and Expenditure Survey 2003/2004 (Central Bureau of Statistics, (2006).

¹ Sex ratio = males per 100 females

10.1.2 Implications of gender and income on freshwater aquaculture development in Namibia

There is a suggestion that in the northern regions around 60% of household heads may be females and this could have some impact on freshwater aquaculture development. These impacts could translate into availability of disposable income to buy services and goods including farmed freshwater fish for consumption or an opportunity to enter aquaculture as an economic activity. Therefore we assessed the capacity of Namibian households across regions to purchase farmed fish and engage in aquaculture as an economic activity.

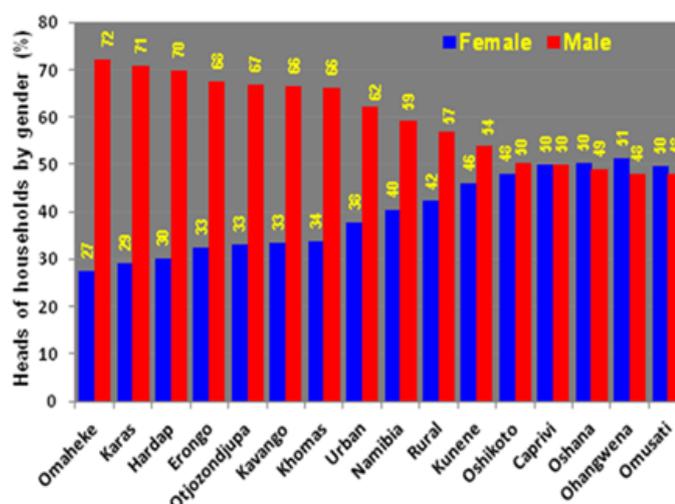


Figure 24. Ranked regional and national distribution of household heads by gender. Source adapted from the Namibia Household Income and Expenditure Survey 200-2004 (Central Bureau of Statistics, (2006).

Evidence could not be found to establish the suggestion that female households are in the majority. Although, the number of female heads of household increased in the last two decades no statistical evidence could be found to suggest they are in the majority. Based on the last census data, the national average percentage of female heads of households increased by 6 points from 39% to 45% between 1991 and 2001, maintaining male household heads as the majority. The regional breakdowns of heads of households based on the 2003-2004 household survey also shows that males, as head of households, predominate (Figure 24). The national male to female household ratio being 62:38 in urban areas and 57:43 in rural areas, respectively. Only in Oshikoto, Caprivi, Oshana, Ohangwena, and Omusati do the sex ratios approach 50:50 (Figure 24). This would suggest that in the majority of households, the male may still be most influential in considering risk and on deciding the uptake of aquaculture. Interestingly, with the exception of the Caprivi Region, households with similar sex ratios are also in regions where reliance on income from subsistence farming is high (see Table 15), in contrast to other regions.

Table 15. Sources of income as % of total households by region¹

Region	Salaries/wages	Business	Commercial farming	Subsistence	Pension	Remittances	Maintenance grants	Drought relief	Other	%	No. households
Caprivi	32.5	7.0	0.1	17.8	12.9	10.4	1.3	-	7.2	100.0	18 607
Erongo	75.3	9.5	2.0	2.3	7.7	2.3	1.4	0.1	1.1	100.0	27 713
Hardap	61.7	2.8	2.9	4.9	19.4	3.8	2.3	0.1	1.3	100.0	16 365
Karas	73.1	4.0	2.2	4.8	10.4	2.1	0.9	0.2	1.3	100.0	15 570
Kavango	28.1	12.8	0.2	33.9	11.3	5.7	0.8	0.2	5.9	100.0	32 354
Khomas	80.0	10.3	0.6	0.2	3.8	2.3	0.2	0.1	1.0	100.0	64 918
Kunene	44.0	5.5	3.3	19.2	16.0	9.5	1.2	-	0.1	100.0	13 365
Ohangwena	15.5	3.5	-	57.8	19.4	3.0	-	0.0	0.2	100.0	37 844
Omaheke	51.7	4.5	2.0	19.9	6.1	9.8	0.3	2.1	3.1	100.0	13 347
Omusati	13.1	1.9	-	80.2	3.3	0.3	0.0	-	0.5	100.0	39 248
Oshana	30.8	9.5	0.1	48.3	3.9	4.2	0.2	0.5	0.3	100.0	31 759
Oshikoto	25.7	2.7	2.0	49.9	12.2	7.4	0.1	1.0	0.7	100.0	31 871
Otjozondjupa	72.9	4.5	1.9	3.7	7.1	5.3	0.8	1.7	1.6	100.0	28 707
Namibia	46.4	7.1	0.7	28.9	9.2	4.3	0.6	0.4	1.6	100.0	371 668
Urban	77	11	0	1	4,9	4	1	0	1	100	150 533
Rural	26	5	1	48	12,1	5	0	1	2	100	221 136

¹ Based on household survey of 2003-2004. Source adapted from the Namibia Household Income and Expenditure Survey 200-2004 (Central Bureau of Statistics, 2006).

Overall, there appears to be no clear relationships between the sex ratio of household heads and wealth index. In some regions, where male households are

higher than female household heads, income from subsistence may also be as high as in female-headed households.

The following synthesis instead looks briefly at major sources of income as a factor

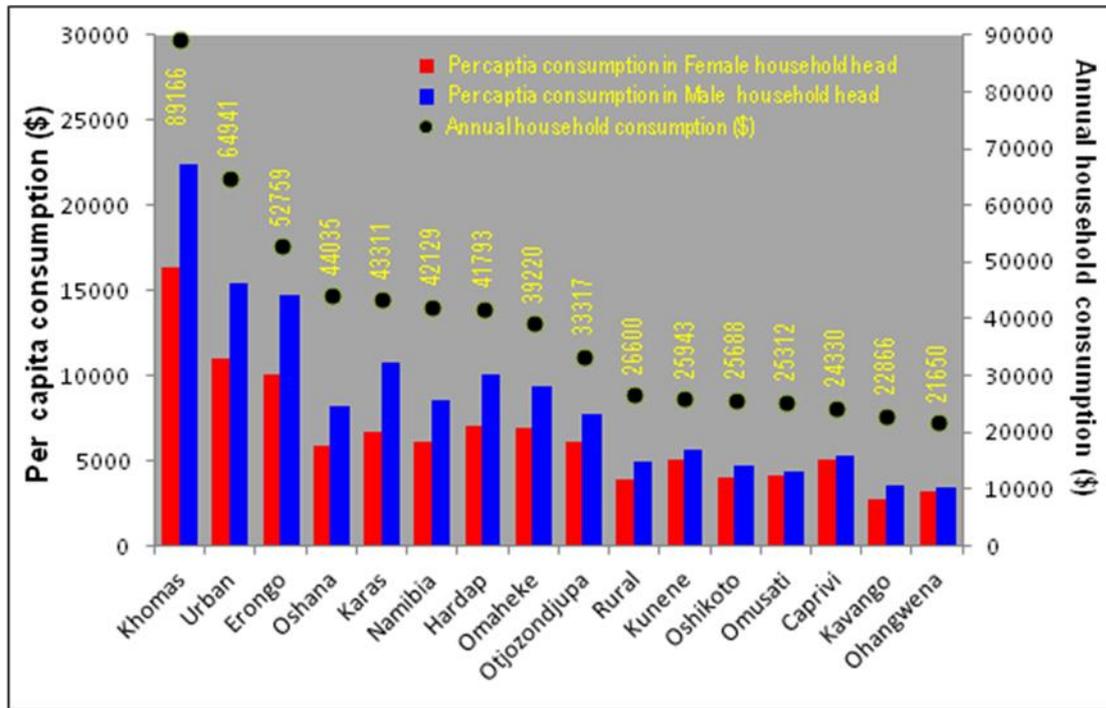


Figure 25. Relationship between gender of households and income. Source : adapted from Namibia Household Income & Expenditure Survey 2003/2004

that could influence aquaculture development with respect to gender.

Figure 25 also provides the annual regional and national consumption of households and the average per capita consumption by of household head by gender, highlighting large variations between regions and between urban and rural areas. Eight regions have a lower per capita consumption compared with the national average. Oshana has the lowest per capita consumption (N\$3 460) but household sizes are larger. Khomas has the highest (N\$22 392) per capita consumption. The rural households make up almost 60% of all households but account for only 38% of total consumption suggesting there is less money in the rural economy. By contrast about 40% of all households live in urban areas accounting for 62% of total consumption.

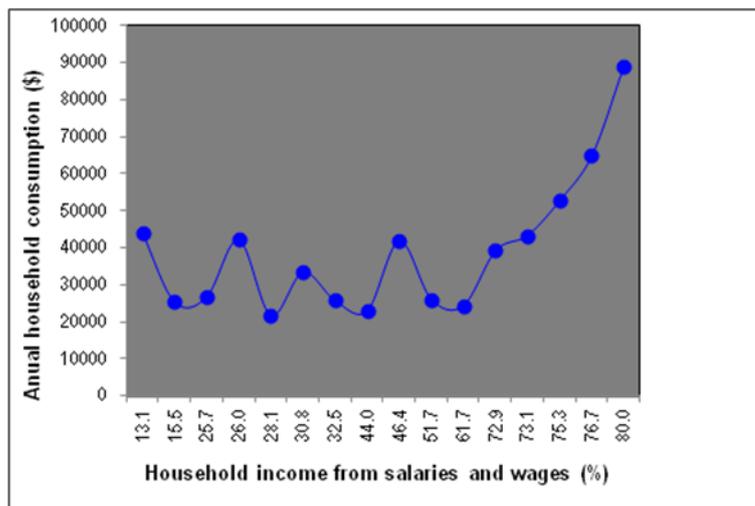
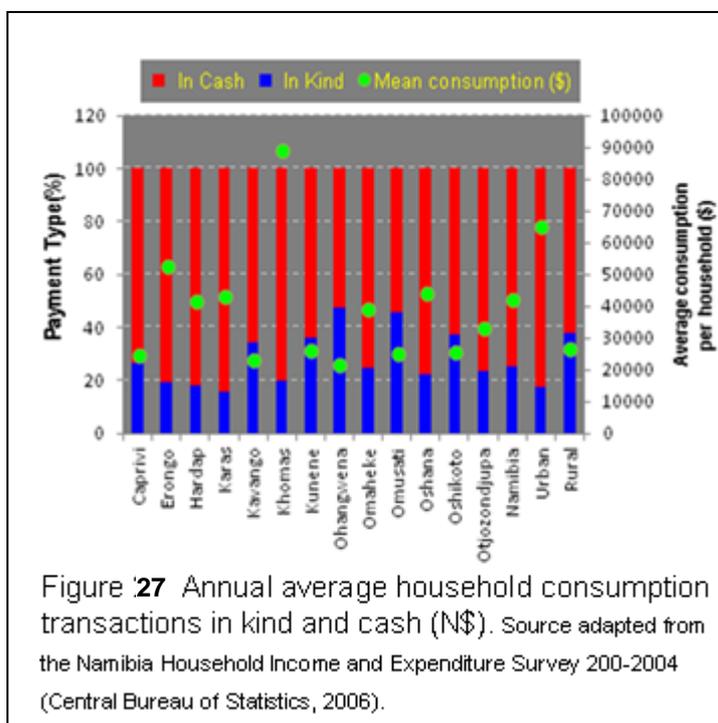


Figure 26. Impact of income from salaries and wages on household consumption. Source : adapted from Namibia Household Income & Expenditure Survey 2003/2004

For all regions male-headed

households provide a higher total and per capita consumption compared with female-headed households. At the national level male-headed households account for 70% of total consumption and female-headed households account for 29%.

An explanation of this bias may be gleaned from sources of income, irrespective of regions, rather than gender-based household heads. The associated changes in annual household consumption with increasing income of salaries and wages are given in Figure 26. These data, based on the household survey of 2003-2004, suggest a threshold of around 50% of income from salaries and wages is required to make a significant difference to household spending. For households



where income from salaries is below 50%, annual consumption is stagnant. When income from salaries exceeds 50%, annual consumption increases linearly (Figure 26). Such information may be useful in planning for aquaculture development to help target areas for siting aquaculture production such that disposable income is available to purchase farmed freshwater fish thus making the activity more profitable.

In rural economies, where disposable income may not be currently high or evenly distributed, payments for goods and services may be in kind. Such information could have a bearing on aquaculture development where cash transactions will be preferred. Fortunately, in Namibia, around 75% of total annual consumption transactions are in cash and only 25% in kind. There are, however, notable regional differences (Figure 27). In all regions, apart from Ohangwena and Omusati, cash transactions range between 62% and 84%; while in Omusati and Ohangwena cash and kind transactions are similar suggesting a limited circulation of cash in the local economy and therefore perhaps limited capacity to purchase fish. In Khomas Region, only about 20% is in kind.

The importance of females as household heads, however, does offer an opportunity for females to enter aquaculture as an economic activity. Opportunities may be created by carefully segmenting the aquaculture production value chain (Figure 44). Female farmers can be assisted and contracted to grow feed ingredients for aquafeeds. These include wheat, maize and sorghum. In addition, female-headed

households can be nurtured into seed production which is typically less capital intensive and produces relatively small biomass of fish for sale. Women can also be organized in cooperatives and set up in the marketing and distribution of fish produce.

The demographics are encouraging and point to potential for encouraging more women and youth into aquaculture

10.2 Domestic Market

10.2.1 The consumer and potential size of domestic market

Nationally, Namibian's are principally and traditionally red meat eaters and therefore fish does not have as high a priority in households and consequently fish consumption in Namibia is low. Local variations do exist, however, and rural communities, along the perennial river systems in the northern regions are traditional fish eaters.

The INFOSA study identifies three major consumer segments in the Namibian market place based on purchasing power. These are (i) a large group of low- and no-income consumers; both in the cities and rural areas, (ii) a relatively small high-income group of Europeans and Namibians, and (iii) tourist and recreational trade i.e. restaurants, hotels and resorts.

(i) Low- and no-income consumers, both in the cities and in the rural areas.

This group is perceived to adopt more traditional diets in rural areas than those in cities who are likely to have come from the north and therefore familiar with freshwater fish. In the Kavango and Caprivi Regions more than 100 000 people depend on this resource for their daily protein needs. Freshwater fish consumption in the Caprivi Region ranks over beef, game and poultry and also has a significant economic value for the communities.

(ii) High-income group of Europeans and Namibians

This group is mainly located in the capital and towns with Western consumption patterns and relatively high purchasing power. This group typically shops at supermarkets such as Pick n' Pay and Shoprite and local stores. They have buying power to purchase a range of fish product forms products such as skin-off and skin-

on fillets, smoked fish, portions, whole gutted, headed and gutted, and fresh fish on ice such as salmon.

In another recent marketing study in the capital, three main types of frozen finfish species were commonly purchased. These were horse mackerel (68%), hake (35%), and snoek (23%). The reasons for purchasing fish were that it was less expensive (46%) relative to meat (mutton and beef) and it was healthy and nutritious (41%) (Musaba and Namukwambi, 2011). These findings also suggest that high-income households were less likely to purchase mackerel than low-income households but more inclined to purchase hake. Snoek was purchased by larger households. Unfortunately, this study did not ask questions on freshwater fish preferences.

(iii) Tourist and recreational trade

This market segment is potentially lucrative but probably small. Namibian freshwater fish products could be promoted in cooperation with The Namibian Wildlife resort and the Aquaculture Association using a similar model to that of fresh vegetables from the Etunda project. This will require skillful marketing given that a large tourist base is likely to be German.

The INFOSA studies suggest a growing demand for fish in the domestic market. Consumption has been spurred on by the nationwide campaign by the Fish Promotion Trust established by MFMR whose main objective is to increase domestic fish consumption. No information, however, could be located to verify any impact of this initiative.

10.2.2 Market opportunities

The populations in the northern regions such as Oshana, Oshikoto, Otjozondjupa, Kavango and Caprivi are traditional freshwater fish consumers with potential for increased fish consumption. The southern region is characterized by very low population densities and



there may be more resistance of the local ethnic groups towards fish as food. Given the labour mobility from north to south and education and promotion, fish consumption in all regions is predicted to increase but it is clear the government will need to have a more proactive and innovative campaign to increase consumption through the Fish Promotion Trust (Figure 28). The potential of the market for this assessment is based on the demographics of the regions.

There are some positive indicators that point to potential increase. The household survey of 2003-2004 confirmed that about half the households in Namibia and 77% of urban households obtain their income through salaries and wages suggesting that there should be adequate cash in the economy to purchase fish. In addition, this survey reports that 75% of purchases in Namibia are in cash and only 25% in kind. Even in rural areas, over 60% of transactions are in cash (Table 15).

Table 16. Predicted **total** fish consumption (tonnes) by region at varying levels of anticipated per capita consumption (kg/yr)

Region	Population	Purchases (%) in:		Mean household consumption (N\$)	Per capita consumption (Kg/year)			
		Kind	Cash		10	7.5	5	2.5
Caprivi	86437	26.7	73.3	24330	864	648	432	216
Erongo	99013	19.6	80.4	52759	990	743	495	248
Hardap	68194	18.1	81.9	41793	682	511	341	170
Karas	62465	15.8	84.2	43311	625	468	312	156
Kavango	208441	34	66	22866	2084	1563	1042	521
Khomas	258504	19.9	80.1	89165	2585	1939	1293	646
Kunene	61647	36.1	63.9	25942	616	462	308	154
Ohangwena	236776	47.5	52.5	21650	2368	1776	1184	592
Omaheke	56037	24.4	75.6	39221	560	420	280	140
Omusati	225405	45.4	54.6	25312	2254	1691	1127	564
Oshana	170190	22.3	77.7	44035	1702	1276	851	425
Oshikoto	172636	37.3	62.7	25688	1726	1295	863	432
Otjondjupa	124283	23.4	76.6	33317	1243	932	621	311
Urban	634322	17.8	82.2	64941	6343	4757	3172	1586
Rural	1195706	37.9	62.1	26600	11957	8968	5979	2989
Namibia	1830028	25.4	74.6	42129	18300	13725	9150	4575

According to FAO the domestic per caput (= capita) fish consumption is estimated at about 10 kg/year. Assuming a per capita fish consumption of 10 kg, Namibia will

require a total of 18 300 tonnes of fish annually. Regionally, the highest populated areas in the north such as Kavango, Ohangwena, Omusati, will require around 2 000-2 500 tonnes/year of fish in total. If per capita fish consumption is lower fish requirements will accordingly be reduced (Table. 16).

Table 17 provides estimates total **freshwater** fish requirements. Unfortunately information on the contribution of freshwater fish to total fish consumption is unavailable. Therefore freshwater fish requirements were modelled using three scenarios under four per capita consumptions (Table 17). Assuming a conservative per capita consumption of 5 kg/person/year and if market share freshwater fish is 75, 50 or 25% of total fish consumption, Namibia will require 6 863, 4 575 and 2 288 tonnes of freshwater fish per year, respectively. Similar data for the regions under other scenarios are given in Table 17.

10.2.3 Availability and price of freshwater fish

The sale of tilapia and catfish to the public usually takes place on days of harvesting. In the north, some sales of tilapia are made to nearby lodges and retail outlets. According to the INFOSA study demand far exceeds supply. Eco-Fish Farm, the only current commercial farm, at Hardap, supplies red *O. niloticus* hybrid tilapia through Beira Foods in Windhoek. At present, 5 kg boxes of frozen, gutted tilapia are sold in Windhoek for N\$120, i.e. N\$24/kg, a price considered reasonable by consumers. Tilapia fillets are sold for around N\$55/kg. Their study indicates that the middle class consumer appears to be willing to pay more for tilapia, either whole, gutted or fillets, than for hake.

According to surveys, INFOSA states that fish consumption in the Kavango Region, is around 600 tonnes/yr, and that for Caprivi was estimated at over 790 tonnes/yr. Estimates for potential market for tilapia in the northern regions were 1 500-2 000 tonnes/yr. Presently, according to Erongo Marine, Namibia's largest supplier of horse mackerel, 500-700 tonnes of frozen whole horse mackerel are sold monthly into the northern regions of Namibia, suggesting high demand for fish. This estimate seems high and should be verified. Horse mackerel sales decline when the Oshanas flood and wild fish becomes abundant. For 6-8 months of the year, however, the Oshanas are dry, creating a good market for farmed freshwater fish. Similarly, if imposed, the closed fishing season in the Kavango and Caprivi Regions for 3-4 months also provides an additional opportunity for farmed fish.

10.2.4 Potential value of fish to the domestic economy

An attempt is made to model potential income to the local economy for freshwater fish farming. Estimated revenue streams (at a gate price of N\$20/kg) that can be expected, based on varying total per capita fish consumption and the contribution of freshwater fish to total per capita fish consumption is presented in Table 18. If per total capita fish consumption is pegged at 10kg/year and if 75% of fish consumed originates from freshwater fish farming, then nationally the subsector will be worth N\$275 million/year. Similarly at the other extreme, a total per capita value of 2.5 kg where only 25% fish comes from freshwater farming will reduce this revenue stream to just N\$23 million/year.

Successful promotion of freshwater farming will also to have a greater benefit in rural areas when compared with urban areas thus creating much needed cash in the rural economy. At 10 kg per capita, where 50% of consumption comes from freshwater farming, the subsector in rural areas could be worth N\$90 million, double that of urban areas. This and potential regional income streams are given in Table 18.

Table 17. Predicted volumes of freshwater fish (tonnes) required at varying per capita consumption (kg/year) and varying percentage of contribution from freshwater fish farming

	Per Captia Consumption (kg/year)											
	10			7.5			5			2.5		
Percentage from freshwater fish farming	75	50	25	75	50	25	75	50	25	75	50	25
Region												
Omaheke	420	210	70	315	210	105	210	140	70	187	70	35
Kunene	462	231	77	347	231	116	231	154	77	205	77	39
Karas	468	234	78	351	234	117	234	156	78	208	78	39
Hardap	511	256	85	384	256	128	256	170	85	227	85	43
Caprivi	648	324	108	486	324	162	324	216	108	288	108	54
Erongo	743	371	124	557	371	186	371	248	124	330	124	62
Otjozondjupa	932	466	155	699	466	233	466	311	155	414	155	78
Oshana	1276	638	213	957	638	319	638	425	213	567	213	106
Oshikoto	1295	647	216	971	647	324	647	432	216	575	216	108
Kavango	1563	782	261	1172	782	391	782	521	261	695	261	130
Omusati	1691	845	282	1268	845	423	845	564	282	751	282	141
Ohangwena	1776	888	296	1332	888	444	888	592	296	789	296	148
Khomas	1939	969	323	1454	969	485	969	646	323	862	323	162
Urban	4757	2379	793	3568	2379	1189	2379	1586	793	2114	793	396
Rural	8968	4484	1495	6726	4484	2242	4484	2989	1495	3986	1495	747
Namibia	13725	6863	2288	10294	6863	3431	6863	4575	2288	6100	2288	1144

Table 18. Estimated revenue stream (N\$ millions) from freshwater fish with a gate price of N\$20/kg, at varying per capita consumption and varying percentage contribution from freshwater fish farming												
Collective revenue stream from freshwater fish gate sales at N\$20/kg												
Per Capita Consumption (kg/year)	10			7.5			5			2.5		
Percentage from freshwater fish farming	75	50	25	75	50	25	75	50	25	75	50	25
Regions												
Omaheke	8.41	4.20	1.40	6.30	4.20	2.10	4.20	2.80	1.40	3.74	1.40	0.70
Kunene	9.25	4.62	1.54	6.94	4.62	2.31	4.62	3.08	1.54	4.11	1.54	0.77
Karas	9.37	4.68	1.56	7.03	4.68	2.34	4.68	3.12	1.56	4.16	1.56	0.78
Hardap	10.23	5.11	1.70	7.67	5.11	2.56	5.11	3.41	1.70	4.55	1.70	0.85
Caprivi	12.97	6.48	2.16	9.72	6.48	3.24	6.48	4.32	2.16	5.76	2.16	1.08
Erongo	14.85	7.43	2.48	11.14	7.43	3.71	7.43	4.95	2.48	6.60	2.48	1.24
Otjizondjupa	18.64	9.32	3.11	13.98	9.32	4.66	9.32	6.21	3.11	8.29	3.11	1.55
Oshana	25.53	12.76	4.25	19.15	12.76	6.38	12.76	8.51	4.25	11.35	4.25	2.13
Oshikoto	25.90	12.95	4.32	19.42	12.95	6.47	12.95	8.63	4.32	11.51	4.32	2.16
Kavango	31.27	15.63	5.21	23.45	15.63	7.82	15.63	10.42	5.21	13.90	5.21	2.61
Omusati	33.81	16.91	5.64	25.36	16.91	8.45	16.91	11.27	5.64	15.03	5.64	2.82
Ohangwena	35.52	17.76	5.92	26.64	17.76	8.88	17.76	11.84	5.92	15.79	5.92	2.96
Khomas	38.78	19.39	6.46	29.08	19.39	9.69	19.39	12.93	6.46	17.23	6.46	3.23
Urban	95.15	47.57	15.86	71.36	47.57	23.79	47.57	31.72	15.86	42.29	15.86	7.93
Rural	179.36	89.68	29.89	134.52	89.68	44.84	89.68	59.79	29.89	79.71	29.89	14.95
Namibia	274.50	137.25	45.75	205.88	137.25	68.63	137.25	91.50	45.75	122.00	45.75	22.88

10.2.5 Planning and key requirements for meeting potential regional freshwater fish demand in Namibia

The projected regional and national demand for freshwater fish is given above. To meet this anticipated demand fish farms are required across the Namibian regions. The rationale for advocating small farms across suitable regions is to reduce transaction cost, given that Namibia is a vast country, and as illustrated in Table 19, generate economic activity for the local economy

Table 19. Estimated potential freshwater fish demand, number of required farms and value to local economies by region assuming a per capita consumption of 5kg/ha with 50% consumption derived from farmed freshwater fish

Region	Annual demand @ 50% of 5kg/capita/yr	No. farms projected	Main system type	Production @ 100 tonnes/unit	Jobs			Gate value of production (N\$ millions)	Money spent in local economy by staff (80% of earnings)
					Full time ¹	Casual	Construction/maintenance		
					10/farm	4/farm	5/build	20/kg	N\$224 000/farm
Omaheke	140	1	Raceway	100	10	4	5	2.8	0.224
Kunene	154	1	Raceway	100	10	4	5	3.08	0.224
Karas	156	1	Raceways/cage	100	10	4	5	3.12	0.224
Hardap	170	2	Raceways/pond/cage	200	20	8	10	3.4	0.448
Caprivi	216	3	Pond	300	30	12	15	4.32	0.672
Erongo	248	2	Raceways/cage	200	20	8	10	4.96	0.448
Otjozondjupa	311	3	Raceway	300	30	12	15	6.22	0.672
Oshana	425	4	Pond	400	40	16	20	8.5	0.896
Oshikoto	432	4	Pond	400	40	16	20	8.64	0.896
Kavango	521	6	Pond	600	60	24	30	10.42	1.344
Omusati	564	6	Ponds/cage	600	60	24	30	11.28	1.344
Ohangwena	592	6	Pond	600	60	24	30	11.84	1.344
Khomas	646	1	Raceway	100	10	4	5	12.92	0.224
Total	4575	40		4000	400	160	200	91.5	8.96
Feed requirement at FCR² 1.5 (tonnes)				6000					
Retail value of production @ N\$ 25/kg								115	
Total jobs including support construction and maintenance							760		

¹ One supervisor @ N\$100 000/yr and 9-labourers @ N\$20 000/yr

² FCR (Food Conversion Ratio)

Assuming a moderate per capita total fish demand of 5kg/year where 50% of the fish originates from freshwater fish farming, a total of 4 575 tonnes are required annually, ranging between 140-646 tonnes of fish/region (Table 19). Based on a farming unit of 100 tonnes a total of 40 farms could be envisaged across Namibia ranging from 1 to 6 farms/region. These farms can create 560 direct jobs and 200 in the construction and maintenance services, a total of 760 nationally. Based on a gate price of N\$20/kg such production will have a value of N\$91.5 million. In

addition, assuming 80% spend, N\$9 million/year will be spent in the local economy by farm employees. This production will, however, require around 6 000 tonnes of feed (Table 19). The current government feed plant at Onavivi only has a capacity of 1 200 tonnes/year and therefore as production is increased capacity to increase feed production will also have to be increased.

10.3 Regional Market

The Southern African Development Community (SADC) region could offer a market for Namibian farmed freshwater fish, taking advantage of free trade arrangements. In particular, neighbouring and nearby countries such as Angola, Zambia, Botswana, Mozambique, Democratic Republic of Congo (DRC) may provide more immediate markets, keeping transaction costs to a minimum. Namibia has a good road network system that links the country to the bordering countries. Currently, Namibia exports marine aquatic products to the region, and therefore it is suggested that the distribution channels for Namibian fish are already in place, providing access for aquaculture product to the existing markets. It should be considered, however, that freshwater fish could be seen as competition for cheap marine fish that is diverted by large companies to these markets and therefore alternative mechanisms may need to be explored to export freshwater fish in the region.

10.3.1 Fish imports in the region

Although freshwater species such as tilapia and catfish form part of the traditional diet in the region this is not recorded in the FAO import statistics of countries in the region. In addition, much of the import fish data are estimates by FAO rather than country submissions and therefore probably inaccurate. Nevertheless, it is the best dataset available and is used in this discussion.

Table 20. Fish Imports of main commodity types (tonnes)¹ by neighbouring countries of Namibia

Commodity types	Angola	Botswana	DRC	Malawi	South Africa	Zambia	Zimbabwe
Fish, prepared or preserved	17 424	2 182	6 572	86	46 506	211	198
Fish, fresh, chilled or frozen	12 694	762	44 933	113	23 799	2 844	1 672
Fish, dried, salted, or smoked	4 332	43	11 970	3 025	368	380	403
Fishmeal	369	10 789	174	511	15 306	4 001	1 806
Total <u>fin-fish</u> imports	34 819	13 776	63 649	3 735	85 979	7 436	4 079
Total imports	35 167	13 836	63 712	3 740	109 791	7 473	4 124

¹ source; adapted from FAO, 2010

The neighbouring countries import between 4 000-110 000 tonnes of fish and shell fish (see Table 20). With the exception of South Africa most countries import mainly fin-fish in various forms. In Botswana and Zambia 79 and 53% of imports was fishmeal used for the livestock feed industry. In all countries most of the fish imported was of marine origin and the majority is imported in the fresh, chilled or frozen form. The major species groups imported were sardines, mackerel and unidentified marine frozen fish. Whilst large quantities of mixed marine fishes were imported there were no specific imports of tilapia or catfish by neighbouring countries. In recent years, however, unknown quantities of whole frozen tilapia are known to be imported into South Africa from China and Zimbabwe and aquaculture plans akin to that of Namibia are also being developed in neighbouring countries to meet growing internal demand for fish.

Indeed, a 2007 survey by Lake Harvest, the largest cage farmer in SADC, suggests a significant and growing demand for tilapia in the region (Table 21). Due to their vertical integration and lower production costs they are the major competitor in the region. Their study suggests current annual tilapia consumption of around 10 000 tonnes which is expected to increase 4 to 5-fold in the next 5 to 10 years with an estimated gate value of over a N\$1 billion (at US\$3/kg and N\$8/US\$).

Table 21. Estimates of present and projected tilapia consumption in selected countries

Country	Current consumption (tonnes)	Projected need in next 5 to 10 years (tonnes)
Angola	2 000	4 000
Botswana	100	2 500
DRC	1 000	10 000
Malawi	>3 000	>10 000
Mozambique	250	1 000
South Africa	500	10 000
Zambia	2 000	6 000
Zimbabwe	1 000	2 500
Total	9 850	46 000

Source: pers comm.. Gerry McCollum, Lake Harvest Aquaculture, 2007

10.4 Conclusions

- Around 75% of purchase transactions in Namibia are conducted in cash, suggesting that there should be money in the economy to pay for fish.
- The average rural and urban annual household spends in 2003-2004 were N\$27 000 and N\$65 000, respectively. This is likely to be notably higher now.

- A good estimate of per capita fish consumption is unavailable but indications suggest that the FAO estimate of 10 kg/capita/year is high.
- The current practice by MFMR of producing and selling fish at N\$15/kg is untenable and comprises market development and opportunities for freshwater aquaculture uptake.
- The national domestic demand for Namibian grown freshwater fish is estimated at between 1 100 to 14 000 tonnes depending on the per capita consumption that can be achieved and on what percentage of fish consumed comes from farmed freshwater fish.
- The corresponding gate sales revenue from such demand is estimated at N\$23 to N\$275/year at N\$20/kg.
- No information was available on the effectiveness of the Fish Promotion Trust in increasing consumption of farmed freshwater fish.
- At a per capita of 5kg/year where 50% of the fish originates from freshwater fish farming, 4 575 tonnes/year is required , ranging between 140-648 tonnes of fish/region,
- 40 farms are envisaged across Namibia ranging from 1 to 6 farms/region generating 570 jobs with a gate value of N\$91.5 million.
- N\$9 million/year will be spent in the local economy by farm employees.
- A regional demand for farmed freshwater fish exists in neighbouring countries but the capacity to compete in this market will need to be carefully assessed.
- Data reported to FAO suggest that most of fish imported into neighbouring countries are cheap frozen marine fish and canned products.

10.5 Recommendations and the Way Forward

- i. The MFMR should conduct a detailed field study on the domestic market using innovative approaches to understand household consumption patterns of fish by regions.
- ii. The GRN should focus on serving the domestic market ensuring that farms are strategically located to reduce production and translocation costs.
- iii. In parallel, the GRN should develop a national strategy and regional implementation plan for increasing the per capita consumption of freshwater fish.
- iv. Currently fish is the cheapest of animal protein when compared with poultry or red meat. The MFMR must put in place immediate measures to increase the gate price of fish from N\$15 to N\$25/kg.
- v. A national plan be constructed to detail the distribution of farms and put in place measures for a phased increase in fish feed production.
- vi. The GRN should conduct a survey of neighbouring countries to estimate fish demand and price and understand the market distribution channels of fish.

11 CHALLENGES AND CONSIDERATIONS FOR PROMOTING THE NATIONAL AQUACULTURE MASTER PLAN FOR FRESHWATER AQUACULTURE: Human Resource Development Requirements and Needs Profile

11.1 Background

Freshwater aquaculture in Namibia commenced less than ten years ago and is relatively new compared with the culture of organisms in marine waters. Further, unlike other agricultural activities with a tradition and thus accumulated indigenous knowledge such as livestock, Namibia has neither tradition nor indigenous knowledge in freshwater fish farming. The freshwater aquaculture subsector is regulated by MFMR in accordance with the Aquaculture Act 2002 and related regulatory and strategic frameworks. This subsector is being developed for small-scale activities especially, though not exclusively, to enhance food and nutritional security of rural communities. The GRN rationalized and promoted freshwater aquaculture this millennium through a series of interventions. These include *inter alia* establishing: (i) an Aquaculture Directorate (AD), (ii) community and government-run fish farms in several predominately northern regions of Namibia, (iii) government extension, research and training facilities, and (iv) a government-owned fish feed factory, all of which will require appropriately trained and skilled staff.

One activity of the NAMP-FW development process was therefore to conduct a rapid appraisal to ascertain the training and skills required to drive the freshwater sector forward.

11.2 Methodology

The approach adopted to ascertain critical human resource needs requirements was based on competences required to consolidate current initiatives of MFMR in freshwater aquaculture and to expand farming into areas where it is likely to be feasible.

Secondary data on the development of freshwater was reviewed to establish the scope of aquaculture activities. This was followed by an extensive field visit of regions of the country where aquaculture has been promoted to some extent and government staff, farmers and relevant stakeholders were in operation. These visits were used to interact, discuss and consult stakeholders in the subsector on the ground. Mostly, informal interviewing techniques and field-based participatory approaches were used to assess the human resource needs. The needs were then grouped into areas for further action.

11.3 Outcomes for Training Needs Assessment

The training needs required to support and facilitate freshwater aquaculture development are grouped as seven strategic thematic areas which in turn is segmented as nodal action points. These are illustrated in Figure 29. To identify where human resource needs should be focused each nodal action point is segmented in a cluster of specific activity requiring competent staff and farmers. Specific rationale and recommendations on areas for training to address key strategic thematic and action points are given below:

1. **Administrative** and **regulatory** requirements are mainly a function of government departments, in particular MFMR. Although a Directorate of Aquaculture is established its management and implementation of freshwater aquaculture issues on the ground show noticeable inadequacies. The situation was largely attributable to ineffective numbers of administrative staff and professional limitations of some available staff. It is essential that MFMR seriously consider creating a **specific** administration with trained staff for inland aquaculture with competence in regulations and management and monitoring and evaluation

For example, currently, there is a detrimental confusion between inland capture fisheries and aquaculture activities resulting in limited and incomplete outputs from institutions such as the Kamutjonga Inland Fisheries Institute (KIFI).

2. The education and training requirements to address **aquaculture promotion at educational institutions should** consider the fact that Namibians do not have a fish farming culture and therefore orientation and training should first address rudimentary skills using appropriate training tools as well as specialised training requiring formal training at vocational and university levels.

The tertiary institutions in Namibia, especially vocational, agricultural colleges and university level have the facilities to develop and provide most of the human resource base required to support freshwater aquaculture in Namibia drawing on the caution to train persons in accordance to market requirements. Courses currently offered at schools, vocational and tertiary establishments will benefit from a curriculum review to incorporate appropriate levels of aquaculture modules. To achieve delivery, however, complementary training may be required for current or new staff. Such initiatives will also benefit from collaborative networks, specialized courses and further studies at overseas institutions. In particular, there should be a trained liaison officer between such institutions and government facilities such as Onavivi and Epalela for field-based training and capacity building.

3. Prioritized specific subject areas of training needs, addressing: **consolidating and increasing fish production and efficiency** identified during field visits and six workshops include:
- i) An orientation for all engaged in management and production issues, and government institutional and cooperative fish farms on major fish farm on-growing involvements and their planning.
 - ii) Identification, reorientation and/or training of key extension personnel.
 - iii) Hatchery practices and management for tilapia and catfish.
 - iv) On-growing production management and business skills and production systems including intensive farming systems.
 - v) Recirculating aquaculture systems (RAS).
 - vi) Researchers and technical staff in fish feed ingredient identification, quality assessment and control, and feed formulation and processing.
 - vii) Drafting and assessment of business plans.

Apart from tertiary education, class room training at the **technical and skills level** should also be provided at a vocational level and as well on-farm training. Further considerations for more detailed skills required for farm staff are provided and discussed in Subsection 12.

Specialized Support Services

Fish feeds: Namibia is fortunate in having a government fish feed plant and have local supplies of all required macro-ingredients. Staff capacity at this facility, however, should be updated to ensure that a dedicated core team of trained staff is available to monitor and continuously work to enhance feed quality and performance. At this stage of development the sector is small for the private sector to undertake such initiatives. Staff need to be trained in raw material sourcing, guiding production of such ingredients, storage and evaluation.

Production systems: Although expertise in relation to engineering and construction is best provided by the private sector it will be prudent for a very few selected government staff that are currently suitably qualified in aquaculture to be better able to assess the quality of design and have inputs into farm design and evaluation. This was mainly borne out at KIFI, where the systems recently designed and installed were assessed to be inadequately conceived from a management and operations perspective, yet none of the staff could assess the situation. There may also be merit for better collaboration with engineering institutions to develop local hybrids of production systems at a more affordable cost.

4. Funding structures for promoting aquaculture

The GRN is committed to promote intensive freshwater aquaculture. To achieve this objective two crucial areas need to be serviced i.e. initial capital for infrastructure (CAPEX), and feed and seed (OPEX), both of which constitute a significant cost to production. Whilst the GRN have collaborated with various financial institutions, including the Namibian Development Bank and the Agri-Bank, to establish funding programmes in support of the development of the sector, staff at these institutions are not adequately oriented and trained in aquaculture to assess the technical feasibility of proposal and assess risk.

11.4 Conclusions

- Only a rapid appraisal of training need assessment (TNA) could be conducted in the timeframe of this NAMP.
- There is a disjunction between infrastructure and human capacity development required to operationalize freshwater aquaculture development objectives.
- There is a clear shortage of appropriately trained staff at all tiers of operation and across the whole value chain including allied sectors of Namibia
- Failure to address such shortages will compromise the GRN's infrastructure investment further.

11.5 Recommendations and Way Forward

- i. A comprehensive "National Extension Strategy" should be developed to strengthen the capacity building of MFMR officials, including researchers and extension officers,
- ii. Training material and extension manuals should be developed and field-tested
- iii. An in-depth TNA be conduct and used to design a suitable Namibian training programme that will enable MFMR and other local training institutions to provide appropriate training to the right people at the right place and at the right time using the right approach.
- iv. Collaborate with neighbouring countries to upgrade training capacity in Namibia.
- v. Review all existing training curricula for the freshwater aquaculture sector and upgrade where necessary to include innovations and trends for freshwater aquaculture in Namibia and the African region.

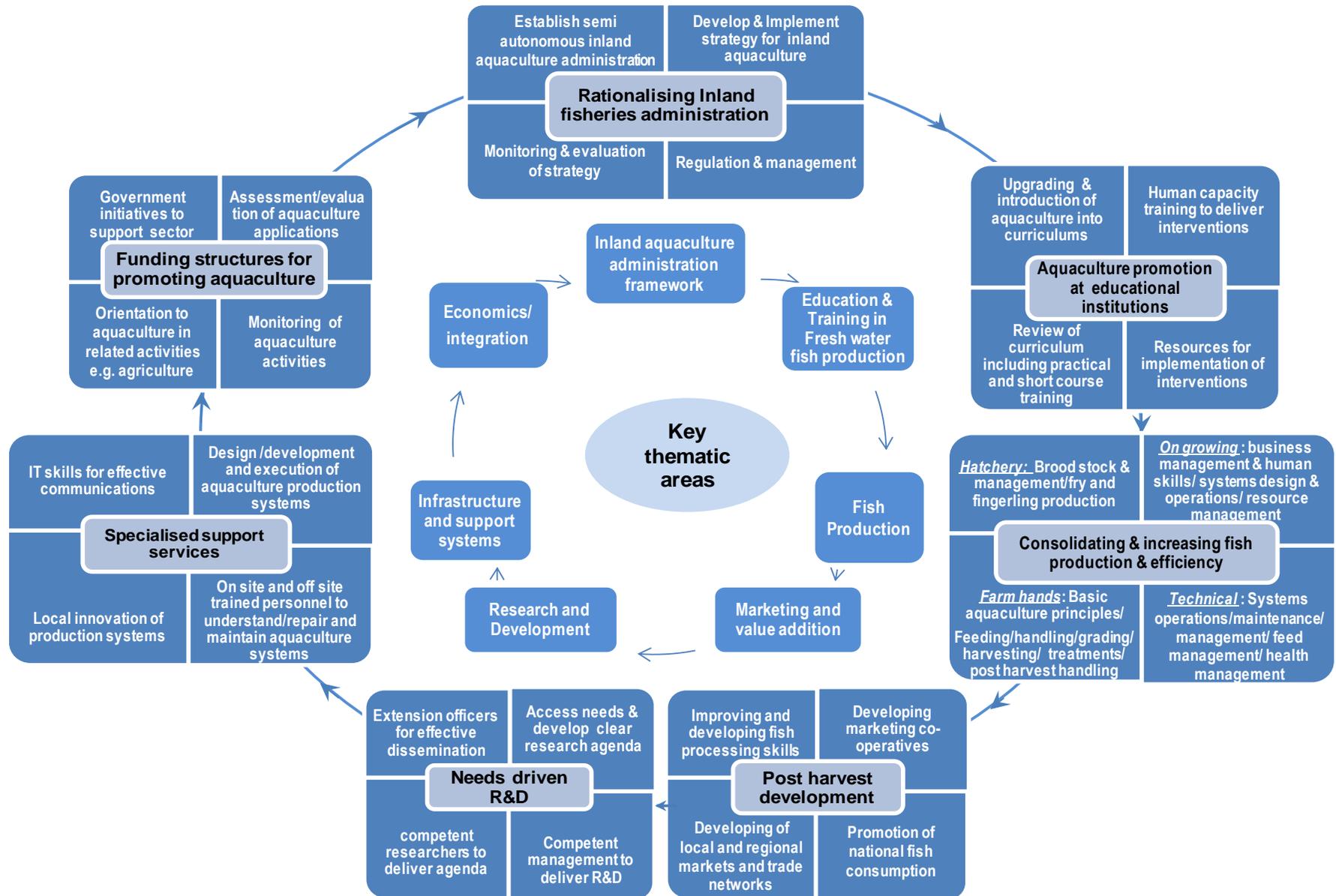


Figure 29. Matrix of key thematic areas and its key nodal action points to identify human needs requirement for freshwater aquaculture development in Namibia

12 CHALLENGES AND CONSIDERATIONS FOR PROMOTING THE NATIONAL AQUACULTURE MASTER PLAN FOR FRESHWATER AQUACULTURE: Training Needs, Knowledge and Skill Guidelines for the Community/Small-Scale Fish Farmer/Business Entrepreneur to Effectively Run a Fish Farm

12.1 Knowledge and Skills Requirements within Freshwater Aquaculture Enterprises

The human capacity complement on fish farms will be a reflection of the size, complexity and scale of the aquaculture operation. The larger the operation, the greater the segmentation of duties and staff responsibilities. The fledgling freshwater sector of Namibia is typified by small-scale farms where the skills required will be merged into a fewer number of persons, grouped here as unskilled and skilled workforce. The range of skills given in Table 22 may not be applicable to all farms in Namibia but provided in this report as a broader guide to cover the whole production value chain.

The unskilled worker cluster such as farm hands, farm labourers or farm workers will be expected to be carry out a range of basic work activities/duties under close direction and supervision, such as feeding, handling and harvesting stock, minor construction, general cleaning and maintenance of rearing structures. The unskilled workers will be expected to learn on the job. Work carried out and duties may vary between aquaculture enterprises depending on management and size of farm. Skilled workers, on the other hand, are expected to work as aquaculturists or technicians and to include some supervisory capacity. An indicative range of technical skills and duties and their weighting across these human capacity profiles are given in Table 22. The knowledge base of the farm owner or entrepreneur will vary depending of the scale of investment or government intervention. Nevertheless, basic knowledge is expected in all areas identified in Table 22. Such knowledge may be acquired as the farm develops. For a successful enterprise, however, the owner is expected to have greater knowledge and experience in areas given higher weighting in Table 22, ideally before entering into freshwater aquaculture.

Table 22. Expected levels of knowledge and skills within freshwater aquaculture enterprises

SCOPE OF SKILLS	Owner/ entrepreneur	Skilled	Unskilled
		Technician	Labourer/ farmhand
A. LABORATORY SKILLS			
1. Monitor water quality	x	xxx	x
2. Maintain good records/data	xx	xxx	x
3. Use and maintain laboratory equipment	x	xxx	x
4. Practise safe work habits	xx	xxx	x
5. Handle organisms	x	xx	xxx
6. Apply aseptic techniques	x	xxx	x
7. Use hatchery laboratory skills	x	xxx	x
8. Use a microscope	x	xxx	xx
9. Diagnose disease	x	xxx	x
B. MATHS SKILLS			
1. Use basic mathematics	xx	xxx	x
2. Calculate rates	x	xxx	x
3. Calculate volumes	x	xxx	x
4. Apply statistics	xx	xxx	
5. Design research trials	xx	xxx	x
C. KNOWLEDGE OF BASIC CHEMISTRY			
1. Practise safety	x	xxx	x
2. Monitor water quality	x	xxx	x
3. Working knowledge of environmental chemistry	x	xxx	
4. Working knowledge of basic chemistry	x	xxx	x
5. Make solutions	x	xxx	xx
D. FIELD EXPERIENCE			
1. Practise safety	xxx	xxx	xxx
2. Maintain equipment	xx	xxx	xxx
3. Understand the natural environment	xxx	xxx	x
4. Handle organisms	x		xxx
5. Keep accurate records in the field	x	xxx	xxx
6. Conduct proper field sampling protocols	x	xxx	x
7. Conduct on-site public relations	xxx	xx	
8. Practise good time management	xxx	xx	x
9. Organize equipment	xx	xxx	x
10. Improve	xx	xxx	xx
E. KNOWLEDGE OF BASIC BIOLOGY			
1. Manage water quality	x	xxx	x
2. Practise efficient and effective feed management skills	x	xxx	xx
3. Practise animal husbandry skills (e.g. feed, harvest)	x	xx	xxx
4. Working knowledge of the anatomy and physiology of aquatic organisms	x	xxx	xx
5. Manage broodstock	x	xxx	x
6. Working knowledge of fish health and disease recognition	x	xxx	x
7. Working knowledge of basic genetics	x	xxx	x

Table 22. Expected levels of knowledge and skills within freshwater aquaculture enterprises

SCOPE OF SKILLS	Owner/ entrepreneur	Skilled	Unskilled
		Technician	Labourer/ farmhand
F. MECHANICAL SKILLS			
1. Maintain aeration equipment	x	xx	xxx
2. Act in an innovative and resourceful manner	xx	xxx	xx
3. Maintain filters	x	xx	xxx
4. Work with electrical systems	x	xx	xxx
5. Work with piping	x	xx	xxx
6. Work with/on electronics e.g. instrumentation	x	xx	xxx
7. Work on pumps	x	xx	xxx
8. Perform basic carpentry/brickwork	x	x	xxx
9. Drive and/or use non-traditional equipment	x	x	xxx
10. Tie knots and mend nets	x	x	xxx
G. COMMUNICATION SKILLS			
1. Use good verbal communication techniques	xxx	xx	x
2. Use good written communication techniques	xxx	xxx	x
3. Read and write technical information	xx	xxx	x
4. Apply good people management skills	xxx	xx	x
5. Interpret/translate data to others	xx	xxx	x
6. Practise good public relations	xxx	xx	x
7. Practise social awareness	xxx	xx	
8. Present/speak in public	xx	xxx	
9. Practise good writing skills	xxx	xx	
H. ANALYTICAL SKILLS			
1. Awareness of regulations and statutes	xxx	xxx	x
2. Record and interpret data	xx	xxx	x
3. Perform trials	x	xxx	x
4. Use statistics	x	xxx	x
5. Design research projects	xxx	xxx	x
J. TIME MANAGEMENT SKILLS			
1. Make sound decisions	xx	xxx	x
2. Meet deadlines	xx	xxx	x
3. Drafting schedules	xxx	xxx	x
4. Prioritize tasks	xxx	xxx	x
5. Delegate responsibility	xxx	xxx	
K. COMPUTER SKILLS			
1. Use word processing software	xx	xxx	
2. Use spreadsheet software	xx	xxx	x
3. Use e-mail	xx	xxx	x
4. Use the Internet	xx	xxx	x
5. Apply statistics	xx	xxx	x
6. Use graphics software	xx	xxx	x
7. Create computer-assisted presentations	xx	xxx	x
L. BASIC BUSINESS SKILLS			
1. Write clearly	xx	xxx	x
2. Maintain inventory records	xx	xxx	x
3. Interpret accounting data	xxx	x	
4. Calculate profit and loss	xxx	x	
5. Make long-range plans	xxx	xxx	

Table 22. Expected levels of knowledge and skills within freshwater aquaculture enterprises

SCOPE OF SKILLS	Owner/ entrepreneur	Skilled	Unskilled
		Technician	Labourer/ farmhand
6. Assist in product development	xx	xxx	x
7. Perform forecasting	xxx	xx	
8. Possess a working knowledge of economics	xxx	x	
9. Provide input to marketing plans	xxx	xxx	x
M. STAYING UP-TO-DATE			
1. Awareness of regulations and statutes	xxx	xxx	x
2. Stay informed of aquaculture technology advances	xxx	xxx	x
3. Read trade journals	xxx	xx	x
4. Participate in professional activities (e.g. conferences and workshops)	xx	xxx	
5. Food safety and regulations	xxx	xxx	x

x = some knowledge expected and rapid learning on-the-job.

xx = formal knowledge acquired and applied with some rigour

xxx = high competence and reliability required which can be acquired through training

12.2 Conclusions

- Skills requirements provide a framework to direct training.
- The knowledge required by technical staff on freshwater fish farms is high in all aspects of farm operation while greater responsibility for field and mechanical skills and knowledge of cultured species falls on labours.
- Where such skills are unavailable on farms MFMR extension services may have to fill this role.

12.3 Recommendations and Way Forward

- i. A skills audit of staff and facilities of farms should be conducted.
- ii. Act on deficiencies to improve production efficiency and profitability.
- iii. Extension officers should be adequately trained to support knowledge gaps of farmers.

13 CHALLENGES AND CONSIDERATIONS FOR PROMOTING THE NATIONAL AQUACULTURE MASTER PLAN FOR FRESHWATER AQUACULTURE: Fish Feeds and Related Challenges in Namibia

The GRN has had the foresight to build a functional fish feed manufacturing plant at the Ministry's Inland Aquaculture Centre (IAC) at Onavivi in 2009 which currently supports the freshwater fish culture activities in Namibia. The fish feed factory, which was inaugurated on the 28th March 2009 produces fish feed in the form of sinking pellets for the entire country, including both government-owned and private fish farms. The current capacity of the feed mill is estimated at 1 200/year capable of supporting around 800 tonnes of fish production. The NAMP-FW proposes production of 4 000 tonnes of freshwater fish by 2023 requiring 6 000 tonnes feed/year.

The MFMR therefore requires to plan to secure fish feed ingredients and secure high quality feeds to service future expansion.

13.1 Fish Feed Ingredients

Fish, like all animals require balanced feeds to grow efficiently. The appropriate diet needed, should have as components: carbohydrates, proteins, lipids, vitamins, minerals and some additives.

Carbohydrates in fish feed produced at Onavivi are mainly used as a relatively cheap source of energy for the fish compared with proteins, which can also be used to provide energy to fish. Feed ingredients containing mainly starch are the usual source of carbohydrate in animal feed, including that of fish. At Onavivi fish feed plant, **maize and millet** are the ingredients of choice as sources of carbohydrate for their fish feed. The starches of both maize and millet are easily digestible into simple sugars, such as glucose, from which fish can derive energy for its life activities. Carbohydrates also serve as a binder for ingredients of artificial or prepared feeds. For this diet function Onavivi includes wheat bran in its feed formulation as the main source of starch for binding ingredients.

For **proteins**, Onavivi incorporates **fishmeal** in the feed they formulate and produce. The protein provided by the fishmeal in the feed is broken down in the bodies of fish into amino acids, the building blocks of new protein in the fish.

Fats or lipids in the formulated feed at Onavivi are provided by additions of appropriate vegetable oils which are then complemented by fish liver oils in the fishmeal component of the formulation. The fats eventually provide the necessary lipids needed for building of fish cell walls and particular requirements of juvenile fish for their survival and energy source.

Vitamins mixes, salt and feed additives, in appropriate amounts, are eventually added when the feed is being prepared at Onavivi to ensure a nutritionally balanced diet.

Fish feed produced and used in Namibia is made from ingredients which are all presently available in sufficient amounts locally. The availability of the aquafeed, made from local ingredients and backed by in-country resources could be considered as a great boost for freshwater aquaculture, which is at its very early stages of emergence in sub-Saharan Africa.

13.2 Challenges and Issues for Fish Feed in Namibia

13.2.1 Production (quantity and quality) and availability

Presently, complete pelleted diets are available to fish famers throughout the country. However, there is only one feed plant, at Onavivi with a maximum capacity of about 1 200 tonnes of feed a year. This translates to production of 800 tonnes of fish a year. With a substantial amount of feed produced at Onavivi going to government related farms, it is evident that not much private sector fish culture production is taking place. However, with current promotion of the activity at all levels and in almost all communities a sudden increase in demand for fish feed could be imminent if aquaculture uptake is widespread. The challenge is to increase the rate at which research and testing of alternative ingredients is currently being pursued.

Physical feed attributes

Two main issues were identified: high dust levels and pellet stability. The pellets currently produced have high dust levels, suggesting a review is required of ingredients, proportional component of main binding materials, cooking temperatures and duration.

The feed plant currently produces feed as sinking pellets. The state has attracted some negative comments from some stakeholder users that feed sinks to the bottom of culture units, which currently are mostly ponds and some tanks. We are almost certain that if the feed accumulates at the bottom of culture units, the situation would be more related to feeding regimes adopted by farmers rather than the sinking nature of the pellets. The station at Onavivi is aware of the sinking rate (8-9 cm/sec) of the feed and is working to improve on the rate. Secondly and something which does not seem to be commonly acknowledged is that tilapias are not obligate surface feeders. They certainly graze on substrates and can thus pick feed from the bottom of culture units. However,

where feed is virtually 'poured' into culture units, daily feed would accumulate at the bottom. Our observations suggest that in the majority of cases, feed rations used are far too high. Thus while the feed plant is working towards improving the sinking rate of current feed and exploring the possibility of facilities to produce floating feed, feeding regimes and rations for different sizes of fish should be given serious attention.

The pellet production process at the plant will require re-evaluation. The current equipment is unable to generate enough heat to cook the ingredients adequately; consequently the binding properties of the formed pellets are not optimal. Further, the plant needs to be assessed to determine if it can be modified to produce extruded pellets.

13.2.2 Issues of fish feed distribution in Namibia

Namibia has a surface area of 824 300 km² with long distances between inhabited areas. Fish feed is produced at one location, Onavivi. Freshwater aquaculture and farms are few, and at great distances from each other and each is small and non-commercial. Thus translocation costs are high. Under the circumstances, only small requirements of small farmers are distributed. It is therefore obvious that the scale of operations would not economically justify the transportation and distribution of fish feed throughout the country. However, the government has supported the activity so far.

Fish feeds also deteriorate when stored for long periods. Under the best of conditions, which include storing in airy, cool indoor places and not touching the ground, it could be kept for about five to six months. These conditions do not allow present small-scale operators to store fish feed for long, since the feed loses quality with time. Thus the frequency at which small quantities of feed have to be transported around the country is not likely to become economical for a long time to come.

Issues raised above also indicate that the private sector are unlikely to enter the fish feed trade for some years because the bulk of civil society in Namibia is yet to recognize freshwater fish culture as a wealth creation activity. Any consideration of locating the government feed production centre elsewhere is countered by the situation that no region is farming adequate volumes of fish to merit or justify a separate feed plant. Acquiring feed stores in regions so that movement of material from the production centre is reduced in frequency appears to be the best option for now if it could be accompanied by excellent regional storage facilities to reduce transportation and distribution cost of fish feed till the culture activity picks up a bit.

13.3 Conclusions

- ✚ The MFMR together with assistance from the Spanish government have built a fish feed plant at Onavivi in 2009 with a capacity of 1 200 tonnes/yr
- ✚ This facility can support around 800 tonnes of fish production per year.
- ✚ The feed ingredients are available in adequate quantities and of suitable quality.
- ✚ The sinking pellets produced is high and farmers feeding regimes needs to be improved.
- ✚ Parts of the current feed mill components are inadequate and needs evaluation.
- ✚ The key issues with the aquafeed relate to pellet stability, consequent high dust levels and fast sinking rate of pellets.
- ✚ Given small fish volumes produced it is unlikely that private sector will enter this activity.

13.4 Recommendations and the Way Forward

- i. The MFMR should investigate if the feed plant can be modified to increase cooking temperatures to above 60-65 °C and plant can be economically modifies to produce extruded feeds.
- ii. Conduct studies to improve pellet stability and reduce dust levels in diets
- iii. Investigate alternative protein and lipid sources for fish feeds
- iv. Assess the feasibility of regional feed distribution centres
- v. Plan for additional feed plants to meet any planned expansion.



Onavivi fish feed factory. Well organised and managed production. Issues pellet stability due to low cooking temperature. Desire to modify equip extruded diets. Focus should be pellet stability



Local feed ingredients used in diet formulation and preparation. The fineness and consistency of the ingredients used for diet preparation should be investigated.



Varying level of protein diets produced.



Pellets from feed plant showing high levels of dust or fines.



Seal meal as potential protein source may be trailed for aquafeeds. Note non uniformity and coarseness of meal and finesse will affect digestibility.

14 CHALLENGES AND CONSIDERATIONS FOR PROMOTING THE NATIONAL AQUACULTURE MASTER PLAN FOR FRESHWATER AQUACULTURE: Potential Aquaculture Systems

14.1 Types of Aquaculture Systems and Potential Use

This section first summarizes the major classes of culture systems based on how water is used for culture. This is followed by which types of systems could be used in Namibia successfully based on environment types and water resources.

There are four major aquaculture culture systems categorized by how water is used to culture fish. These systems are a reflection of capital input and human resource competence and environment. These systems are as follows:

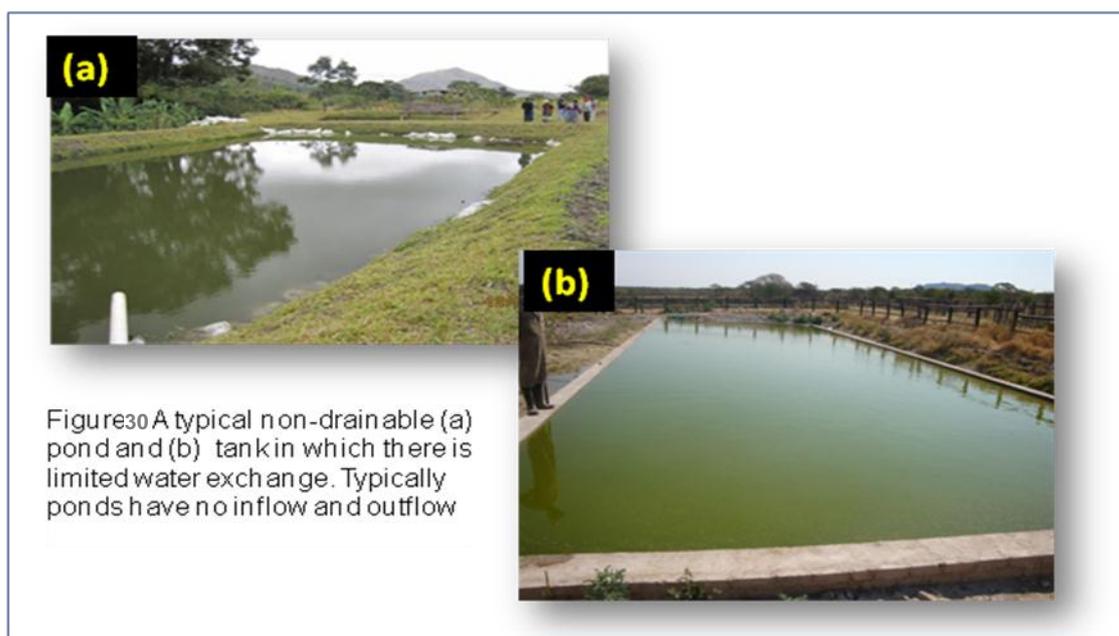
1. **Still water culture system:** This is usually practiced in stagnant water in ponds, but tanks are also used. Pond fish culture system is about the most conventional form of freshwater aquaculture in the world and especially in Africa. The organism mostly involved in the culture has been fish and in Africa, tilapia and catfish.
2. **Running water or flow-through culture system:** This is usually practiced in tanks and race-ways made of various such materials as wood, fibreglass, plastic, cement with fish as the main organism cultured. If abundant water is available earthen ponds are also used.
3. **Water recycling system or recalcitrating system:** In this system the running water, used for culture is recycled and 'reconditioned' (i.e. filtered of dirt and re-oxygenated) by some mechanical device. Non-earthen structures tanks and race-ways made of various such materials as wood, fibreglass, plastic, cement with fish as the main organism cultured.
4. **Cage culture system:** Cage culture may also be considered as a kind of flow through system because water in the fish rearing cage units is always being exchanged with water from outside the cage.

Major characteristics and conditions of culture in the systems: these could be summarized as follows:

14.2 Still Water Fish Culture System

Figures 30a and 30b show a typical fish pond and a tank respectively as examples of still water aquaculture system. Essentials of still water aquaculture are as follows:

- Water in culture units is stagnant. Additional water may be added if seepage occurs, in the pond or evaporation in both makes it necessary. Once a pond is filled or flooded to start a culture activity, it would only be emptied of water at the end of a culture period to totally harvest the pond. Or the pond could be refilled after a number of culture sessions to renew water or recondition the culture units in one way or another.



- In subsistence still water fish culture, food materials for the fish is produced through natural productivity could be the only source of food to the fish or organism being cultured. Natural productivity of still water aquaculture units is usually facilitated by fertilization of the water with organic or chemical fertilizers. Currently, fish farmers use aqua feeds as supplements to natural food production in still water culture units. Application of fertilizers and feed to stagnant culture systems, however, has to be done with care to avoid, eventually reduction of oxygen in culture unit and consequent mortality. Given the location of these systems, predation can be high and productivity low.

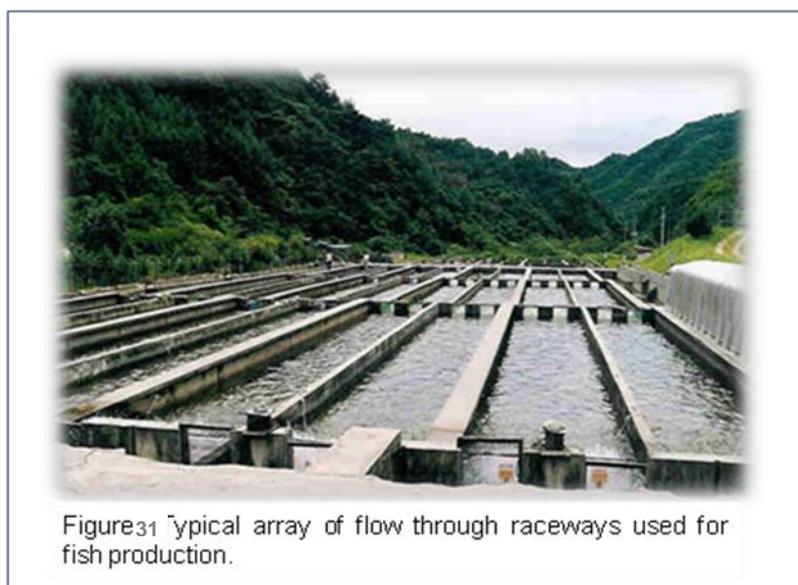
Potential use of system in Namibia: The still water fish culture system is already used in Namibia, with ponds more widely used, as at all Fisheries and Aquaculture Centres of MFMR and at cooperative farms compared with tanks. Use of tanks as stagnant fish culture units has so far been encountered with a farmer near Grootfontein. Potential for greater use of the system is anticipated and encouraged where environmental conditions allow.

14.3 Running Water System

Figure 30 shows raceways in use as a running water fish culture unit. The system is usually made of raceways but tanks are also used.

Essentials of running water aquaculture system are as follow:

- In running water aquaculture systems water is continuously supplied through an inlet and allowed to flow through and out through an outlet.
- Fish are densely stocked in the culture units. The density of stocking is dependant on amount of water available to run through culture units and capacity of units.



- Incoming water provides clean fresh water with maximum oxygen while outgoing water carries away fish metabolic waste and uneaten feed away. Thus maintaining optimum environmental quality for fish to perform best.

Potential use of system in Namibia: The running water aquaculture system is not known to be in use in Namibia yet. However, assessment of some potential aquaculture sites where source of water have been springs, with water flow under 'reasonable' pressure and rocky surroundings to be unfavourable for pond construction, lend themselves to running water aquaculture considerations.

Locations so far identified, by the Master Plan development team, with potential for relatively low cost running water fish culture systems include spring location in Kaoko

Otavi and Oruvandjei , both within 25-30 Km of Opuwo on Opuwo-Sesfontein road, Waamquelle and Bernafay in Marienteel District.

14.4 Water Recycling System

Figure 32 shows a functional water recycling fish culture unit and one under construction.



Figure 32 Examples of recirculatory systems used in aquaculture

Essentials of water recycling aquaculture system are the following:

- It is another type of 'running water system'.
- However, water running through culture unit(s) area is water which had already been through it/them but been 'refreshed'. The refreshment is done mainly by filtering 'dirt' from the water and water re-oxygenated by some mechanical devise.

For these processes, the 'water recycling system' has four essential units as follows:

- Culture chamber

- Segmentation chamber
- Biological filter chamber and
- A final clarification section.

Fish could be stocked at high densities depending on water reconditioning success both in the filter and re-oxygenation chambers. In practice, some of the units may be combined. It is good to keep in mind that for continuous re-circulation system power availability and its reliability is paramount.

Potential use of system in Namibia: The recirculation aquaculture system is highly effective where land or water availability or both are limited. It is also appropriate where temperature would be necessary to control. In parts of Namibia, especially in the northern and north-western parts, including areas surrounding Opuwo, Fransfontein, Sesfontein, Warmquelle, and Grootfontein Also in the south of the country, in locations such as Stampriet and Kietmanshoop region, all together a substantial part of Namibia, real water available for aquaculture is ground water. Thus water available for aquaculture could be considered limited. However, our crude on- the- spot estimation of ground water flow in majority of the places indicated that they were adequate for small flow -through or recirculation aquaculture systems

Also, elevations of most of these areas are above 1000 m. Thus during winter months of the year, temperatures are expected to be or known to be lower than 20 °C, which is not conducive for indigenous freshwater fishes of Namibia, all of them being typical warm water fishes, e.g. tilapias (*Oreochromis mossambicus* and *O. andersonii* and *niloticus*) and the African Catfish, *Clarias gariepinus* preferring a optimal range of 27-30 °C.

It is therefore our consideration that the recycling aquaculture system has potential use and would have to be adopted in parts of the country, as explained above.

14.5 Culture System

Figure 33 shows some types of cages used to culture fish in freshwater environments. Essentially, cage culture system may be considered as a kind of running water system:



Figure 33 Various sizes of cages used in aquaculture.

- Since water in fish rearing units, the cages, are continuously being exchanged by water in the environment of the cages.
- Cages are typically suspended in the upper layers of lakes or impoundments which enjoy higher temperatures and oxygenation of their environment.
- Thus they can be densely stocked and fed heavily.
- Waste material generated by fish life is scattered and diluted by the exchange of water between cages and surrounding water which is in constant motion. Thus renewing water in culture units.

Potential use of cage culture in Namibia. Cages similar to the one observed in Figure 33 are being used in a pilot fish farm at Uis in Namibia. The water environment, an old mine 'pit', seems to pose special temperature issues. Namibia has several reservoirs or impoundments including the largest behind the Hardap dam. Segments of the Hardap reservoir were considered potential sites for fish cage culture during the Master Plan study team's visit to the site. However, more detailed assessments and consultations with dam authorities are needed before decisions may be made. Similarly, other reservoirs such as one behind Etaka dam, need specific assessments to determine their suitability for fish cage culture practice. For example, for the Etaka reservoir, the abundance of crocodiles and possible theft have been sited as potential hindrances to cage culture. However, a critical assessment of the situation is required.

Potential use of fish cages for special purpose in Namibia.

In Namibia, about six 'cooperative' fish farms exist including: Mpungu, Likunganelo and Kalimbeza fish farms. The major physical 'problem' of the farms is extensive

14.6.1 Flood plains and rain-fed ponds

Flood plains are productive ecosystems that can be harnessed for freshwater aquaculture development in Namibia. Currently such systems have not been explored in Namibia instead feasibility studies have mainly focused on capital intensive RAS systems that are intrinsically complex and require skilled management

The Northern regions of Kavango, Caprivi, Ohangwena, Oshikoto, Oshana and Omusati (see Figure 34) are prone to annual floods during the rainy season. Unfortunately, this period also coincides with the warmest months, compromising the best growing period. Nevertheless, if carefully selected and managed these areas could be used for small scale freshwater aquaculture development at relatively low cost.

Table 23. Aquaculture production systems that are most likely to be successful in Namibia			
Environment Type	Systems possible	Species	Comment
1. Flood plains	Dug out ponds relying on floods to fill ponds	Tilapia, Catfish	Low capital cost and inputs. Low yield but at minimal OPEX. Site selection critical to identify those area which will recede quickest to gain access site to maximise growing season
2. Rain fed ponds	Dug out ponds in elevated areas depending on rainwater to fill ponds	Tilapia, Catfish, <i>Macrobracium</i>	Relatively low cost. Site selection critical as will affect CAPEX due to sandy soils. Site selection critical to identify those area which will recede quickest to gain access site to maximise growing season
3. Irrigation Canals	High stocking low volume cages and stocking canals themselves with fish	Tilapia, catfish, <i>Macrobracium</i>	Relatively low cost. Site selection critical. Difficult to control ownership and larceny. May be a good option for community enhanced fisheries programme
4. Rivers	Ponds nearby using water sourced from rivers	Tilapia, Catfish, <i>Macrobracium</i>	Site selection critical due to soil types and seepage. Liners are a not economical. Other options should be explored
5. Reservoirs	Cages of varying sizes	Tilapia, Catfish	Worthwhile considering but further studies on predators and water temperatures required. Cheaper option compared with RAS but no control on temperature
6. Ground water			
a. Natural springs/aquifers	Ponds fed with ground water	Tilapia, catfish, <i>Macrobracium</i>	Approximately 57% of the water consumption in Namibia comes from groundwater, 23% from the northern border rivers, and 20% from local reservoirs. Best option to explore further. Ideally, geothermal springs and aquifers to significantly reduce CAPEX and complexity of culture system. Three such sites were identified. Level of productivity will depend on volume and temperature of water available.
b. Boreholes	Tank systems using RAS. Water supplied ideally with thermal springs and borehole,	Tilapia, Catfish	
	Flow through systems using thermal aquifers	Tilapia, Catfish	

Figure 35 shows a similar development under the team leaders' supervision in Sierra Leon. Here dugouts are made in the dry season but at slight elevation thus exposed soonest with receding water allowing communities to return as early as possible.



Dugouts in Sierra Leon filled following annual floods

Lumah community returning following floods

Figure 35. Flood plain aquaculture in Sierra Leon

Dug-out ponds (200-300 m²) can also be constructed at slight elevation in non-flood zones as rain water harvesting structures and then stocked and farmed in a conventional manner. These dugouts should be constructed manually and by local communities to endear ownership, perhaps using labour clubs. The number of dugouts will be a function of requirements. As these are flood areas we assume that clay soils can be located for construction of dugouts ponds. During our field visits an abundance of Kaolin type clay was observed in these pans. In both flood plain and rain fed ponds systems water levels will decline over the season due to seepage and evaporation and therefore system specific management needs to be in place to maximize production. The rate at which the water level in ponds drops will have to be empirically established as this will be site-specific and this in combination with species such as tilapia and catfish can be stocked for multiple cropping.

The production of such systems, like all others, will depend on the capacity to supply inputs. If artificial feeds and appropriately sized fingerlings are used, yields of up to 3 tonnes/ha are possible. At N\$20/kg this could attract an income of N\$60 000/ha.

Production of ponds with varying degrees of management and inputs is given Table 23.

14.6.2 Irrigation canals

The waters in irrigation canals in Namibia present an opportunity to for freshwater aquaculture. The irrigation canals can be a source of water which can be pumped or diverted by gravity. Abstracted water can be used as in systems using ground water.

However, we propose that stocking such waters themselves is worthy of exploration. In Namibia such canal systems were visited. These include the canal system serving the Etunda project and beyond, Hardap canal system and Orange River canal system. These systems flow away from their river sources and to our knowledge do not re-enter the rivers.



Figure 16. Examples of irrigation canals in Namibia that can be stocked with freshwater fish.

These canals are approximately 2.5 m wide and 0.75-1 m deep and over 100 km long. Assuming an average depth of 0.75 m each kilometre of canal proves a standing volume of 18 000 m³ of unused water representing a surface area of 25 000 m². This system will successfully produce fish but qualities are beyond the scope of this review. As a conservative guide, if 1 m² can produce 10 g of fish then a 1 km stretch of canal could yield 0.25 tonnes of fish at potentially no cost. For local populations living along these underutilized systems it could an invaluable source of

food. Additionally, subject to adequate water flows and depth high density low volume cages can be used in these canals but larceny and ownership could a challenge.

14.6.3 Cages in reservoirs

Fish are widely reared in cages or hapas. In Namibia, most of the standing water resources are in the form of artificial water bodies i.e. reservoirs. The geographical locations of these 16 national resources are shown Figure 37. The reservoirs are Bondels, Daan Viljoen, Dreihuk, Friedenau, Hardap, Naute, Oanab, Olushandja, Omdel, Omatako, Omatjenne, Otjivero main, Otjivero silt, Von Bach, Swakoppoort and Tilda Viljoen.

It should be noted that these are not natural ecosystems water bodies and therefore the any introductions of exotics should be viewed within this context and that of historic inter-basin water transfer schemes

Cages of various sizes and construction could be used on some of these reservoirs but

fish farming success will depend on the selection the most economically viable fish candidate. A key challenge in farming using cages on reservoirs however will be the suboptimal water temperature and short growing season. Water temperatures were unavailable but some data suggest at Hardap water temperature are unlikely to exceed 25-26°C. This challenge will also be faced when using cages in ex mine works such as that at Uis where water temperature was around 24°C. In such circumstances largest possible fingerlings (ca 60-80 g) should be used to achievable decent market size fish.

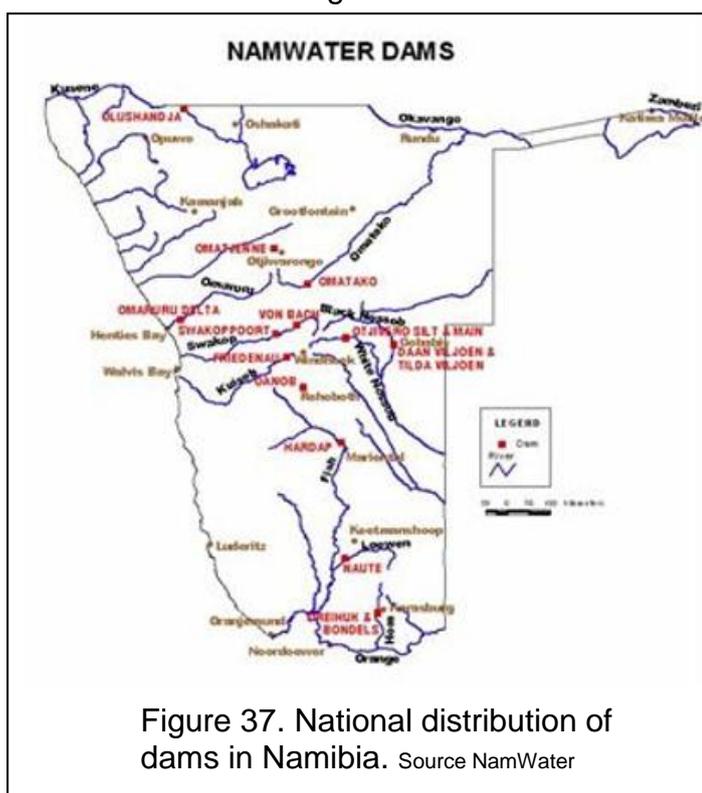


Figure 37. National distribution of dams in Namibia. Source NamWater

14.6.4 Tank systems

High evaporation rates and lower than optimal ambient water temperatures prevents all year around fish production. In these circumstances, indoor recirculatory systems could be considered. Given the very high CAPEX involved in such systems, they hve to used optimally and fish farmed at very high density to prove viable. Indeed, the four feasibility studies conducted to date all show that such systems are not viable even if the CAPEX is considered as an outright grant, especially if this method is used to farm Tilapia. Better prospects are to be had with catfish which can be farmed at significantly higher densities than tilapia. Catfish can be easily stocked at 100kg/m³ in relatively unsophisticated systems whereas with tilapia, this typically is only 25kg/m³.

14.7 Conclusions

- ✚ Six environment types in Namabia were considered suitable for development. These ranged from flood plains to ground water
- ✚ Based on field trips, a range of aquaculture production systems ranging from ponds in floodplains RAS are suitable for Namibia.
- ✚ The productivity of systems will vary depending on inputs and human capacity available.
- ✚ Potential sites visits were such systems could be developed were identified.

14.8 Recommendations and way forward

- i. Identify land in flood prone zones in the northern regions. Sites should be surveyed to identify areas to create suitably sized ponds for freshwater aquaculture. Key consideration will be to ensure earliest possible receding of floodwaters to maximize growing period.
- ii. Identify land in non-flooding zones, but in high rainfall areas for constructing rain fed ponds for freshwater culture during the non-rainy season.
- iii. Investigate the feasibility of covering ponds with simple structures to increase water temperature to accelerate fish growth.
- iv. Discuss with relevant authorities the possibility of using canals for direct stocking of fingerlings of fish and shellfish for local communities
- v. Investigate borehole, aquifer and spring sites to quantify water volumes available and prioritize those sites that have geothermal water for development (see Figure 38).

- vi. Establish a project to monitor and collect minimum and maximum monthly water temperatures of all water reservoirs and ponds.
- vii. Identify suitable reservoirs for cage culture using large juveniles (80 g).

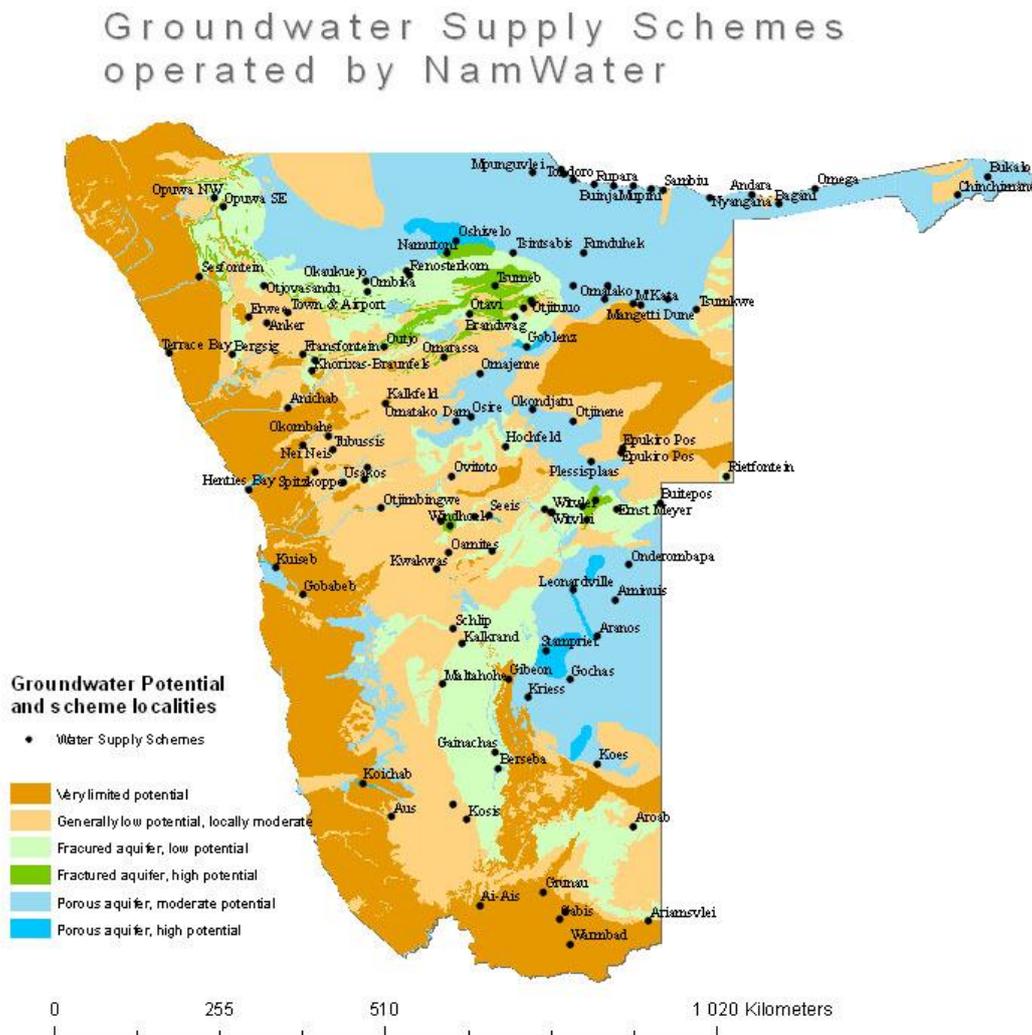


Figure 38. . Locations of groundwater managed by NamWater in Namibia

15 CHALLENGES AND CONSIDERATIONS FOR PROMOTING THE NATIONAL AQUACULTURE MASTER PLAN FOR FRESHWATER AQUACULTURE: Estimates of Fish Farm Yields under Varying Farming Systems and Stocking Models

15.1 Factors Governing Yield under Namibian Conditions

This section addresses the specific task to estimate farm yields based on various stocking models and make recommendations on appropriate stocking densities. The yields and stocking density is a function of farming systems, level of inputs and management and hence no one solution is possible. We therefore first discuss the factors that MFMR should consider and then provide a range of options that can apply under Namibian conditions.

The yield of fish harvested from farms is a function of several **interrelated factors**, the net result of which determine site-specific yield at any given time. For this analysis these factors are grouped to include, (i) the choice of candidate species being farmed, (ii) climate, (iii) quality of inputs such as feed, (iv) type of production system, (v) management of the production system and (vi) security. The above factors accumulatively impact on the individual fish **growth rate** and hence the eventual size of the fish. Given these variables and the site-specific nature of inputs it is impossible to provide exact fish yields that can be attained. Instead we offer here is potential yields based on key variables of consequence that can be **quantified** and modelled. In addition, it must be recalled that whilst the above what biomass can be attained it will be the harvesting competence that will finally dictate the measured yield or biomass. Therefore the ability to **completely** harvest a production facility may also need to be considered. These variables were considered most relevant for Namibia, following our field trips.

The outcome of the above factors will have three major influences on farm fish yields. These outcomes are (i) The average size and size range of the fish attained, determined by its growth rate, (ii) the total number of fish recovered i.e. survival and (iii) biomass harvested. These variables can be quantified and are therefore used to model to estimate yield in various scenarios. The outcomes of the model are then interrogated based on potential scenarios that are likely to apply under Namibian conditions.

15.1.1 The average size of fish at harvest

Over the lifetime of the fish, fish growth is sigmoid. The fish growth starts of slow then accelerates during the main growth phase when growth is close to linear and then slows down. As indicated in the model presented in Figure 39 below, the higher the growth rate factor (2.23 to 3.5) the quicker it will take the fish reach a given size. Hence for any given age, fish with a higher growth rate factor will be larger. At five

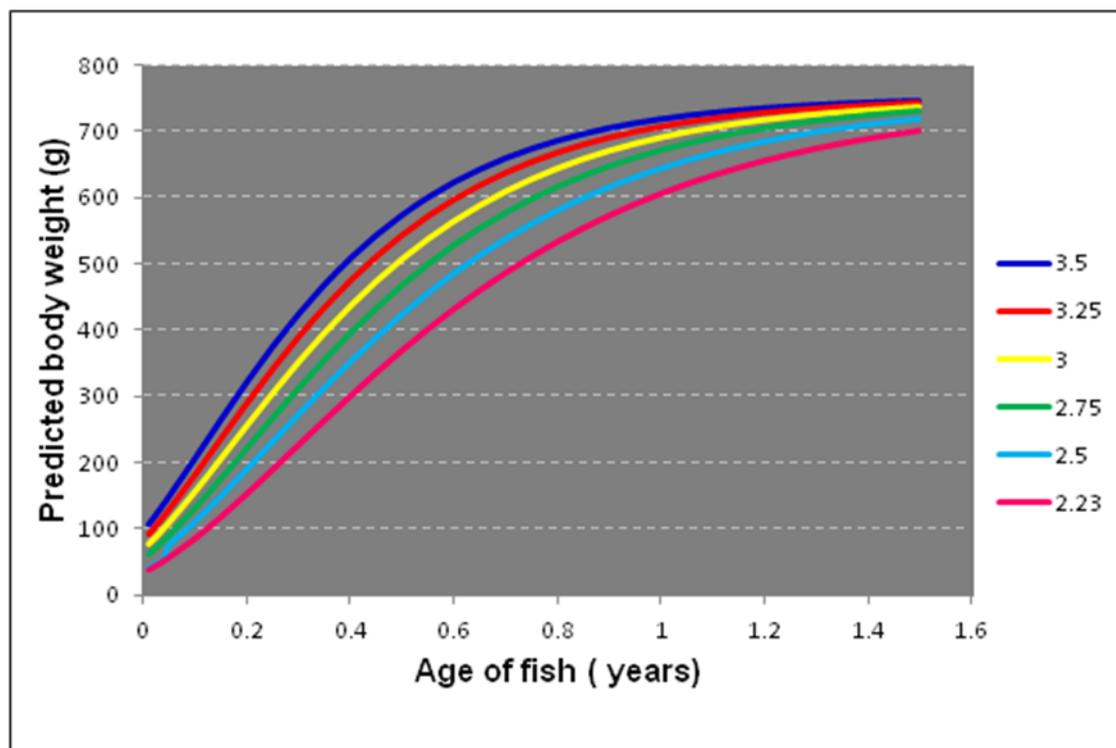


Figure 39 Predicted growth of *O. niloticus* for different growth rate parameters

months for example, fish with a growth factor of 3.5 can potentially reach 500 g. If the growth factor is 2.23 it would have only attained 300 g, highlighting the importance of maintaining a good average growth rate

Under Namibian conditions we have assumed that the main culture period, which is governed by water availability, temperature and perhaps flooding, will be about 6-7 months and at middle values of growth rate factors. A simpler model assuming linear growth pattern, is therefore considered, following its validation as illustrated in Figure 40. Over a shorter period of time (up to 8-months) 99% of the variation in growth can be accounted for by a linear growth line and therefore used to estimate growth rate for this discussion.

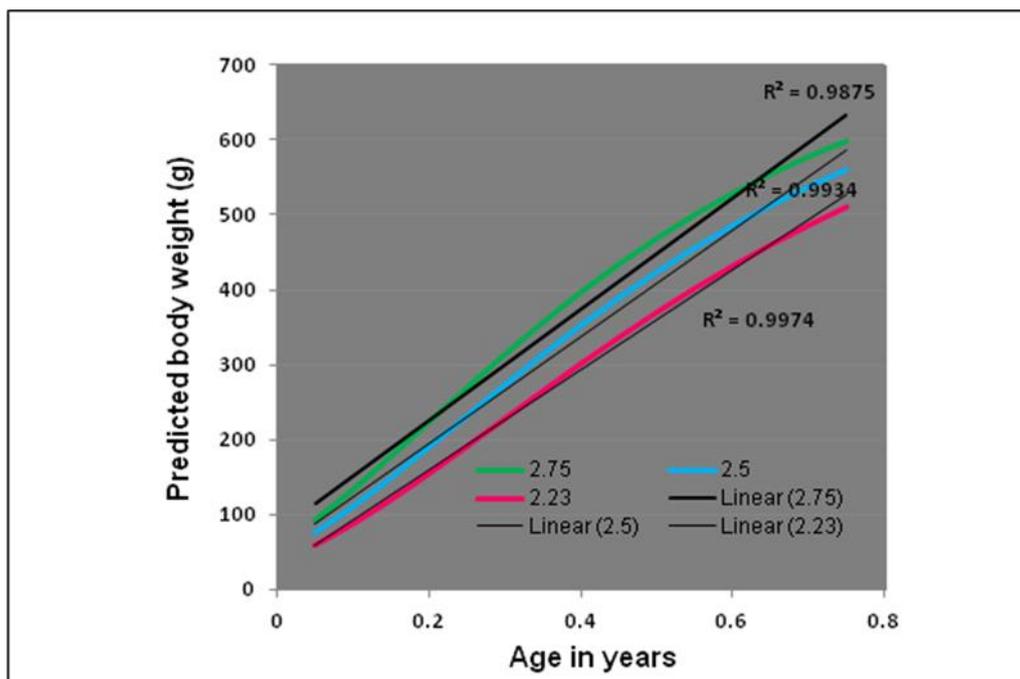


Figure 40 Predicted growth rate of fish using achievable growth rate factors over a 10 month culture period showing growth rate to be approximately linear. NB linear trend lines accounting for 99% of the data.

15.1.2 Prediction of yields using linear model (specific growth rate)

The growth rate or specific growth rate (SGR) of fish is typically calculated using the natural log weight gained over a specified time, expressed as a percentage as follows:

Based on limited data available in the literature, the upper average growth rate over

$$\text{SGR (\%/day)} = \frac{\text{Ln}W_0 - \text{Ln}W_x}{T_x - T_0} \times 100$$

the production cycle, obtained for *O. niloticus* (i.e. 1.90%/day) is used as the benchmark for fish reared under optimum water temperature and rearing conditions to predict potential size of fish for various periods of culture. In addition, the predicted mean fish size is also calculated if this growth rate changes, in this scenario from 1.9% to 1.5%/day. The output of this model is presented in Table 24 and graphically in Figure 41.

Table 24. Predicted size (g) of fish achieving varying average specific growth rates (%/day)

SGR (%/day)	Culture period (days)							
	0	30	60	90	120	150	180	210
1.90	30.0	52.8	92.8	163.2	287.1	505.0	888.1	1562.1
1.85	30.0	52.0	90.1	156.2	270.7	469.1	813.0	1409.1
1.80	30.6	51.2	87.5	149.4	255.2	435.8	744.3	1271.0
1.70	30.0	49.7	82.5	136.8	226.8	376.1	623.6	1034.0
1.60	30.0	48.3	77.8	125.2	201.5	324.5	522.4	841.0
1.50	30.0	46.9	73.3	114.6	179.1	279.9	437.5	683.9

The impact of a reduced SGR on final fish size and therefore yield is marked. Fish averaging a growth rate of 1.9%/day should attain almost 888 g by 180 days, if stocked at **30 g**. If, however, the average growth rate over the culture period is 1.5%/day then the same fish would only attain 50% of its mass i.e. 438 g (Table 24).

The drop in the average growth rate from 1.9%/day to 1.5%/day on the potential size of fish at harvest is significant and is illustrated in Figure 41. This reduction is not linear. By 60 days a reduction in weight of 20% is evident but by day 180 the fish will only be half the size and hence half the yield. Achieving target growth rates will therefore be crucial for management to attain expected yields.

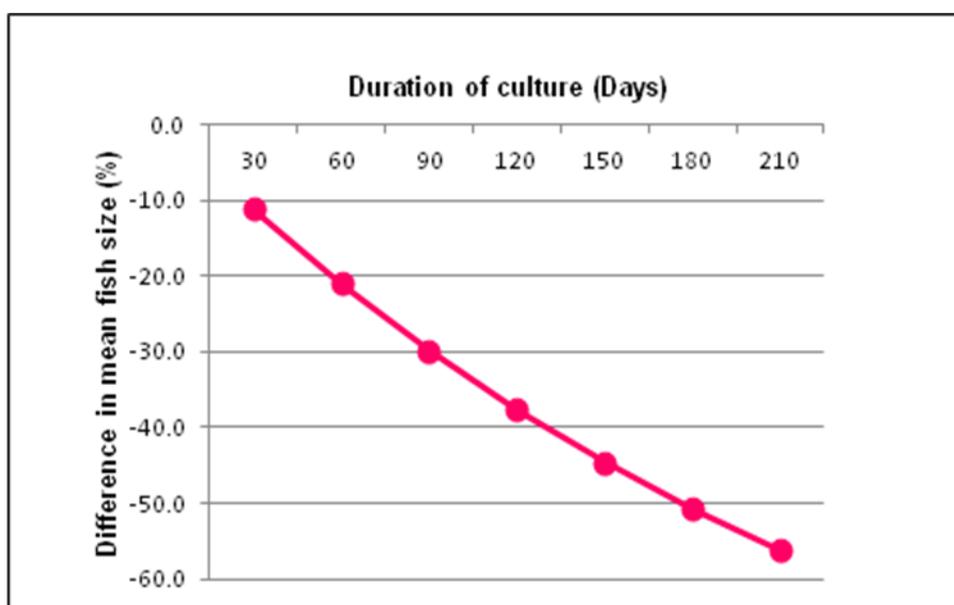


Figure 41 Effect of reduction in specific growth rate from 1.9 to 1.5 %/day (20%) on final fish size .

Table 24 could also be used to establish level of achievement under Namibian conditions for any given culture period. For example, if the mean weight of harvested fish was 325 g over 150 days, it should have grown at 1.6%/day. Deviations from this would suggest management shortcomings.

The SGR model also illustrates that the final mean weight the fish attains is a function of its initial weight, and given that growth of fish is exponential, small changes in initial size may have a noticeable effect in final size of harvested fish. This is explored below to draw attention to Namibian conditions, were the best growing season for fish under ambient conditions may be only 5-6 months. The objective should therefore be to maximize the size of harvested fish and therefore yield under these conditions.

15.1.3 Effect of initial fingerling size on potential fish size at harvest

One method of direct relevance for Namibia would be to consider the effect of initial fingerling size on final average fish size, and hence yield. Such modelled data for a 150 day culture period is presented in Table 25

Table 25. Effect of initial weight on final weight of harvested fish (g) at various average growth rates over 150day production cycle

If Initial weight (g) is:	Then mean predicted final fish weight growing at an average specific growth rates (SGR-%/day) below is:					
	1.9	1.85	1.80	1.7	1.6	1.5
5	84	78	73	63	54	47
10	168	156	145	125	108	93
20	337	313	291	251	216	187
30	505	469	436	376	324	280
40	673	625	581	501	433	373
50	842	782	726	627	541	467
60	1010	938	872	752	649	560

Currently, Namibian farmers stock fish at around 5 g. As shown in Table 25 if these fish attain a SGR of 1.9%/day, they will only reach 84 g over 150 days, resulting in small fish which are likely to fetch lower prices. At this SGR, if a half kilo fish is desired, 30 g fingerlings should be stocked. **A first and foremost critical strategy for Namibia should therefore be to increase the stocking size of fingerlings to ensure larger fish at harvest.**

The actual growth rate attained by fish under different Namibian conditions is limited and where available is incomplete to access growth and should be determined to

establish what size of fish should be stocked given the actual water temperature, which is generally less than optimum and available duration of culture. Available data from Epalela fish farm tend to confirm low growth rates. Acquired data suggest that average daily weight gain ranged between 0.3-0.8 g/day which corresponds to a SGR of below 1%/day. **This is about half the rate expected under optimal farming conditions for such species.** It should be recalled that the final fish size is an accumulative outcome.

The above provide information to illustrate the effect of initial weight of fingerlings on average fish growth rates on harvest size of marketable fish. Another outcome that will significantly effect yield is mortality and its effect of feed loss and hence production cost.

15.1.4 Effect of mortality on potential yield during on-growing

When developing management strategies the implication of mortalities should be considered. Whilst the reasons for mortality are beyond the scope of this assessment, the implications of quantified mortality on production efficiency yield and cost is considered here. Based on the literature mortality in various on-growing systems can range between 20-50%. The effect of such a mortality range on yield at 180 culture period, assuming a specific growth rate of 1.9%/day, where the initial fingerling size is 30 g is considered below.

Table 26. Estimated loss in yield during on-growing of tilapia at varying mortality rates. Assumed SGR of 1.9%/day and initial fingerling size of 30 g. Initial stocking 1 000 fish.

Mortality rate (%)	No. fish lost/1 000 fish stocked	Biomass lost (kg)/1 000 fish stocked	Yield at harvest (kg) if 100% survival	Biomass lost at harvest (%)
20	200	76	771	10
30	300	94	622	15
40	400	99	533	19
50	500	112	444	25

Table 27 highlights the importance of containing mortality. For every 1 000-30 g fish stocked, the farmer will lose between 76-112 kg fish accounting for 10-25% of harvest. For a one hectare pond typically stocked at 10 000 fingerlings this estimated loss will total 760 -1 120 kg of fish.

Losses in revenue streams may be greater. Direct revenue losses will be associated with cost of fingerlings, costs of feeds and sales of fish. These are estimated below

for assuming mortality rates between 20-50% during grow out over a 6 month production cycle.

Mortality rate (%)	Cost of loss of fingerlings/ha @N\$1 each		Loss of harvest/ha – revenue loss		Cost of feed loss/ha @ N\$6/kg		Total financial loss/ha (N\$)
	No. lost/ha	Cost of lost fingerling/ha (N\$)	Biomass/yield lost/ha (kg)	Cost of lost of yield N\$	Feed loss (kg)	Cost @N\$6/kg	
20	2 000	2 000	760	15 200	1 140	6 840	24 040
30	3 000	3 000	940	18 800	1 410	8 460	30 260
40	4 000	4 000	990	19 800	1 485	8 910	32 710
50	5 000	5 000	1 120	22 400	1 680	10 080	37 480

For a one hectare pond, total losses could range between N\$24 000 to N\$37 500, as mortalities increase from 20-50%. A conservative stocking of 1 m² is used in this assessment. In intensive ponds stocking density may be significantly higher and therefore financial losses will be notably higher.

As indicated in Figure 42, over 60% of the financial loss is due to revenue from sales of lost harvest followed by 27-28% due to lost feed and 8-12% due to fingerling cost.

The above analysis is presented to highlight the importance of understanding the implications growth rate, mortality and initial stocking size on fish yields. It also emphasizes that given that these outcomes will be determined by farm management which invariably varies between farms, the yield will also be site-specific.

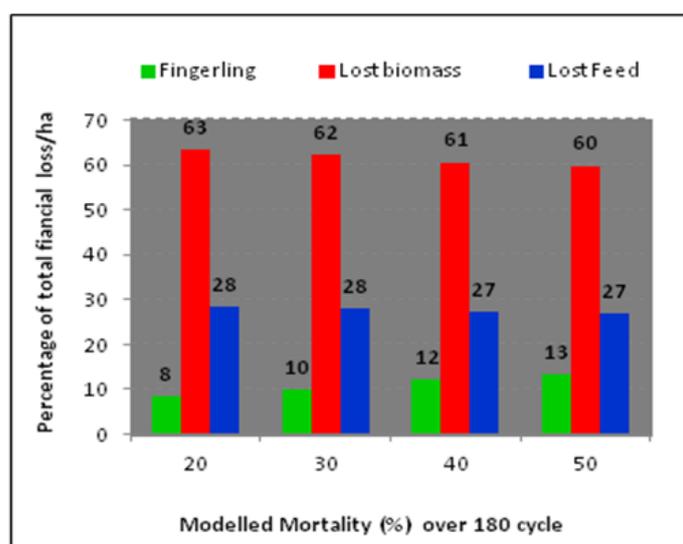


Figure 42 Contribution (%) of major items to financial loss at varying predetermined mortalities. Assumptions: 1ha pond stocked at 1m² for 180 days with 30g fish

15.1.5 Effect of species and sex ratio on yields

Growth estimates suggest species specific-growth differences (Table 28).

O. andersonii ranked second and fourth from the bottom with *O. niloticus* showing the fastest growth rate. Based on this comparison *O. niloticus* is the species of choice to farm. It is well known that *O. mossambicus* mature earlier than *O. niloticus* and growth rates slow down after 100 g when compared with *O. niloticus*.

Species	Average growth per day (g)
<i>O. niloticus</i>	3.21
<i>O. aureus</i>	3.15
<i>O. machrochir</i>	2.8
<i>O. andersonii</i>	2.79
<i>T. rendalli</i>	2.6

¹ Source Pauly et al., 1993

It should be noted that *O. mossambicus* was imported into Asia in the 1950 and was a key factor for the demise of its farming of tilapias until it was abandoned in the 1980s and replaced with *O. niloticus*. This species now accounts for 98% of world tilapia production. *O. andersonii*, however, should be further explored since it is more cold tolerant. Comparison of these two species in Zambia also confirms *O. niloticus* superiority over *O. andersonii* but also notes its lower temperature tolerance advantage. Both these traits can be combined for farming in all areas away from the Angolan-Zambian-Namibian border. Further deliberations are beyond the scope of this report.

Irrespective of species, the sex ratio of stocked population will affect tilapia fish yields. In tilapias, males grow significantly faster than females and this is one key reason why all male tilapia farming is preferred, especially where large fish is required. In *O. niloticus*, males on average are 20% larger than females and differences between average all male and mixed sex is considerable. An empirical example of growth of monosex and mixed-sex *O. niloticus* populations is illustrated in Figure 43 to highlight the

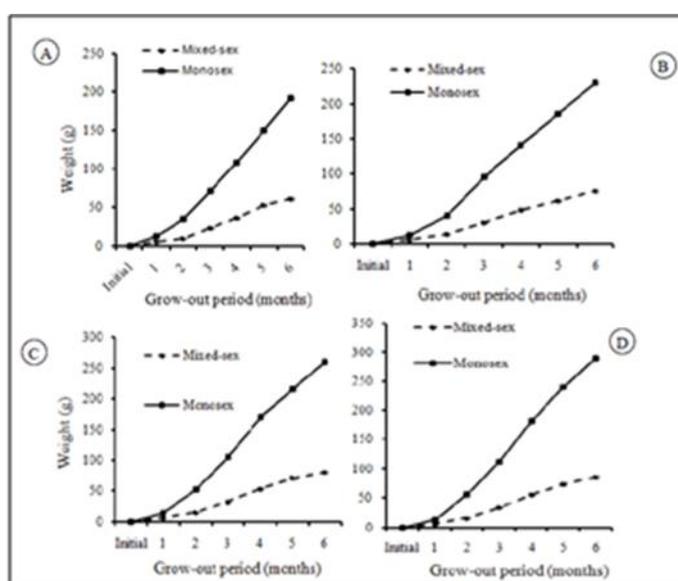


Figure 43. Growth rate of mixed-sex control and monosex 17αMT treated Nile tilapia in (A) tanks, (B) flow-through, (C) pen and (D) pond culture systems. Source adapted from Chakraborty et al. 2011.

value of using all male fingerlings. In this study, the final weight of **mixed-sexed** fish after 5 months growth in the four culture systems ranged **61 to 86 g** whereas for **sex-reversed monosex** fish, final size ranged from **191-290 g**.

These results together with considerations above are used below to model potential fish yield projections for Namibian conditions.

15.2 Fish Farming Yield Projections Based on Various Stocking Models

The fish farming yield projections and stocking densities to achieve these yields are considered below for various culture systems that could apply to Namibia. Given the site specificity of farming conditions it can only be a prediction. Irrespective of system type, yield will be driven by level of inputs; lower the input lower the yield. For Namibian conditions the culture systems considered are:

- i) Open ponds with no inputs
- ii) Open ponds with fertilisation only
- iii) Open ponds with supplementary feeds
- iv) Open ponds with complete feeds and aeration
- v) Indoor or outdoor recirculatory aquaculture systems (RAS)
- vi) Outdoor and indoor flow through systems
- vii) Cages in reservoirs

Based on the above discussion the following conditions are applied in estimating farm yields:

- i) Species of choice is *O. niloticus* but *O. andersonii* is not excluded
- ii) All-male fingerling of sizes 20 and 30 g are stocked
- iii) Mortality during grow-out is pegged at 30% in open ponds and 15% for other systems
- iv) Average temperature over growing cycle assumed to be 25-26 °C
- v) Specific growth rate used 1.3% (outdoors) - 1.8%/day (indoors) depending on system
- vi) Growth cycle 5 months (150 days)
- vii) Feed and pond management are adequate
- viii) Predation minimised and effective security in place

The estimates of farm yields under seven farming systems that can be applicable under Namibian conditions are presented in Table 29

Table 29. Predicted farm yields under Namibian conditions for seven culture systems using all-male tilapia fingerlings

	Types of Culture Systems													
	Open ponds with no inputs		Open ponds with fertilisation only		Open ponds with supplementary feeds		Open ponds with complete feeds and aeration		Indoor or recirculatory aquaculture systems (RAS)		indoor flow through systems - thermal water		Cages in reservoirs + complete feed	
Size at stocking (g)	20	30	20	30	20	30	20	30	20	30	20	30	20	30
Stocking density:														
No./ Hectare	8000	8000	10000	10000	15000	15000	30000	30000						
No./m ³									80	80	80	80	50	50
Mortality loss to harvest ¹	25	25	25	25	25	25	25	15	15	15	15	15	15	15
No fish at harvest	6000	6000	7500	7500	11250	11250	22500	22500	68	68	68	68	43	43
Culture period(days)	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Assumed SGR (%/day)	1.2	1.2	1.3	1.3	1.4	1.4	1.65	1.65	1.9	1.9	1.9	1.9	1.6	1.6
Calculated final average size (g)	120	180	149	224	161	241	233	349	337	505	337	505	216	324
YIELD														
Tonnes/ha	0.7	1.1	1.1	1.7	1.9	2.9	5.2	7.9	-	-	-	-	-	-
Kg/m ³	-	-	-	-	-	-	-	-	22.9	34.3	22.9	34.3	9.2	13.8

¹ Adequate predator control assumed

The stocking densities applied are those that are typically used in such systems and adjusted to Namibian conditions. Based on field visits and experience mortalities were pegged at 25% for open systems where predation loss are expected to be higher but reduced to 15% for indoor systems. If appropriate measures are not put in place mortalities from predation can be considerably higher.

Two initial sex reversed fingerling size is considered for each culture system, 20 and 30 and are fed a declining feed ration in relevant systems. We have assumed good pond management practices.

Conservative growth rates are used, largely due to the uncertainty of good information on water temperature, which will have significant impact on fish growth rate, hence size at harvest and farm yield in Namibia. Limited data collected on field trips suggest that ambient average water temperature over production is likely to be 25-26 °C. This is reflected in the lower SGR allocated to open water pond and cage systems while indoor systems which can be heated with various methods or water from geothermal sources used have been allocated higher SGR.

For all systems, the benefits of using a larger fingerling size are clear. By stocking a 10 g larger fish the farm yields are increased by 50-80% (Table 29).

The predicted yield for open ponds with no inputs is estimated at 0.7 tonnes/ha. With increasing inputs through pond fertilization and management up to 8 tonnes/ha could be realised. For indoor systems around 35 kg/m³ could be possible. The cooler water temperatures in the reservoirs and potentially shorter season are expected to reduce yields to about 9 kg/m³ even though they will be fed complete diets. This yield, however, could be increased to around 14 kg/m³ if initial fingerling size was increased from 20 to 30 g. Increasing fingerling stocking size to 50 g should yield 23 kg/m³. It is emphasised that these conditions and estimated unit yields will have to empirically clarified and fine tuned at the appropriate sites and based on number of sites the GRN allocates, the potential national output can be estimated

15.3 Conclusions

- Of the key factors determining fish yield in Namibia; initial size of fingerlings stocked, use of sex-reversed fingerlings, water temperature, and mortality are most crucial.
- Mortality has a significant effect on economic viability. over 60% of the financial loss is due to revenue from sales of lost harvest followed by 27-28% due to lost feed and 8-12% due to fingerling cost.
- Both outdoor and indoor production systems can be used in Namibia depending on region and resources.
- Growth rates and therefore yields in all outdoor systems will be lower than indoor systems where water temperature can be raised. The only exception could be where large volumes of geothermally heated water is available.
- Given the Namibia climatic conditions rearing facilities under some type of cover will be aid to optimise farm yields
- Cage farming does offer some possibility to rear freshwater fish.
- Under well managed pond conditions between 5-8 tonnes/ha can be realised.

15.4 Recommendations and Way Forward

- i. It is imperative that MFMR immediately source annual water temperature data for the water bodies and initiate, implement and enforce simple protocols to routinely monitor water temperature in their facilities.
- ii. Immediately increase the size of fingerlings stocked in all on-growing rearing facilities and implement a programme for well planned production of **larger sex-reversed fingerlings**, ideally *O. niloticus* and *O. andersonii*.
- iii. Given the suboptimal temperature conditions in Namibia for farming freshwater fishes MFMR should explore and compare performance of other suitable species, such as *O. niloticus*.
- iv. Conduct-well designed pilot trials (2/production system) at predetermined sites for a selected number of outgrowing systems and species described above to optimize fish farm yields for local conditions.
- v. Conduct a detailed competent technical due diligence on government fish production farms such as Epalela fish farm. Current data suggest growth performance in outdoor systems is low, probably due to water temperatures.

16 CHALLENGES AND CONSIDERATIONS FOR PROMOTING THE NATIONAL AQUACULTURE MASTER PLAN FOR FRESHWATER AQUACULTURE: Assessment of Potential Candidate Species for Freshwater Aquaculture in Namibia - Initial Screening of Candidates

16.1 Introduction

To address the National Vision 2030 for developing an expanding aquaculture sector, the current fledgling status of freshwater aquaculture should be acknowledged. Moreover, given that currently the private sector has had a limited role in kick-starting freshwater aquaculture, the government role will continue to be pivotal in shaping, consolidating and expanding the early phases of expansion. Given this scenario, and the current financial challenges, the GRN would have to prioritize how best to achieve its goals from several angles. Two questions need careful consideration: firstly, can scope for expansion be best served by concentrating on existing and related candidate species for whom technologies are known or by promoting new ones for which technology has to be largely developed? Secondly, if the approach is to develop new candidate species, on what basis should they be selected?

To assist in selecting species, the present report assesses/considered criteria and attributes of species or species groups with potential for developing the freshwater aquaculture sector under Namibian conditions.

16.2 Methodology

Several approaches can be applied for selecting and assessing the economic viability of potential aquaculture species. For this assessment a structured approach was adopted, forming a nexus between socio-economics, culture attributes of species, field assessments and stakeholder consultations.

The initial screening was achieved through consulting secondary literature to identify those *internationally* acknowledged criteria, attributes and success factors in globally successful aquaculture sectors. These qualities were then used to draft a ranked master model for assessing freshwater species currently under culture globally (Table 30). The ranked criteria were also assessed and grouped in terms of their perceived importance based on the frequency with which the international

aquaculture industry considered them relevant and these were grouped from crucial or essential criteria to noted criteria.

The master model was then adapted and criteria ranked and applied to Namibian conditions based on field assessments and stakeholder consultations. The potential species were scored on a scale of 1 to 5, where 1 indicated 'very poor' and 5 'very good' (Table 31). The aggregated scores were then used to assess the priority for development. In assessing some criteria, especially in the culture technology and species biology category, scores reflect knowledge available elsewhere which can be relatively easily acquired to promote development.

16.3 Global Attributes of Freshwater Species for Development in Namibia

The criteria and success factors for species in Table 30 reflect global attributes of the species and are therefore not specific to Namibia but provide a framework for judging the potential and challenges for farming these species in Namibia.

The species listed in Table 30 met all crucial or essential criteria except carps for marketability (criterion 1), and (criterion 2) for red claw for adaptability to aquaculture and ease of grow-out farming. Given that carps are mainly consumed domestically, their price on the international market is unclear.

For the cluster of highly important criteria, red claw fared the worst for criteria 5 and 6. With the exception of tilapias (mouth brooding species) all other species were scored "No" for criterion 12 due to high cannibalism in the early phases of catfish rearing and fragility of fry for the other species. For all these species, however, mortality stabilizes after the fingerling growth phase. Hatchery requirements for freshwater prawn, red claw and carps are relatively more complex and therefore fail criterion 16. The increased complexity of these hatcheries also means that, unlike tilapias and catfish, these species fail criterion 18.

All species meet criterion 25 which does afford the opportunity to produce cheaper diets when compared with carnivorous species such as salmon and trout. Due to its low tolerance to salinity the red claw fails criterion 27. Given the high possibility of integrating the farming of these species with each other or with agriculture, all species pass criterion 28.

With a global production of over 1 million tonnes, tilapias serve a high global volume market. Similarly the United States catfish, Vietnamese catfish and Nigerian catfish (African catfish) serve high national and global volume markets so they both pass

criterion 36. As both the freshwater prawn and red claw serve the high value global market they also meet this criterion. The global marketing of tilapia and Vietnamese catfish as a commodity is now well established and therefore, along with freshwater prawn passes criterion 38. By contrast, marketing of carps has yet to exploit global opportunities and therefore currently fails criterion 38. The carps (Chinese and Indian), however, have a significant domestic focus and therefore are unlikely to be a potential threat for other countries. All species passed criterion 41 and therefore could be a future threat to Namibia, especially if they fail criterion 39.

A positive sign for the potential species is that all species have passed criterion 40, knowledge of species biology/hatchery cycle, making way for securing seed supply, a prerequisite for promoting a species for development. Even though such knowledge may not be available in Namibia, it can be procured from elsewhere at minimal developmental cost to kick-start aquaculture. The production of these species in several countries is also environmentally acceptable and therefore all species meet criterion 35.

Table 30. Master model for benchmarking potential freshwater species for using globally ranked criteria.

No.	Criterion/attribute/success factor	Rank	Species/species group					Assessed as
			Tilapia ¹	Catfish ¹	FW prawn ¹²	Red Claw	Carps ¹	
1	Marketability ³	1	Yes	Yes	Yes	Yes	No	Crucial criteria
2	Adaptability to aquaculture & ease of grow-out farming	2	Yes	Yes	Yes	No	Yes	
3	Well priced (Gate price >US\$ 2.50)	3	Yes	Yes	Yes	Yes	Unsure	
4	Availability of sites	4	Yes	Yes	Yes	Yes	Yes	Highly important criteria
5	Easy to produce/obtain fry and fingerlings ²	6	Yes	Yes	Yes	No	Yes	
6	Available feeds/ able to develop diet	6	Yes	Yes	Yes	No	Yes	
7	Short grow- out production time	6	Yes	Yes	Yes	Yes	No	
10	Available technology	6	Yes	Yes	Yes	Yes	Yes	
11	Robust/environmentally tolerant	7	Yes	Yes	No	Yes	Yes	
12	Low mortality rate	7	Yes	No	No	No	No	
13	Disease and parasite resistant	7	Yes	Yes	No	Yes	Yes	
14	Good FCR ⁴	7	Yes	Yes	No	No	Unsure	
15	Closed lifecycle with knowledge of species biology & hatchery cycle	8	Yes	Yes	Yes	Yes	Yes	
16	Easily duplicated	8	Yes	Yes	No	No	No	Important criteria
17	Economically farmed	8	unsure	Yes	Yes	Yes	Unsure	
18	Decentralisation of hatcheries	9	Yes	Yes	No	No	No	
19	Availability - regularity of product on sale	9	Yes	No	No	No	No	
20	Can meet export quality	9	Yes	Yes	Yes	Yes	Unsure	
21	Adaptable to translocated environment	10	Yes	Yes	Yes	Yes	Yes	
22	Shortage of fish supply	10	Yes	Yes	Yes	Yes	Unsure	
23	Serves an established or potential market	10	Yes	Yes	Yes	Yes	Unsure	
24	Government financial/institutional support	10	Yes	Yes	Yes	Yes	Yes	
25	Herbivorous/omnivorous	11	Yes	Yes	Yes	Yes	Yes	
26	Locally available species	11	Yes	Yes	Yes	No	Yes	
27	Tolerant to brackish water	11	Yes	Yes	Yes	No	No	
28	Synergies with current operations	11	Yes	Yes	Yes	Yes	Yes	

No.	Criterion/attribute/success factor	Rank	Species/species group					Assessed as
			Tilapia ¹	Catfish ¹	FW prawn ¹²	Red Claw	Carps ¹	
29	Market and consumer knowledge of species	11	Yes	Yes	Yes	No	Yes	
30	Attractive – species of consumer choice	11	Yes	Yes	Yes	Unsure	No	
31	Potential for value addition	12	Yes	Yes	No	No	Unsure	
32	Shelf-life	12	Yes	Yes	Yes	Yes	Yes	
33	Suitable to environment	13	Yes	Yes	Yes	Yes	Yes	
34	High recovery rate/fillet yield	13	Unsure	Yes	No	No	Unsure	
35	Environmentally acceptable production	14	Yes	Yes	Yes	Yes	Yes	Relevant criteria
36	Can serve a high-value or high-volume market	14	Yes	Yes	Yes	Yes	Unsure	
37	Competitive advantage	14	Unsure	Unsure	Yes	No	No	
38	Well marketed	14	Yes	Yes	Yes	No	No	
39	Globally competitive/serve a global market	14	Yes	Yes	Yes	Unsure	Unsure	
40	Knowledge of species biology/hatchery cycle	14	Yes	Yes	Yes	Yes	Yes	
41	Similar species grown overseas	15	Yes	Yes	Yes	Yes	Yes	Noted criteria
42	Minimum use of chemicals	15	Yes	Yes	Yes	Yes	Yes	
43	Potential to become a mainstream fish	15	Yes	Yes	No	No	Unsure	
44	Customer safe perception	15	Yes	Yes	Yes	Yes	Yes	
45	Innovative/marketed in a new form	15	Yes	Yes	No	No	No	
46	Improvement on existing product	15	Yes	Yes	No	No	Yes	

1. Species clusters: Tilapias = *Oreochromis andersonii*, *niloticus*; Catfish = *Clarias gariepinus*; FW prawn = African FW prawn *Macrobrachium vollehoveni*; Carps= common and Chinese carps
2. The life cycle is closed, mass production possible and there is a hatchery nearby operating efficiently
3. Ease by which the product is accepted and exchanged in the market place.
4. Food conversion ratio based on artificial feed

16.4 Selection Considerations under Namibian Conditions

The criteria/attributes from the global master model considered relevant to Namibian conditions were then selected based on field trip assessments to establish if species identified in Table 30 can be potentially developed.

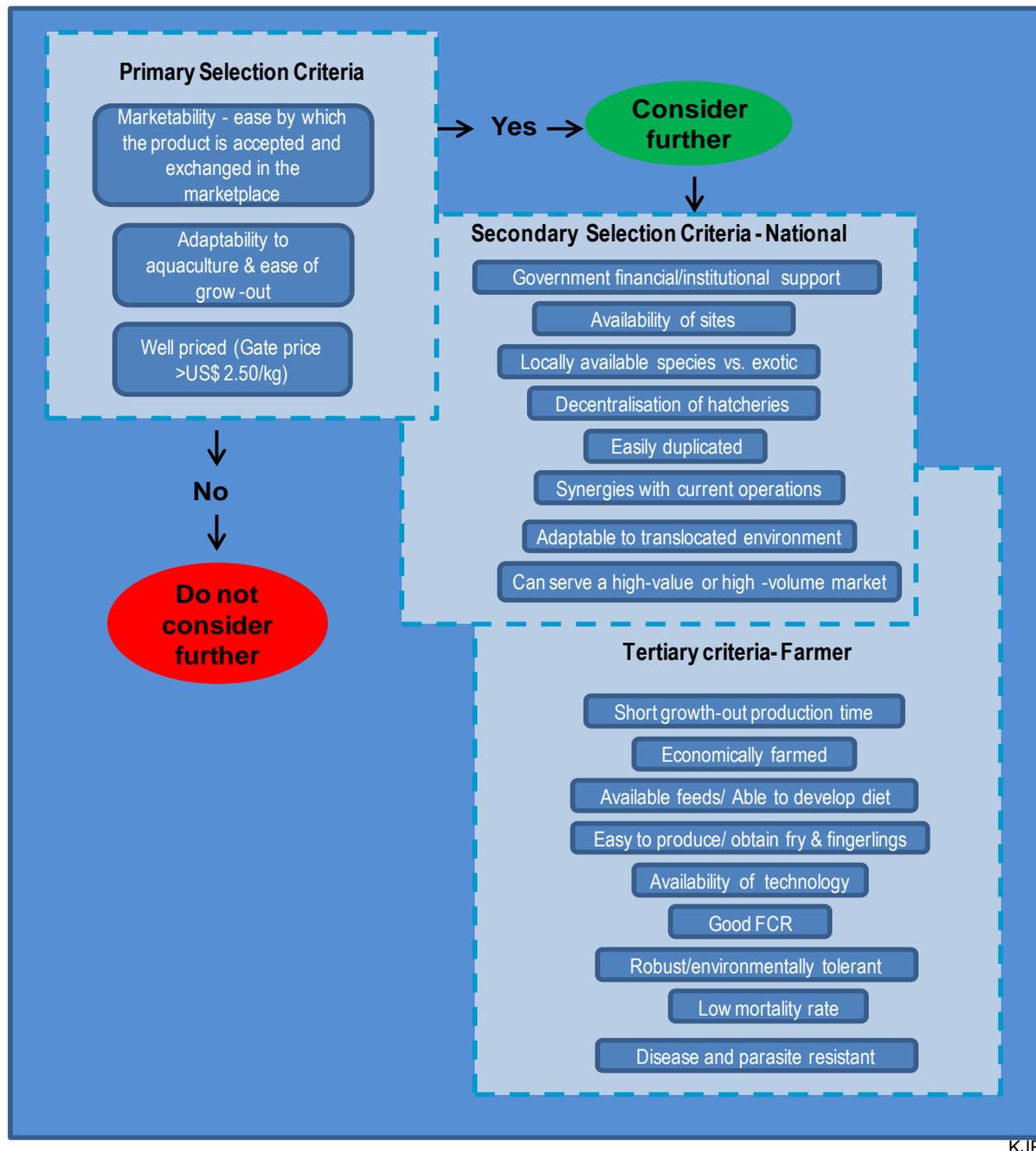


Figure 43. Schematic flow chart showing selection process for freshwater species in Namibia using essential attributes within each selection level. Selected criteria and attributes identified for Namibian conditions.

These predominant criteria were schematically and hierarchically arranged within three levels showing overlaps of criteria between the three levels to identify which species could be considered for further development (Figure 43). Species which do not to meet the primary selection criteria can be eliminated.

The application of Figure 43 to the species listed in Table 30 suggests that all five species/species groups could potentially be farmed in Namibia but with varying degrees of challenges. To help MFMR prioritize the development of these freshwater species to kick-start and expand freshwater aquaculture in Namibia the criteria and attributes considered most relevant were identified. These 22 criteria and attributes were grouped under three broad categories, viz, marketing and Socio-economics, Geo-political and Production and, Culture Technology and Species Biology (Table 31).the criterion was scored on a scale of 1 to 5 for each species /species group. The scores for each species or species group were then added to give a final ranked score (Table 31). Based on this assessment the tilapias, with an aggregate score of 87, offered the best chance for development followed by catfish (75), freshwater prawns (67), red claw (62) and carps (52). The score for individual criteria can also be used to focus on specific challenges to increase probability of specific success factors.

Tilapias and catfish offer the best opportunity for domestic and regional markets (criterion 4) whereas the freshwater prawns and red claw (criterion 5) could be developed for the domestic tourist trade and global markets. The actual choice of tilapia species, however, will be a matter of government decision. Currently *Oreochromis andersonii* is farmed but other species such as *O. niloticus* are also available in Namibia which may offer better growth performance and therefore higher probability of success. It is our understanding that fresh water African freshwater prawn, *Macrobrachium vollenhoveni* exists in the Kunene region and this offers an opportunity to develop a higher value freshwater species for culture. Additionally, we were informed that the red claw was trialled in Hardap but it is unclear if these species are still available in Namibia.

The ease of culture and adaptability of species to farming are strong features for all species in Table 31 with tilapia and catfish scoring 5 and 4, respectively, for criterion 14. The technologies for all named species are available; either within Namibia (to a basic extent) or elsewhere but in all cases requires fine tuning for Namibian conditions. All species of tilapia seed are currently produced in the country and catfish seed production can be rapidly established. Although the freshwater prawn and red claw are extensively farmed elsewhere, currently no technology is available in Namibia. Pelleted feed, especially for tilapias is also available and hence for

Table 31. Assessment/scoring of freshwater species to identify potential candidates for developing aquaculture under Namibian conditions. Scores: 1, very poor; 2, poor; 3, adequate; 4, good; 5, very good.

No	Criterion/Attribute/Success factor	Species/Species group				
		Tilapia	Catfish	FW Prawn	Red Claw	Carps
Marketing and Socio-economics						
1	Marketability	5	4	4	3	2
2	Economically farmed	3	3	4	4	2
3	Well priced (Gate price >US\$ 2.50) ²	4	3	5	5	2
4	Can serve a high value or high volume market	4	4	5	5	2
5	Globally competitive/serve a global market	1	1	5	5	1
6	Serve national & regional market	4	4	2	2	2
7	Good FCR	4	4	3	3	3
Geo-political and Production						
8	Government financial/institutional support	5	4	1	1	2
9	Availability of sites	3	3	3	3	2
10	Availability of technology	5	3	1	1	2
11	Locally available species vs. exotic	4	5	5	2	3
12	Easily duplicated	5	4	3	3	3
13	Decentralisation of hatcheries	5	3	2	2	2
14	Adaptability to aquaculture & ease of grow- out farming	5	4	3	3	3
15	Available feeds/ able to develop diet	4	4	3	3	3
16	Short growth- out production time	4	4	3	3	2
17	Synergies with current operations	4	4	4	4	2
Culture Technology and Species Biology						
18	Closed lifecycle with knowledge of species biology & hatchery cycle	5	3	1	1	3
19	Easy to produce/obtain fry and fingerlings	4	2	1	1	2
20	Robust/environmentally tolerant to farming	4	4	3	2	4
21	Low mortality/high survival rate ³	2	2	3	3	2
22	Disease and parasite resistant ³	3	3	3	3	3
	Total Score	87	75	67	62	52

¹Refers only to mouth brooding *Oreochromis species*

¹ *Macrobrachium rosenbergi* / *(Vollenhoveni)*

² NAM\$ 18.75 @ 7.50/US\$

³ Considered over the entire life cycle. Note for all species survival rate during grow out is acceptable (3), score for FW prawn and red claw form elsewhere.

criterion 15 scored 3-4 for all species. Currently tilapia and catfish scores low (2) for criterion 21 (Table 31) as field data indicate that survival at the fingerling stage and grow-out phase is low but with appropriate management this can be significantly improved. The prawns and red claw fair better (score 3) as they are bottom dwelling and therefore not as prone to avian predation as the fin-fish.

The choice of candidates within the tilapia species groups should also be considered as several candidates with differing biological attributes are available. *Oreochromis niloticus* is also locally available as a species at Hardap and should be considered as a candidate of choice. In deciding species choice it should be noted that under ambient conditions the growing season is limited and therefore species exhibiting the best growth performance be considered to ensure optimal production and production efficiency. The details of the technical requirements for the culture of potential species will be a subject of a separate report.

16.5 Conclusions

- Internationally acknowledged criteria, attributes and success factors were applied to identify potential farming candidates for freshwater aquaculture under Namibian conditions
- The tilapias, had the highest aggregate score of 87 and offered the best chance for development followed by catfish (75), freshwater prawns (67), red claw (62) and carps (52).
- Tilapias and catfish offer the best opportunity for domestic and regional markets whereas the freshwater prawns and red claw could be developed for the domestic tourist trade and global markets.

16.6 Recommendations and Way Forward

- i. The choice of tilapia species, allowed for aquaculture is a matter of government decision. Currently, *Oreochromis andersonii* is farmed but other species such as *O. niloticus* also available in Namibia which may offer better growth performance should be seriously considered.
- ii. A well designed and planned comparative study of the growth performance of these tilapia species should be initiated as soon as possible.
- iii. *Macrobrachium vollehoveni* found in the Kunene region should be given high priority for development. This species offers an opportunity to develop a high value freshwater species for culture
- iv. Technologies for all the above species are available and collaboration should be initiated with appropriate institutions to promote these species.

17 CHALLENGES AND CONSIDERATIONS FOR PROMOTING THE NATIONAL AQUACULTURE MASTER PLAN FOR FRESHWATER AQUACULTURE: Technical and Cultural Requirements of Selected Freshwater Species

17.1 Introduction

This synthesis explores the **technical and cultural requirements** of the top four species/species groups identified for freshwater aquaculture development in Namibia. The species identified for tilapia are *O. andersonii*, *O. niloticus*, and *O. macrochir*, the catfish, *Clarias gariepinus*, and two invertebrate species, the giant freshwater prawn, *Macrobrachium spp.*, and the red claw, *Cherax quadricarinatus*.

As in other animal production sectors, fish farming is divided into discrete segments/phases, each having their own technical requirements and culture emphasis. In large aquaculture operations all these segments may be horizontally integrated. Typically, however, the core businesses of fish farms focus on one of the two main segments *viz.* seed production and on-growing (Figure 44).

As a farming activity, all of the above species share many cross-cutting activities in the four **product flow** phases *viz.* (i) seed production, (ii) on-growing production, (iii) pre-harvest and (iv) post-harvest (see Figure 31). Each product flow segment is comprised of interrelated **technical areas**. These technical areas require specific knowledge bases and sets of technical skills to run a farm proficiently and efficiently. The essential knowledge base required for the species are considered elsewhere, here the important technical skills are explored by first identifying the duties to run a fish farm. The technical requirements for all tilapia (*Oreochromis*) species listed above are similar and therefore treated collectively.

Most of the species identified have similar systems requirements and operational duties and therefore the initial section of this report considers skills requirements for these common activities across the production value chain making reference to species were relevant. The essential knowledge and technical skills are illustrated in Figure 31 and expanded below.

17.2 Production Value Chain

17.2.1 Seed production

Prerequisite for aquaculture development

The availability **on demand** of high **quality** seed in the **required quantity** is a prerequisite for aquaculture and therefore closure of the lifecycle or reproductive control is essential for the successful development of new species or expanding culture an existing species. Failure to control reproduction is therefore an inhibitor to new species development. Fortunately, the life cycles for all the targeted freshwater species identified for promoting freshwater aquaculture development are closed and in the case of tilapias, their lack of reproductive control is potentially an inhibitor.

17.2.1.1 Broodstock management and breeding

What are broodstock and broodstock management?

Broodstock denotes a group of sexually mature female and male fish, kept separate for breeding purposes in a controlled/managed environment eliminating the reliance on wild populations for seed.

Good broodstock management is essential to ensure sustainable production of high quality viable offspring. Broodstock management essentially refers to the management of two components: (i) the rearing environment of the brooders, and (ii) health, nutrition and genetic status of the broodstock to minimize negative elements whilst maximizing positive or desired benefits. The objective is to identify broodstock with desirable attributes and enhance their gonadal development, maximize fecundity and egg quality and survival and growth performance. As such, it is one of the most critical phases of the production value chain.

Managing the rearing environment

- To enable broodstock to adjust to and perform under local conditions broodstock are selected, often as immature juveniles, and reared in suitable conditions to sexual maturity in ponds, hapas or tanks. These animals require good consistent water quality and a well-balanced, species-specific, protein rich diet to boost germinal tissue development.

- The facilities in which broodstock are held must be of a suitable size to allow for an increase in biomass and fish size to promote the condition the broodstock.
 - The characteristics of the water in which the mature broodstocks are held may need to be manipulated to trigger breeding. The aquaculturist must consider appropriate temperature, light, oxygen concentration and pH of the water, all of which can be species-specific.
 - The diets and feeding regimes of broodstock are paramount as they influence growth and gonadal development. Fecundity is a function of fish size and hence growth, therefore smaller fish of the same age are likely to produce fewer eggs. The composition of the food especially the protein and lipid composition are particularly important. The quantity of food intake will influence spawning and maturity. Low rations have been shown to reduce the proportion of fish reaching maturity and spawning.
- i) Selective breeding for broodstock performance

An understanding of **genetic** broodstock management is critical to ensure sustained genetic stability of stock. There are two main components to bear in mind (a) genetic degradation of stock with time due to uncontrolled breeding, termed **inbreeding** and (b) Genetic selection of broodfish that meets and improves the desired traits. Such traits typically include faster growth, temperature tolerance, delayed sexual maturity, better flesh quality, disease resistance.

a. Genetic degradation of stock

In any stock, the broodstock population will genetically degrade with time unless careful management plans and are put in place. A common cause of broodstock degradation is inbreeding, which is the mating of mating of closely related fish e.g. between siblings or half siblings. The rate with which inbreeding can negatively affect broodstock performance will depend on the time to maturation of fish species. In tilapias for example, since breeding can start at just 2-3 months, a farmer can theoretically go through 3-4 generations of fish in a year whereas in salmon which breeds at 2-3 years old this will take 10yrs to go through the same number of generations. Therefore for a given period, species such as tilapias are more prone to inbreeding effects than salmon. As the level of inbreeding increases, their productivity often decreases, which is termed "inbreeding depression". Inbreeding depression is a decrease in growth rate, fecundity, etc. that is observed in the inbred group when it is compared with

populations where there is no inbreeding. The human capacity to look for tell-tale-signs and the need to monitor and keep detailed records record of broodstock are therefore are important requirements.

b. Genetic selection of broodfish

Genetic selection entails choosing individuals displaying specific traits from the population to produce more offspring carrying the required traits. These individuals are selected from sexually mature fish since it is their reproduction that affects the future population. It should be noted that selection does not create new genes, but rather changes gene frequencies. The frequencies of alleles (one or more forms of a gene) with favourable effects on the phenotype under selection are increased whilst those of less favourable genes are decreased. Therefore prolonged selection results in the discarding and reduction of some gene types but with this elimination other useful qualities may also be lost.

Farmers should be aware of the three main technical approaches used in fish selection: **mass selection** where the individuals making up the top 5-10% of the population for that trait are selected from a population and reserved for breeding, **family selection** where groups of fish are maintained separately as families are grown under identical conditions. Families with the best desired traits are selected for further development and **pedigree selection** where selection is based on their parents and grandparents. An understanding of these methods and their merits will be expected if staff at MFMR or farmers intend to develop genetically superior fish. These programmes are complex and best conducted in external collaboration with institutions having such competences.

ii) Broodstock conditioning /selection

Significant effort and resources are required for broodstock selection and management programmes. One aspect of this programme is to ensure that the identified broodstock are optimally housed, handled and maintained in their rearing facility and given the best possible diet using appropriate feeding regimes. During spawning, broodstock need to be examined to establish readiness for spawning and such experience in examination is important to increase the probability of success.

Box 1. Snapshot requirements: Broodstock management and breeding

- Broodstock performance, Selective breeding
- All year seed production
- Broodstock selection/conditioning
- Hormonal induction
- Gamete management

Typically broodstock sexes are kept apart when not breeding and fish can be individually tagged. Generally workers should be trained in recognizing preferences in body form and condition. The larger adults with good body form (e.g. body thickness) and the required pigmentation/colouration should be selected for breeding. They should also look healthy, lack physical deformities, be well fed and display advanced gonadal development.

iii) All year seed production

Planned fish production will require stocking material for on-growing all the year round, and therefore one key hatchery challenge is to be able to spawn fish on demand. The challenges to achieve this vary between species and an understanding of the cues that trigger gonadal maturation are important. In temperate species cues such as be light and temperature may be more important, whereas in some tropical species such as catfish and carps it may be rain and floods. For tilapia and African catfish water temperature and rainfall are important and therefore under Namibian conditions the water temperature is likely to be the most important factor to appreciate. Spawning will usually begin above 22-25 °C. If water temperature can be maintained above 25 °C, these species, if in good condition, can be spawned all year round for seed production.

iv) Hormonal induction and gamete management

Many fish spawn in environments that are difficult or not practicable to simulate under hatchery conditions. In this circumstance hormone-induced spawning is the most widely used and reliable method to induce spawning of these fishes. Experience in understanding and applying such techniques is therefore critical if these species are being farmed. Farmers require training in establishing sexual maturity, correct fish handling including experience in sedation techniques, knowledge of chemotherapy options, preparation and administering of hormones and collecting of gametes and fertilizing techniques. Capacity for preparation and administering hormone will also required knowledge and experience in preparation, dosage calculation, and injection techniques for induction of spawning.

17.2.1.2 Hatcheries and fry rearing

Having procured the spawn, either as fertilized eggs or hatchlings, several interrelated skills are required to optimize fry and fingerling production (Box 2).

Irrespective of species, an understanding of the early ontogenic development stages of species is helpful to ensure proper timing of feeding and handling.

Under Namibian conditions, hatcheries are most likely to be indoors and therefore knowledge, and ideally experience, in design, operation and management of indoor incubations systems will be required. The nature of these systems and critical areas of consideration will vary between species. For tilapias, emphasis will be on managing incubation systems for the naturally spawned clutch. In the case of catfish, particular care is required to minimize spoilage of eggs during incubation whilst in *Macrobrachium spp.* facilities for harvesting and caring for the fragile hatchlings is the challenge.

Box 2: Snapshot requirements: Hatchery and fry rearing

- Understanding developmental physiology
- Design, operation & management of incubation systems
- Operation and management of breeding ponds/hapas/tanks
- Competence in use of microscope etc.
- Capacity in live feeds, feeding management

Under some conditions seed production may be carried out in breeding ponds which may or may not be under cover. General management of such facilities are required to ensure health and reproduction capabilities of broodfish. In particular, farm hands need to be trained in fry harvesting and handling techniques. Should red claw be farmed juveniles can be produced naturally in ponds but staff will require specific training.

In more centralized hatcheries, larger farms or able farmers, hatcheries may have analytical equipment and microscopes for which staff require training for their effective use, the former for monitoring the physico-chemical environment and the latter for monitoring egg and fry quality and knowledge gathering.

During the initial fry development stages, feeds and weaning onto artificial diets are amongst the most critical phases of artificial seed production where the highest mortalities can occur. Therefore this area of the product flow requires focused attention, especially where hatchlings originate from small eggs, e.g. carps, catfish and *Macrobrachium spp.* In circumstances where seed are produced outdoors, experience in pond fertilization techniques and live feed enhancement will be valuable.

The fry of all species proposed are extremely fragile and damage to body and scale loss can often be fatal. Hatchery staff therefore need to pay particular attention to how fry are handled especially during netting grading and transfer. Growth of fry in any population is not uniform and during this rapid growth phase

these differences between fry will encourage cannibalism. Staff will have to familiarize themselves with grading equipment and grading procedures for fish of varying sizes to minimize cannibalism and produce uniform-sized fry.

Differences in growth rate between sexes are a well-known phenomenon. In some species such as salmonids the females are preferred by farmers for their better performance than males whilst in tilapias the reverse is true and tilapia farmers prefer to farm males. Additionally in tilapia, unwanted spawning in production facilities comprises management and results in small-sized fish at harvest. One method to overcome unwanted breeding is to farm all male tilapias.

Several methods are available to produce all-male fish. Fingerlings can be hand sexed and only the males are on-grown. All-males can be produced using super males produced using “YY” technology, or fry can be sex reversed during the early ontogenic stages with androgenic hormones. Of these technologies sex reversal is globally the most widely used methods and is applicable to Namibian conditions. The capacity to consistently produce sex-reversed seed will be of paramount benefit to tilapia farmers in Namibia.

Box 3. Snapshot requirements: Fingerling production

- Husbandry of fry to fingerlings (5-50g)
- Measurements of growth and performance traits
- Feed and feed management
- Fry/Fingerling Transport
- Grading methods
- Monitoring/ optimising water quality and systems performance

If outdoor fry rearing facilities are used it is important that farmers are pay due attention to predation. Training is required to ensure farmers are aware on how to protect their fry form predators such as birds, frogs, nymph larvae.

17.2.1.3 Fingerling production

This phase of the product flow generally encompasses rearing the fry to juveniles in tanks, hapas or ponds and farmers should be acquainted with husbandry practices and experience to manage and operate such rearing systems.

During this phase the fish are more robust and can be better handled than the fry stage. Farmers should be familiar with techniques for routine monitoring of fish growth. Fingerlings need to be measured (length and weight) and in some instances

fish may need to be sedated before taking measurements. Such data are used to calculate and adjust feed rations for drawing up feeding regimes. Hence, for such tasks, staff need to be familiar with measurement techniques, use of weighing balances, types of fish length measurements, and how such information is used to calculate feed requirements for cultured stocks. Additionally, they should be trained in relevant record keeping and be computer literate to enter, store and analyse data.

The level of expertise and knowledge required in fish feeds will depend on the source of the feed. In Namibia a government fish feed plant exists and it is envisaged therefore, that farms will acquire ready-made pelleted feeds. In such cases farmers should have knowledge on feed storage methods and be able to make assessments of quality especially with respect to acceptable levels of dust in feed. In instances where feeds are made on the farm, farmers should have experience and knowledge on feed ingredients quality and performance and acquire simple techniques for producing on-farm pelleted feeds.

Where fingerling are transported, staff need to familiarize themselves with the fish transporters to be used, have an understanding of safety and use of oxygen cylinders and loading of transporters and ensure minimum stress conditions for fingerlings during handling.

Juvenile fish display high growth rates and populations often display a high degree of size variation. If left unchecked this could reduce survival due to cannibalism and/or reduce their saleability. The grading of fingerlings is therefore an important duty on farms. The ease of grading will depend on culture methods. Fingerlings raised in tanks and hapas are easier to grade compared with ponds. Careful handling, use of grading equipment and recognition of types of damage to fish are important components of training.

As in other phases of production experience in the production systems is crucial for management. Staff will have to be well versed and equipped to conduct routine water quality assessments, It is important that at least temperature and oxygen are routinely measured ammonia regularly monitoring. Such information is of value if recorded, analysed and used in systems management.

If outdoor fingerling rearing facilities are used it is important that farmers pay due attention to predation. Training is required to ensure farmers are aware on how to protect their fingerlings from predators such as birds, frogs, nymph larvae etc.

17.2.2 On-growing (grow-out production)

Two main technical areas are identified in this phase of the production chain; growth performance/optimizing yield and systems operations. In terms of production it is the main phase during which significant fish biomass is generated.

17.2.2.1 Growth performance/optimising yield

Many of the duties and technical requirements for this phase are similar to that for fingerling production but on a larger scale and therefore not repeated here (see Subsection 12). The monitoring of growth is especially important and critical if costly commercial feeds are used. Wastage due overfeeding can result in significant financial loss and mortality and underfeeding will reduce growth performance. Given the exponential increase in biomass in the rearing systems, water quality can fluctuate rapidly and violently and therefore the discipline of monitoring water quality and rearing systems has to be adhered to. The capacity to monitor fish health, understand treatments and their efficient use are crucial elements of management.

Box 4. Snapshot requirements: growth performance/ optimising yield

- Measurements of growth and performance parameters
- Use/maintenance of monitoring equipment e.g. O₂ meter
- Feed storage, feeding regimes & feed management
- Fish health management
- Management of water quality and systems performance
- Grading methods
- Record keeping and data base development

17.2.2.2 Systems operations

The level of knowledge, experience and technical skills required for successful rearing systems will depend on the type of system used and the intensity of operation. Typically three main types can be identified; (i) ponds, which can be farmed extensively with minimal inputs to intensive ponds with high stocking density using aeration, high water exchange and commercial feeds, (ii) cages or hapas which are semi-intensively to intensively used using high stocking density and pelleted feed, and (iii) tanks which are usually intensively used with high stocking density and pelleted feed

For all rearing systems, farmers need to understand and preferably have the building and maintenance skills for the systems being operated. For ponds knowledge of levy repairs, and pipe and valve maintenance will be of value. In circumstances where lined ponds are used farmers should have skills and equipment for repairing liners. Farmers using hapas and cages should be trained in hapa and cage construction and maintenance, in particular net repair and cleaning. Where facilities are indoors, farmers ideally should be involved in construction as understudies so as to ensure that post-construction maintenance/repair skills are in place. Farmers should be trained in awareness and ideally general maintenance of equipment such as pumps, aerators and general plumbing. Where tanks are used, farmers should be familiar with tank construction and operation. Under Namibian circumstances recirculation systems may be proposed; farmers will require specific training on design, maintenance and in particular, understanding of types, function and operation of bio-filtration systems.

Given that fish are reared in an aquatic environment, a good grasp of water quality monitoring/control and use of related equipment, e.g. O₂ and pH meters together with recording and interpretation skills will be essential

Given that a significantly higher fish biomass is being managed at the grow-out phase, farms will be procuring and storing larger quantities of feed on site. Farmers need to be made aware of good feed storage methods and practice and be trained in the administration of feed and feeding regimes for the cultured stocks.

17.2.3 Pre-harvest

Planning the harvest is an equally important phase of production and farm managers will need to ensure that arrangements are in place well in advance of harvesting. Most earthen pond harvesting is done with a seine net. Farmers should be aware of when best to stop feeding and harvest fish to minimize stress on fish and optimize harvest. Additionally, farmers should be versed in any regulations governing the use of chemicals, drugs and fertilizers as withdrawal times of these chemicals may be required. Farm workers should be trained in net repair and use of harvesting equipment.

Box 5. Snapshot of requirements: Pre-Harvest

- Local knowledge of markets
- Conditioning of fish for harvest
- Maintenance and repairs of nets
- Harvesting methods
- Knowledge of harvesting equipment

Under certain conditions fish may acquire off-flavours, caused by certain algae which can be a serious problem that negatively affects fish price. Although there is no cure farmers should be made aware of management practices to minimize off-flavours in saleable fish.

17.2.4 Post-harvest

17.2.4.1 Processing, packaging and transport

Fish can be harvested dead or alive. If fish are harvested for live sales or to be transported, farmers should be trained on how to handle larger fish with minimal stress. Depending on the destined markets, farmers may need to acquire information, and training on flesh quality control. Fish for export to western markets will have to conform to strict import regulations and meet various phytosanitary conditions and farmers need to be informed on protocols such as HACCP. Fish may need to be culled onsite and farmers may have to conform to regulated slaughter conditions which may require specific facilities and equipment for which training will be required. Farmers will accordingly have to ensure compliance. Depending on production scale farmers may have to be familiar with ice machines and use of ice in packing fish for market.

Box 6. Snapshot of requirements: Post-Harvest

- Handling of fish/grading
- Value additions techniques
- Product quality and shelf-life
- Regulations and rules on phyto-sanitary standards

The price of aquatic products varies with fish size. Farm hands will therefore need guidance and training on how to classify and size grade all farmed products.

17.2.5 Business skills

This attribute is not a direct component of product flow but production success will be strongly influenced by the business and entrepreneurial skills of the farmer. Therefore training in basic business skills will determine the sustainability of their operations. The degree of competence in such skills will depend on the status of the farmer or staff. Basic writing skills are essential to ensure that proper inventory and records are kept. For higher roles, the ability to draw up basic accounts and calculation of profit and loss will be required to progress and expand the business and develop the product for the market.

17.3 Conclusion

- ✚ **The technical and cultural requirements** of the top four species/species groups identified for freshwater aquaculture development in Namibia are elaborated
- ✚ **Technical requirements are considered** in the four interrelated **product flow** phases viz. (i) seed production, (ii) grow-out production, (iii) pre harvest and (iv) post harvest
- ✚ Failure to control unwanted reproduction of tilapias in grow-out facilities is a significant inhibitor to progress.
- ✚ Technologies and management plan for broodstock management and all year round fingerling production is critical for all identified species
- ✚ Technologies for hormonal induction and rearing of catfish fingerlings need to be ungraded
- ✚ Under Namibian conditions indoor rearing technologies for all target species will be required and managed
- ✚ Monitoring of growth performance and water quality are crucial requirements for progressing culture

17.4 Recommendations and Way Forward

- i. For each selected species, MFMR should conduct a detailed site-specific technical audit of facilities, equipment, human capacity and target production to assess bottlenecks.
- ii. MFMR should develop an efficient programme for production of sex reversed tilapia
- iii. Increase capacity of staff at IACs on artificial breeding and rearing of catfish and *Macrobrachium spp.*
- iv. Identify an IAC for developing and training farmers in broodstock management.
- v. Given the climatic conditions in Namibia, technologies for indoor farming systems need to be locally developed. Such experience in Namibia, however, is limited and should be developed in collaboration with appropriate expertise.
- vi. The MFMR should put in place protocols and structure to monitor water quality in public water bodies, in particular water temperature.

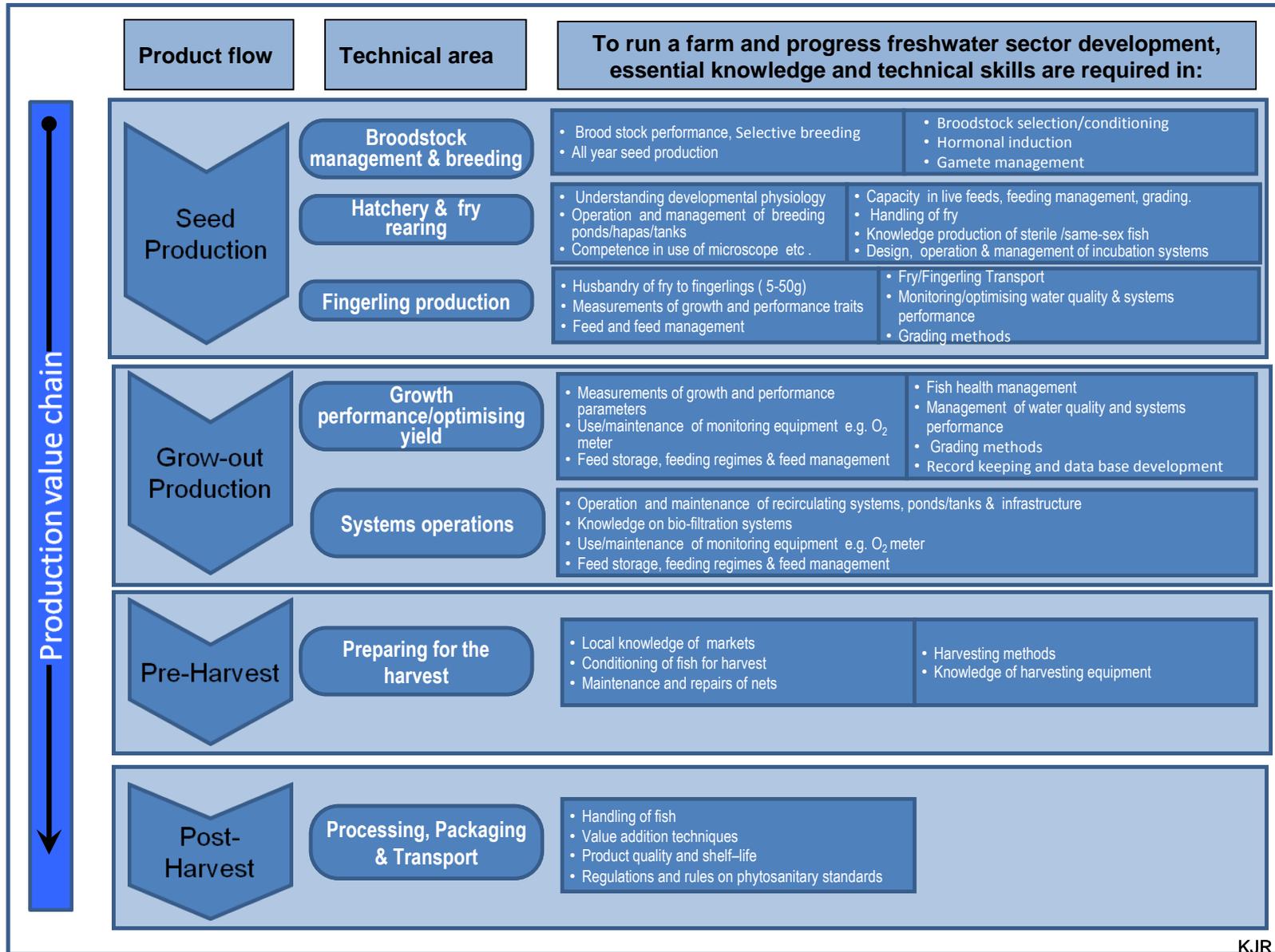


Figure 44. Generic technical requirements for developing the Namibian freshwater aquaculture sector for all identified species.

18 CHALLENGES AND CONSIDERATIONS FOR PROMOTING THE NATIONAL AQUACULTURE MASTER PLAN FOR FRESHWATER AQUACULTURE: Background and Potential for the Culture of Selected Freshwater Species

18.1 Culture and Market Potential for the Culture of Tilapia (*Oreochromis spp.*) in Namibia



18.1.1 Introduction and global importance of tilapia species

Tilapia is the common name of a group of cichlids endemic to Africa and the Levant where more than 70 species have been identified, although few species are of aquacultural significance. The term 'tilapia' is used here to include the various fish species belonging to the family Cichlidae which were formerly grouped under the single genus *Tilapia* but are now separated, according to Trewavas (1982¹, 1983²) into the three genera *Tilapia*, *Oreochromis* and *Sarotherodon*. These classifications were based on morphological and biogeographic traits as well as more critically their specific reproductive characteristics; although all tilapia species are nest builders, they do exhibit varying degree of parental care. The scientific names of tilapia species have been revised several times the last 30 years, creating some confusion.

The scientific name of the Nile tilapia has previously been given as *Tilapia nilotica* and *Sarotherodon niloticus*, but is now known as *Oreochromis niloticus*.

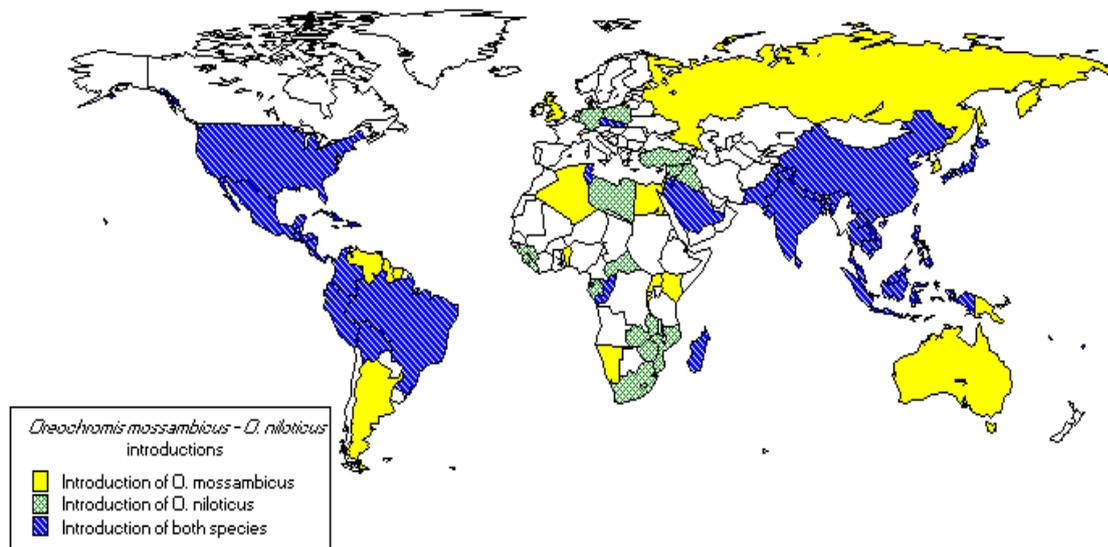


Figure 45. Worldwide distribution of Mozambique and Nile tilapia (FAO, 2010).

The first documented presence of the tilapia outside their native range occurred as early as the beginning of the 20th century, however, it was only by the mid-20th century that tilapia species of biological and economic interest were extensively transplanted for fisheries or aquaculture. The Mozambique tilapia (*O. mossambicus*) was the first species to be distributed worldwide for culture, followed in the 1960s by species that showed better culture characteristics such as faster growth e.g. the Nile tilapia (*O. niloticus*), the Blue tilapia (*O. aureus*) and the three spotted tilapia (*O. andersonii*). Currently, 98% of tilapia production occurs outside the species' native range. Worldwide distribution of the Mozambique tilapia and Nile tilapia are shown in Figure 45. Today more than 90% of all commercially farmed tilapia outside of Africa are Nile tilapia (*O. niloticus*). By 2008, global production of Nile tilapia exceeded 2.3 million tonnes compared with 38 000 tonnes of Mozambique tilapia and only 2 000 tonnes of three spotted tilapia (Table 32). The main producers of Nile tilapia by country can be seen in Figure 46.

Table 32 Global production of major tilapia species spanning two decades (FAO, 2010).

Species	Reported production (Tonnes) ¹		
	1988	1998	2008
<i>Nile tilapia</i>	132,182	723,970	2,338,775
<i>Mozambique tilapia</i>	34,578	40,652	38,140
<i>Blue tilapia</i>	2,657	844	2,687
<i>Three spotted tilapia</i>	964	2,689	1,996

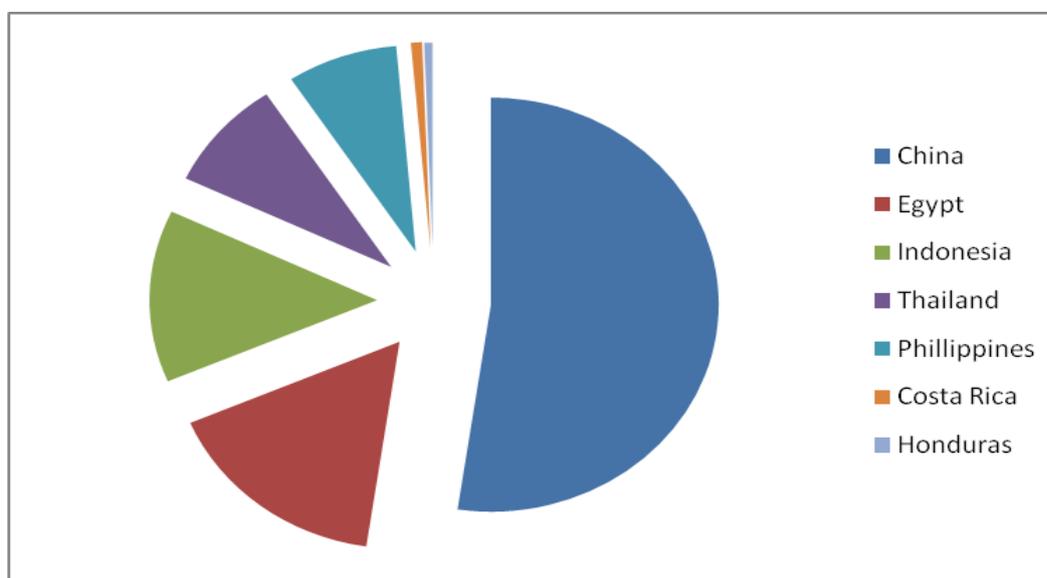


Figure 46. Main producers of Nile tilapia in all environments (*i.e.* freshwater, brackish water and marine) by country in 2008 (FAO, 2010).

The life cycle of *Oreochromis* species of aquacultural interest (Nile, Mozambique, Blue and Three spot) are similar and are therefore considered together below.

18.1.2 Reproductive biology of tilapia and implications for aquaculture production

In many farmed species the closure of the lifecycle is accompanied by artificial spawning of broodstock often through hormonal interventions (*e.g.* carp, catfish and salmonids). In tilapias, however, our inability to synchronise and monitor ovulating

females to date has meant that mass tilapia seed production is achieved by natural spawning under artificial conditions. In view of this fact, the understanding of the natural breeding behaviour and cycle and how this needs to be managed is vital for tilapia fry and fingerling production.

The tilapias have evolved varying degrees of parental care as part of their reproductive strategies in order to ensure their survival. This complex parental care which ranges from guarding of spawn laid on pre-cleaned substrates (*Tilapia spp.*) to mouth brooding is also accompanied by an increase in the size of the eggs and reduction in fecundity. The maternal mouthbrooding habit of *Oreochromis* and

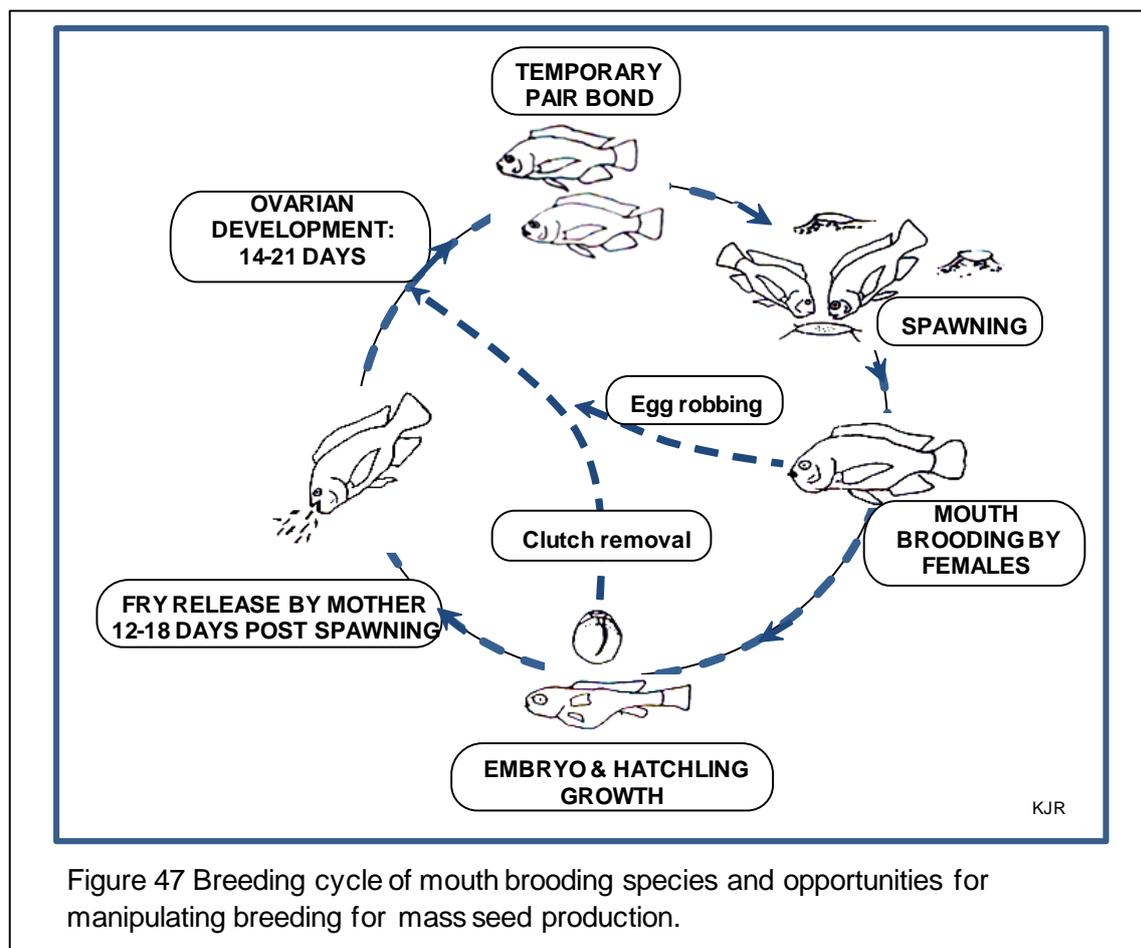


Figure 47 Breeding cycle of mouth brooding species and opportunities for manipulating breeding for mass seed production.

Sarotherodon spp. and their larger eggs confer greater survival on the young during their early ontogeny when compared with *Tilapia spp.* Indeed this reproductive strategy significantly influences the management of these species for seed production under aquaculture conditions.

Importantly, the reduced fecundity of about 500-1 000 eggs/spawn for tilapias when compared with 200 000 - 1 million eggs/spawn for carps and catfish necessitates the use and management of significantly larger number of broodstock for seed production in order to ensure mass seed production. In addition, the number of

eggs/spawn vary between tilapia species; for *O. niloticus* around 400-2000 eggs/spawn are reported depending on size of females whereas in *O. andersonii* the females produce fewer eggs than the other species, usually between 300 and 700 depending on the size.

The mouthbrooding tilapias have evolved complex breeding behaviour in which the survival of the progeny is paramount. The key phases of the breeding cycle are presented in Figure 47. In all *Oreochromis* species the male excavates a nest of varying shape and size. Under wild conditions such nests occur as clusters known as 'leks' but under farming conditions nests can be found throughout the pond but with a greater densities in the shallower regions of the ponds. The purpose of these nests are principally to demark a territory in which to invite females to spawn. The nests are typically saucer-shaped hollows ranging from 30-90 cm in diameter depending on the size of the male and enclosure size. Under farming conditions bottom substrate is not essential and successful breeding can occur in 'hapas' or suspended net enclosures and tanks devoid of any soil substrate.

Once the nests are constructed and defended the males solicits mature females to enter the nest to spawn. On successful enticement a temporary pair bond is formed and nest adjusted by both sexes spawning occurs. The female sheds her eggs in batches into the pit of the nest to be fertilized by the male. To ensure paternity, the male vigorously defends the nest to ward off other males. The eggs are then picked up by the female and brooded in her mouth (buccal cavity) (Figure 48). On completion of spawning the temporary bond is broken and female leaves the nest to rear her clutch. Under aquaculture conditions the success of natural incubation by females will depends on the management.

On leaving the nest and under ideal conditions the brooding female retreats to a sheltered and protected area to rear her clutch for 12 to 18 days. When considered safe the mother releases the fry for feeding and foraging. During this brooding period the females' does not feed and gonadal development is limited. Following the release of fry



Figure 48 Female Nile tilapia with brood in mouth

the female resumes feeding and gonadal develop progress depending of food availability. Under natural conditions the breeding cycle can last up to 4-6 weeks depending of temperature and food availability. The timing of spawning and

spawning frequency is temperature dependant. Spawning starts at temperatures above 20 °C with an optimal range of 25-30 °C.

18.1.3 Technical requirements and considerations for mass seed production of tilapias

Physio-chemical requirements

Tilapia are essentially tropical, lowland fish and display a general tolerance to poor environmental conditions e.g. high ammonia concentrations, low dissolved oxygen, turbidity, salinity and high temperatures. They do possess, however, a limiting tolerance to low temperatures. *O. niloticus* and *O. mossambicus* can tolerate a wide range of temperatures: 8–42°C but feeding is reduced below 20°C, ceases below 16°C and death occurs below 12°C. Suitable temperatures for reproduction are above 20°C. Tilapia can survive low levels of dissolved oxygen (DO) as they can utilise atmospheric oxygen.

Broodfish nutrition, stocking density and male:female sex ratio

In commercial seed production, medium-size broodfish (150-250g) are preferred and are usually discarded once they attain more than 300g as larger fish are difficult to handle during harvesting of seed and relative fecundity (number of eggs per unit weight of female) has been seen to decrease with maternal age, weight and length. There is limited knowledge on the nutrient requirement of tilapia broodfish however it is recognized that reproductive output is maintained at the expense of somatic growth and affects egg quality, total fecundity and inter spawning interval. Broodfish should therefore be provided with optimum levels of protein at 0.5-2% of their body weight daily in the diet from a young age up to the egg producing stage and studies have shown that 32% protein is adequate. The stocking ratio for females to males is 1-4:1 with 2 or 3:1 being the most common. The brood fish stocking rate is variable, ranging from 0.3-0.7 kg/m² in small tanks to 0.2 - 0.3 kg/m² in ponds. Spawning ponds are generally 2 000 m² or smaller. The popular 'hapa-in-pond' spawning system - a common hapa size is 120 m² - in Southeast Asia uses 100 g brood fish stocked 5 fish/m².

Selection of seed production systems

Breeding is asynchronous for *Tilapia*, *Oreochromis* and *Sarotherodon spp.* and may take place year round with suitable temperatures. Under farming conditions hormonal treatment is not required to induce spawning and three main options are available for procuring tilapia seed (see Figure 49). Choice of a suitable system may depend on human capacity, capital, acceptable production efficiency and climate

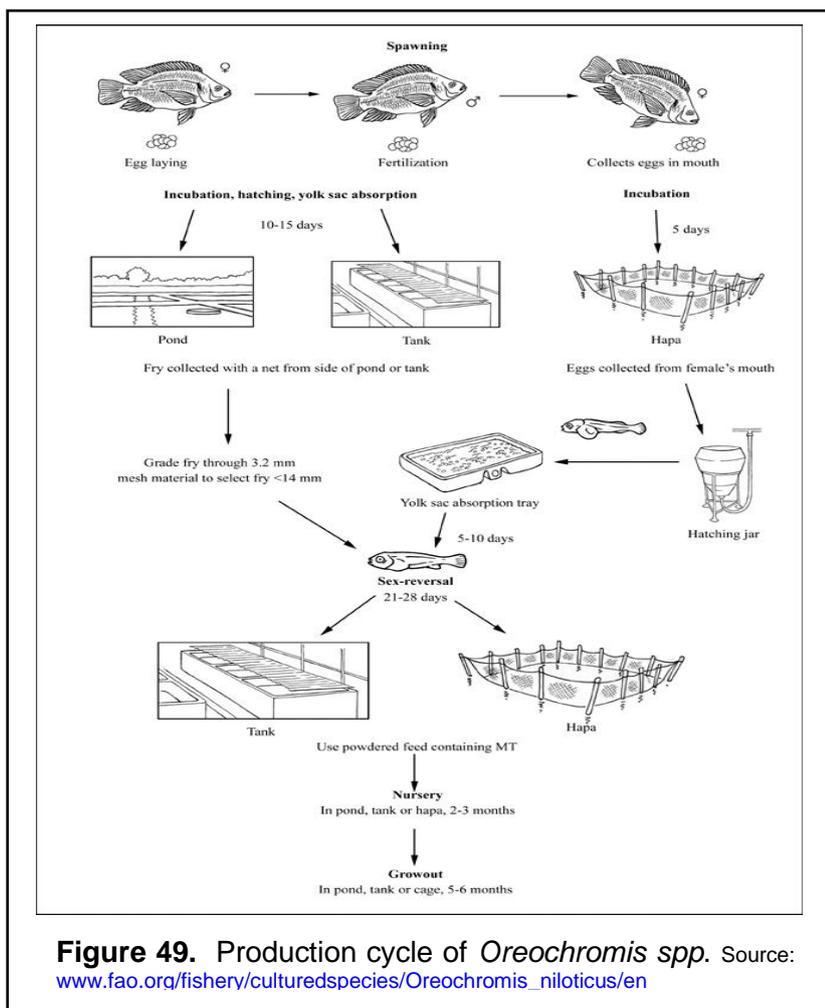
and these may include ponds, tanks or net enclosures (hapas) within tanks or ponds, that each have their own varying degree of management and technical requirements which in turn is reflected in the final seed output.

In tanks and ponds, broodstock can be left to breed and the released fry collected using various techniques at prearranged frequency. Swim-up fry gather at the edge of a tank or pond and can be collected with fine-mesh nets. Fry collection can begin

10 to 15 days after stocking. Multiple

harvests (six times per day at 5 day intervals) are conducted up to a maximum of 8-10 weeks before pond drainage and a complete harvest is necessary. Production of optimum-sized (<14 mm) fry ranges from 1.5 to 2.5 fry/m²/day (20 to 60 fry/kg female/day). Fry production in spawning ponds can be low due to incomplete harvesting and cannibalism.

http://www.fao.org/fishery/culturedspecies/Oreochromis_niloticus/en



Recently, techniques for spawning tilapia broodfish in large 'hapas' or nets (120 m²) suspended in fertilized ponds, harvesting seed from the mouths of females and incubating them artificially in tank-based hatcheries have been developed and commercialized especially in Southeast Asia. Under these controlled conditions, manipulation of inter-harvest interval and conditioning of males and females have improved seed output and spawning synchrony however, this method is much more labour intensive. Fouling of spawning 'hapas' as a result of build-up of uneaten food etc. which reduces water flow, decreases the availability of natural food and lowers

water quality inside the 'hapa' has been identified as a major problem and cleaning of fouled 'hapas' incurs high labour costs.

Frequent removal of eggs/fry can decrease inter-spawning interval (ISI) resulting in higher total seed output. The seed output can be further improved (>350 seed kg/female/day) by harvesting eggs/fry from the mouths of incubating females at 5 day intervals if females are conditioned for 10 days *i.e.* separation of males and females into different units under a good feeding regime (Table 33). However frequency of broodstock manipulation and harvesting is directly associated with labour costs and the level of management should be determined from the availability of labour and the costs involved. A 5-day cycle of seed harvest from the mouths of incubating females is used by the commercial hatcheries in Thailand.

Table 33. Seed output from *O. niloticus* females under different broodstock management regimes (From Bhujel, 2000).

Broodfish management regimes	Seed harvest intervals (days)	Seed output (number/kg female/day)
Fry harvest after natural incubation	-	31
Eggs and yolk-sac fry harvested from the mouth of females:		
No broodfish exchange	10	106
Only spawned females replaced	10	160
All females exchanged with 10-day conditioned females through rotation of 2 female groups	10	274
All females exchanged with 5-day conditioned females through rotation of 2 female groups	5	322
All females exchanged with 10-day conditioned females through rotation of 3 female groups	5	>350

Sex reversal

Commercial tilapia production requires the use of male monosex populations. A mixed-sex population will develop a large size disparity amongst harvested fish affecting marketability. This is due to the fact that males grow at approximately twice the rate of females and, in addition, the presence of females will lead to uncontrolled reproduction resulting in excessive recruitment of fingerlings (up to 70% of total harvest weight), competition for food and stunting of initial stock. The use of the

male sex hormone (17 α methyltestosterone or MT) in the feed of sexually undifferentiated fry will result in the development of phenotypic males. Therefore swim-up fry, collected from breeding facilities, need to be graded through 3.2 mm mesh material to remove fish that are > 14 mm *i.e.* too old for successful sex reversal. MT is dissolved in 95-100% ethanol is added to a powdered commercial feed or powdered fishmeal (< 40% protein) to create a concentration of 60 mgMT/kg feed. The alcohol carrier is usually added at 200 ml/kg feed and mixed thoroughly before the moist feed is air dried out of direct sunlight and then stored in dry, dark conditions. Fry are stocked at 3 000 to 4 000/m² in hapas or tanks with a good water exchange. Stocking densities as high as 20 000 fry/m² have been used if good water quality can be maintained. An initial feeding rate of 20-30% body weight per day is gradually decreased to 10-20% by the end of a 3-4 week sex-reversal period. Rations are adjusted daily and feed is administered four or more times per day. Sex-reversed fry reach an average of 0.2 g after 3 weeks and 0.4 g after 4 weeks. The average efficacy of sex reversal ranges from 95–100% depending on the intensity of management.

Fingerling production

After sex reversal, fingerlings are generally nursed to an advanced size before they are stocked into grow-out facilities. In small ponds they can be stocked at approx. 20-25 fish/m² and cultured for 2-3 months to an average size of 30-40 g. Final biomass at harvest should not exceed 6 000 kg/ha. They are fed extruded feed (30% protein) at an initial rate of 8-15 % of biomass per day, which is gradually decreased to a final rate of 4-9% per day. An alternative method of a more managed rearing to fingerling size is the use of a series of small cages (<4 m³) with a series of size-based gradings; fry can be initially stocked at a rate of 3 000 fish/m³ and grown for 6 weeks until fingerlings average 10 g, restocked at 2 500 fish/m³ to produce 25-30 g fingerlings in 4 weeks and then restocked further 1 500 fish/m³ to produce 50-60 g fingerlings in a further 4 weeks. Fingerlings should be fed 3-4 times daily with a 30% protein diet.

18.1.4 Technical requirements for on-growing of tilapia

Culture systems

A number of culture system options exist for the on-growing to marketable size of tilapia *i.e.* earthen ponds, cages, concrete tanks, and raceways using a variety of different management strategies that range from extensive, semi-intensive, intensive, monosex, culture mixed sex culture, monoculture, polyculture, and integrated with agriculture or animal husbandry (see Box 7). Such systems are widely used in Asia and Latin America and recently in parts of Africa.

Ponds

Pond culture of tilapia is conducted with a variety of inputs such as agricultural by *i.e.* manures, inorganic fertilizers and feed. Animal manures provide nutrients that stimulate the growth of protein-rich phytoplankton, which is consumed by filter feeding Nile tilapia. The nutrient content of manures varies and obtaining sufficient nutrient levels from manures poses a danger of oxygen depletion from excessive loading of organic matter. Therefore, a combination of manures with inorganic fertilizers is used in low-input production systems.

Box 7. Definitions:

Extensive systems: Extensive culture systems are characterized by a low level of intervention, *i.e.* limited feeding and fertilization, low investment capital, and primitive management.

Semi-intensive systems: A relatively higher level of intervention and higher investment capital characterizes this system.

Intensive systems: A higher level of intervention, high level of production, high production risk, and high investment capital characterizes intensive culture systems

In Thailand, applying chicken manure weekly at 200-250 kg DM (dry matter)/ha and supplementing it with urea and triple super phosphate (TSP) at 28 kg N/ha/week and 7 kg P/ha/week produces a net harvest 3.4-4.5 tonnes/ha in 150 days at an initial stocking rate of 3 fish/m² or an extrapolated net annual yield of 8-11 tonnes/ha.

Many semi-intensive farms rely almost exclusively on high quality feeds to grow tilapia in ponds. Male tilapia are stocked at 1-3 fish/m² and grown to 400-500 g in 5-8 months, depending on water temperature. Normal yields range from 6-8 tonnes/ha/crop but yields as high as 10 tonnes/ha/crop have been reported. Dissolved oxygen should be maintained by exchanging 5-15% of the pond volume daily. Higher yields of large fish (600-900 g) have been obtained through the use of a higher quality feed (up to 35 % protein), multiple grow-out phases (restocking at lower densities up to three times), high water exchange rates (up to 150% of the pond volume exchanged daily) and continuous aeration (up to 20 HP/ha). Fish produced through these expensive methods are generally filleted and sold in export markets.

Floating cages

Cage culture also is a common production method, and in some countries, this method is used more widely than ponds and may be located in ponds, reservoirs, lakes, streams, irrigation systems, or estuaries. Cages vary widely in size and construction materials and design ranges from simple ones made on site from

netting of 2-4 m³ volume stocked at 200-300 fish/m³ to cages to larger manufactured cages of c. 100 m² stocked at 25-50 fish/m³. Yields ranging from 150 kg/m³ in 4 m³cages to 50 kg/m³ in 100 m³ cages. Mesh size has a significant impact on production and should be 1.9 cm or greater to maintain free circulation of water. The fish are fed extruded feeds with 24-34% crude protein.

Cage culture offers several important advantages. The breeding cycle of tilapia is disrupted in cages, and therefore mixed-sex populations can be reared in cages without the problems of recruitment and stunting and also it optimizes the use of water bodies that cannot be drained or seined and would otherwise not be suitable for aquaculture. In addition, the close observation of fish feeding response and health and a potential flexibility of management with multiple production units allows for an ease and low cost of harvesting. However, there are a number of disadvantages, which include the risk of loss from poaching or damage to cages from predators or storms, a complete dependence on nutritionally complete diets and a greater risk of disease outbreaks.

Tanks and raceways

Tilapia are cultured in tanks and raceways of varying sizes (10-1 000 m³) and shapes (circular, rectangular, square and oval). An important characteristic of tank design is the effective removal of solid waste; a circular tank with a central drain is the most efficient design. Water exchange ranges from <0.5 % of tank volume/day in tanks to 180 exchanges per day in raceways. Low exchange tanks rely on nitrification in the water column to remove toxic nitrogenous waste, while raceways depend on water flow to flush waste from the tank. Raceways often are elongated concrete troughs 2- to 4-m wide and 10- to 50-m long. They also may be elongated earthen ponds or plastic troughs or tanks. The rate of water flow through raceways also varies greatly, and the normal range in exchange rate probably is about 0.5 to 4 exchanges/hour. The maximum tilapia density in raceways ranges from 160-185 kg/m³, and maximum loading ranges from 1.2-1.5 kg/litre/min. A common production level in raceways is 10 kg/m³/month, as water supplies are often insufficient to attain maximum rates. Production levels are considerably lower in tanks with limited water exchange, but water use efficiency is much higher in these systems.

Harvesting handling and transport

Harvesting in ponds is carried out by seine netting and complete harvesting should be carried out by draining. The pond should be dried between production cycles or treated with pesticides to kill tilapia fry to avoid carry over to the next production

cycle. Partial harvests of tanks, raceways and recirculation systems, which maximize production, are accomplished with grader bars to remove the largest fish. Tilapia must be tested for flavour before they will be accepted for processing and marketing in developed countries and if off-flavour is detected they should be purged in clean water for 3-7 days in holding tanks or ponds. Tilapia are hauled live to processing plants, killed humanely in ice water and processed manually or mechanically. Dressing percentage depends on condition factor. Nile tilapia with a condition factor of 3.11 will dress at 86% with head, 66% without head, and 33% for a skinless fillet.

Diseases and control measures

Tilapia are susceptible to a range of bacterial diseases e.g. MAS (Motile Aeromonas Septicaemia), Vibriosis and Streptococcosis which can be treated with oral administration of antibiotic. Tilapia may also be afflicted with the external protozoan ciliate *Ichthyophthirius multifiliis* and the monogenic trematode *Dactylogyrus spp.* and be treated with chemical baths.

Feed supply

Adult tilapias are predominantly vegetarian but display ontogenic and species specific differences in their feeding habits. Natural foods can range from macrophytes to phytoplankton, but tilapia will also eat aquatic invertebrates, plankton, benthic organisms, larval fish as well as decomposing organic matter. Larval stages and fry feed in shallower water than adults, mainly on detritus and zooplankton and juveniles feed on detritus and periphyton. The use of prepared feeds that offer a complete diet *i.e.* sufficient protein, lipids, carbohydrates, vitamins and minerals) are available in developed countries and also available in developing countries with an existing export market for high quality tilapia products although some of the main feed ingredients such as soybean meal or fishmeal may be imported. If prepared feeds are not available then often farmers will rely on manures and agricultural by-products.

18.1.5 Market and trade potential for Namibian-grown tilapia

Global overview of the culture of tilapia species

World tilapia production has increased significantly over the last decade, with output doubling from 830 000 tonnes in 1990 to 1.6 million tonnes in 1999 and to 3.5 million tonnes in 2008. Table 34 clearly demonstrates that aquaculture was

responsible for this increase, whilst capture fisheries of tilapia stayed more or less stable over the years, at 750 000 tonnes.

Currently Asia represents about three quarter of world tilapia production. China, by far the main tilapia producing country, produced 1.1 million tonnes in 2008 whilst the rest of Asia contributes 0.9 million tonnes. Africa, mainly Egypt, is important with 430 000 tonnes of cultured tilapia production. Latin America only accounts for 280 000 tonnes total tilapia production is mainly Nile tilapia (*O. niloticus*). All new countries entering tilapia production concentrate on this species, which is easy to grow. Indeed, in 2008, around three quarters of world tilapia production were Nile tilapia.

Table 34. Total world tilapia production: 2004-2008 (tonnes) (FAO, 2010)

Source	2004	2005	2006	2007	2008
Capture	756 530	740 194	717 787	777 340	755 362
Culture	1 795 049	1 996 135	2 238 046	2 550 977	2 797 714
World Total	2 551 579	2 736 329	2 955 883	3 328 317	3 553 076

China is the main supplier of tilapia to the international market with 260 000 tonnes in 2009. Out of this amount, some 134 000 tonnes went to the USA and about 19 000 tonnes to the EU market. In addition China exported 36 000 tonnes to Mexico and 22 000 tonnes to Russia. Africa, mainly Egypt and Côte d'Ivoire, is an important importer of tilapia from China at 20 000 tonnes in 2009. In 2009, Taiwan (Province of China) sent 21 500 tonnes of tilapia to the USA and nothing to the EU. Other Asian countries contributed with 10 000 tonnes going to the US market and 2 000 tonnes to the EU market. Finally Central America exported about 12 700 tonnes, all to the US market, and almost all in fresh fillet form, while 9 300 tonnes of this product were shipped from South America – mainly Ecuador – to the same market. Almost no tilapia goes from Latin America to Europe.

Tilapia is internationally in the process of capturing market shares in white fish product markets and there is no doubt that tilapia supply will continue to expand in coming years. It is also a staple source of affordable animal protein for the rural and urban poor. It is clear therefore that China dominates the market, representing c. 90% of total supply.

There also exists a potential for export of tilapia species from Namibia to the EU exists. In 2006 European interest in tilapia increased significantly and imports into Germany, for example, increased by 150%. Imports into Russia also exploded and the country imported 5 500 tonnes of tilapia from China. Although production costs

in Africa are generally higher than they are in Asian countries, this is usually because operations are small and many inputs such as feed need to be imported. If production costs can be reduced then a viable export market to the EU could exist

Overview of tilapia species currently farmed in Namibia

Tilapia species currently farmed on a small-scale subsistence level in Namibia are locally occurring species e.g. three spotted tilapia (*O. andersonii*) and the red breast bream (*T. rendalli*) (Figure 50). A commercially operated farm established in 1998 at Hardap Dam farms a hybrid of the Nile tilapia and is currently (2010) producing 360 tonnes/year and operating costs stand at N\$15/kg.

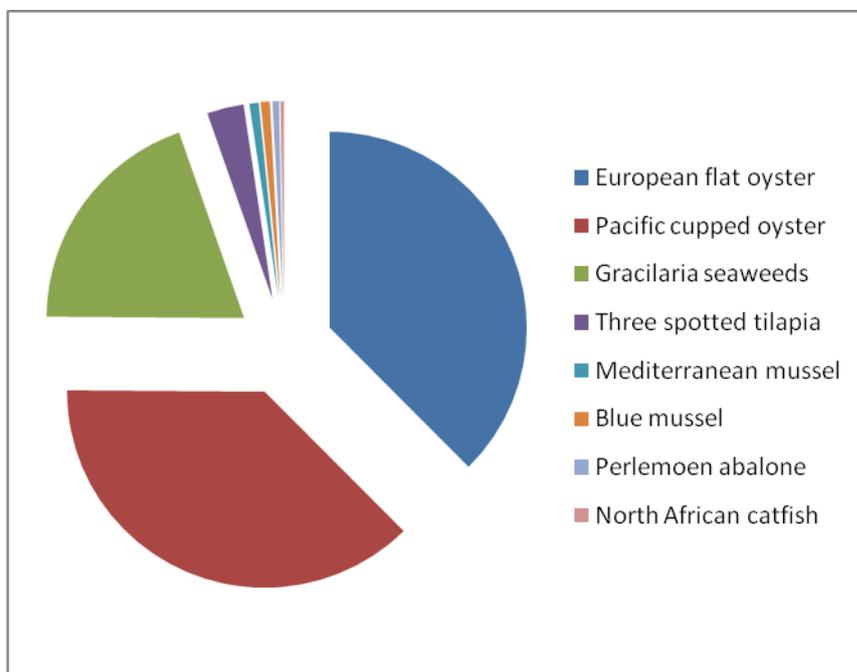


Figure 50 Total cultured species in Namibia 2009 (FAO, 2010).

Local and regional prices of farmed tilapia species

Tilapia is sold mainly round or gutted in this market, at a size of 300-500 g/fish. The price varies from country to country, but for example in South Africa, the farm gate price is around R25-30/kg (US\$3.50-4.20). Zambia and Botswana currently buy commercially farmed tilapia at US\$2.20-2.30/kg whole fish from Lake Harvest in Zimbabwe. The product is seen in Botswana supermarkets at Pula 32/kg. One company in Zambia buys 50 tonnes of frozen farmed tilapia from Zimbabwe every month.

Farmed tilapia fillets have a higher regional price of around US\$5/kg. In addition, tilapia filleting produces by-products, which can be sold cheaply to the local low income earners. A fillet is about 30% of the whole fish, the head, frame and belly flaps (which are also rich in protein) account for another 30%, and the remaining 40% is by-products unfit for direct human consumption (scales, guts etc.). Therefore, for every 1 kg of fillets sold, 1 kg of low priced protein rich, consumable products, and more than one kg of waste products are generated.

Potential target countries for export: regional

Freshwater fish are well known within Namibia and form part of the traditional diet of the population. As the wild catches are diminishing, the region needs alternative sources of cheap fish products for food security. At present, Namibia exports marine products to the regional market; therefore the distribution channels for Namibian fish are already place, providing access for aquaculture product to the existing markets. In addition, Namibia has a good road network system that links the country to the bordering countries.

It is generally accepted that there is an existing and growing demand for tilapia in Africa itself. Lake Harvest Aquaculture identified current and potential consumption patterns of tilapia in the South African Development Community (SADC) (Table 35).

Table 35 Current and potential consumption of tilapia spp. in SADC

Country	Current consumption (tonnes)	Potential in next 5-10 years (tonnes)
Angola	2 000	4 000
Botswana	100	2 500
DRC	1 000	10 000
Malawi	>3 000	>10 000
Mozambique	250	1 000
South Africa	500	10 000
Zambia	2 000	6 000
Zimbabwe	1 000	2 500
Total	9 8590	46 000

Source: pers. comm. Gerry McCollum, Lake Harvest Aquaculture, 2007

Potential target countries for export: global

In Europe, the development of the tilapia market has been slower, but there is now an increasing interest in tilapia products that is reflected in the steady flow of both whole frozen, and fresh and frozen fillets, entering the European market. 2003 saw EU imports of 7 808 tonnes of frozen tilapia with Taiwan as the largest exporter of frozen tilapia at 6 227.1 (Table 35) tonnes and EU imports of fresh fillets at 433.7 tonnes with Zimbabwe as the largest exporter at 384.7 tonnes (Table 36).

Table 35 EU imports of frozen tilapia (tonnes)

Origin	1996	1997	1998	1999	2000	2001	2002	2003
Taiwan	1 476.2	1 856.2	2 833.3	4 042.0	5 087.3	5 543.5	7 382.5	6 277.1
China	85.9	45.5	74.1	132.0	572.8	1 863.1	197.6	988.0
Brazil	21	10.1	10.5	8.5	0.3		107.2	425.4
Ecuador	14.1	37.1	38.6		48.0	55.1	27.7	69.1
Jamaica	1.5							49.0
Others	222.9	128.0	84.3	193.8	180.1	240.7	91.4	
Total	1 821.6	2 076.8	3 040.8	4 376.3	5 888.5	7 702.4	7 806.4	7 808.6

Source: <http://www.globefish.org/homepage.html>

Table 36 EU imports of fresh tilapia fillets (tonnes)

Origin	1996	1997	1998	1999	2000	2001	2002	2003
Zimbabwe			11.7	54.4	29.7	363.8	284.4	384.7
Jamaica	1.5		25.4	37.9	80.7	76.8	90.8	49.0
Brazil					0.4		8.5	
Ecuador	14.1				0.1	2.0		
Others	11.1	16.9	0.1		17.6			
Total	26.7	16.9	37.2	92.3	128.5	442.6	383.7	433.7

Source: <http://www.globefish.org/homepage.html>

18.2 Culture and Market Potential for the Culture of African Catfish (*Clarias gariepinus*) in Namibia



18.2.1 Introduction

Clarias is a genus of catfishes (order Siluriformes) of the family Clariidae, the airbreathing catfishes. *Clarias gariepinus* (Burchell, 1822) or the African catfish has almost Pan-African distribution, from the Nile to West Africa and from Algeria to South Africa. It also occurs in the Levant *i.e.* Israel, Syria and southern Turkey. It is a large eel-like fish, usually grey or black in colouration on the back fading to a white belly. It has an average adult length of 1-1.5 m and can weigh up to c. 30 kg. It has a slender body, a flat bony head and a broad, terminal mouth with four pairs of barbels and only the pectoral fins have spines. It also has a large, accessory breathing organ composed of modified gill arches that allows it to breathe for short periods out of the water (Figure 51).

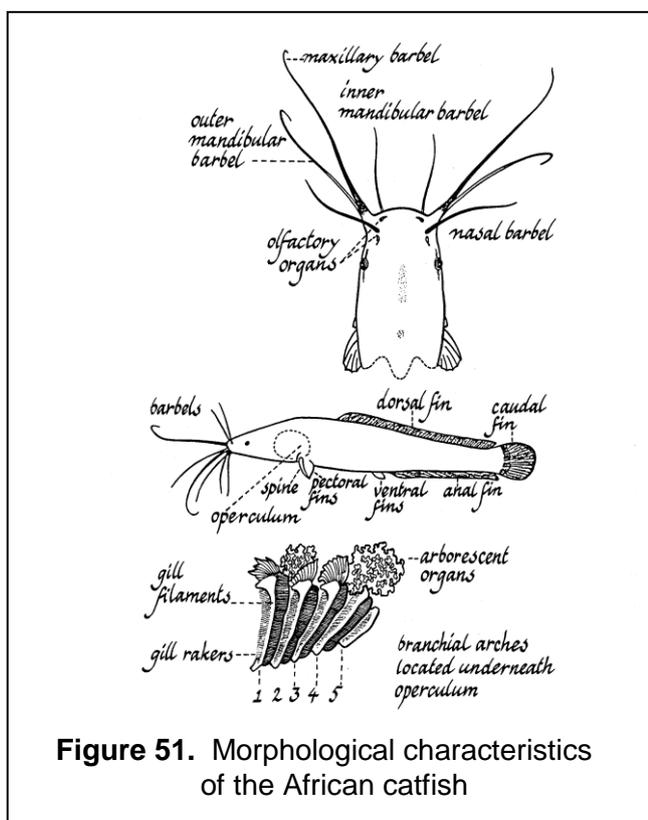


Figure 51. Morphological characteristics of the African catfish

In the 1970s it was recognized that the African catfish offered enormous potential for aquaculture in Africa due to its high growth rate, resistance to handling and stress and, in addition, was already well appreciated as a food fish in a wide number of African countries. The development of a reliable and repeatable method for the mass production of African catfish seed was consequently a priority of aquaculture research in Africa and in the 1980s an intensive production system for African catfish fingerlings was developed. However, this did not guarantee a successful implementation as numerous technical and economic problems were encountered which, to a certain extent, have been overcome in the last 20 years and total aquaculture production now stands at 85 593 tonnes.

18.2.2 Reproductive biology of African catfish and implications for aquaculture production

The African catfish inhabit calm, static or slow flowing water bodies that range from lakes, streams, rivers, swamps to floodplains, some of which are subject to seasonal drying. The catfish can survive during the dry seasons due to the presence of the accessory, air breathing organs. It displays a seasonal gonadal maturation which is usually associated with the rainy season. Indeed, the maturation process of the African catfish is influenced by annual changes in water temperature and photoperiodicity and the final triggering of spawning is caused by a raise in water level due to rainfall. In Lake Victoria (Kenya) reproduction begins in March, just after the start of the first heavy rains, and is complete by July. Thereafter the oocytes start maturing gradually and become ripe again in the following March.

Spawning mostly takes place at night in shallow, inundated areas of the rivers lakes and streams. Courtship is preceded by highly aggressive encounters between males and subsequently takes place in shallow waters between isolated pairs of males and females. The male lies in a U-shape curve around the head of the female and this is held for several seconds; a batch of milt and eggs is released followed by a vigorous swish of the female's tail to distribute the eggs over a wide area. The pair usually rest after mating and then resume mating. There is no parental care for ensuring the survival of the catfish offspring except for the careful choice of a suitable site. The adhesive eggs stick to submerged vegetation and hatch in 20–60 hours, depending on temperature. The yolk sac is absorbed within 3–4 days and the stomach is fully functional within 5–6 days after onset of exogenous feeding. Sexual differentiation begins between 10 and 15 days after hatching.

Female African catfish respond to temperature for the initial stages of oocyte maturation. Indeed the mature female catfish has a fully developed ovary which contains 'ripe' eggs the whole year through, if kept in ponds, if water temperatures

remains above 22 °C, however, oocyte development decreases once the temperature drops below 22 °C. The eggs of a 'ripe' female may make up 15-20% of the body weight. However, it is a response to environmental stimuli such as a rise in water level and inundation of low-lying areas that the final stages of oocyte maturation and egg release occur. These events do not occur in captivity since the environmental factors do not occur on the fish farms therefore artificial manipulation of the spawning cycle using hormone treatment is employed to ensure large-scale production of catfish fingerlings.

18.2.3 Technical requirements for mass seed production of African catfish

The procedures and techniques described below for seed and on-growing catfish production are now used successfully across the developing world. Variations do exist but this often relates to availability and cost.

Semi-artificial hormone-induced reproduction

A mature female is injected with hormones (see Table 37) and placed with non-injected males in either fully filled ponds, 'hapas' (*i.e.* suspended nets *c.* 2-3 m³ made of mosquito netting with a 0.5 mm mesh size) located within a pond or in concrete tanks with a gravel substrate, in order to provoke ovulation, mating and the spawning processes. The adult fish are removed once spawning has taken place and the eggs are allowed to incubate and the larvae can be collected from the respective systems once hatched. Disadvantages of semi-artificial reproduction are that ovulation following hormonal injection is often only partial and low numbers of larvae are produced and, in addition, adult breeders can injure themselves in enclosed spaces often resulting in death.

Table 37. Hormones used for induced reproduction in the African catfish⁽³⁾ FAO, 1996)

Name	Dosage	Comments
DOCA (Desoxycorticosteroid Acetate)	2.5-5 mg/100 g of female	A disadvantage of using this hormone is that it is mostly suspended in oil which causes severe ulcers on the injected female
HCG (Human Chorionic Gonadotropin),	25 I.U./100 g of female.	This hormone works well but it is expensive

Name	Dosage	Comments
Common carp (<i>Cyprinus carpio</i>) pituitary gland material	3-4 mg/kg of female or 1-2 whole pituitaries /female.	In general the common carp pituitary gland material has to be imported from abroad which means that it is usually not accessible for small fish farms.
Pituitaries of the African catfish (<i>C. gariepinus</i>).	A female catfish will respond once it injected with a pituitary of a catfish (male or female) of equal size.	Cheaper and more accessible
Pituitaries of the Nile Tilapia (<i>Oreochromis niloticus</i>),	3-4 pituitaries of a Nile Tilapia (100-150 gram)/female catfish will induce ovulation	Cheaper and more accessible
Pituitaries of Nile perch (<i>Lates niloticus</i>).	1-2 pituitaries per female catfish will induce ovulation.	Cheaper and more accessible

Artificial hormone-induced reproduction

Since the methods described above have not proved to be a liable method for mass production of seed necessary for larger fish farms or distribution centres of catfish fingerlings, hormone treatment followed by artificial fertilization and incubation of fertilized eggs and the subsequent rearing to fingerling size is usually applied. This offers several advantages that include better rates of fertilization and hatching and better control over environmental rearing conditions resulting in better growth and survival.

Broodstock selection

Broodfish are generally selected from nature or from a fish farm and held in earthen ponds at a stocking density of 0.5-1.0/m² and fed regularly with agricultural waste products or trash fish. In order to ensure year round supply of eggs in areas where water temperature drops below 22 °C, broodfish can also be kept indoors in a temperature controlled hatchery.

Male broodstock should be larger than 200 g and not less than 7 months old. Females are selected according to the following criteria:

- Weight between 300-800 g
- Displaying a well-distended, swollen abdomen with reddish coloured papilla from which ripe eggs, generally uniform in size with a clearly visible nucleus, can be obtained with slight pressure.

Hormone injection

Females are moved to holding tanks and injected with hormones or pituitary gland material in order to induce final maturation of oocytes and ovulation (see Table 37 for dosages). The required quantity of powdered acetone dried pituitary material or the required number of whole pituitaries are pulverized in a porcelain mortar, mixed with the required quantity of physiological salt solution (9 g of common salt/litre of water). A syringe is filled with the suspension and the injection can be given. The most common method of administering the hormone solution is by intra-muscular injection into the dorsal muscle (see Figure 52).

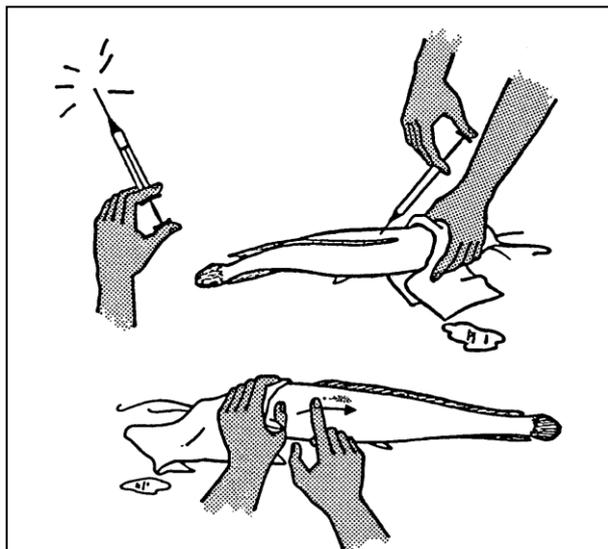


Figure 52. Injection of female broodstock

Maturation process and stripping of gametes

The final stages of oocyte maturation and ovulation *i.e.* release of ripe oocytes into the ovarian cavity take place and then the eggs must be stripped. *Note* the time interval between injection and final stripping is temperature dependant so timing should be adjusted according to existing water temperature (see Table 38). Stripping is carried out by gently pressing their abdomen with a thumb from the pectoral fin towards the genital papilla and ovulated eggs will flow out easily in a thick jet from the genital vent and are usually collected into a dry plastic container (Figure 53).

The males of the African catfish cannot be stripped and consequently the sperm can only be obtained by sacrificing a male. The male is killed and the body surface

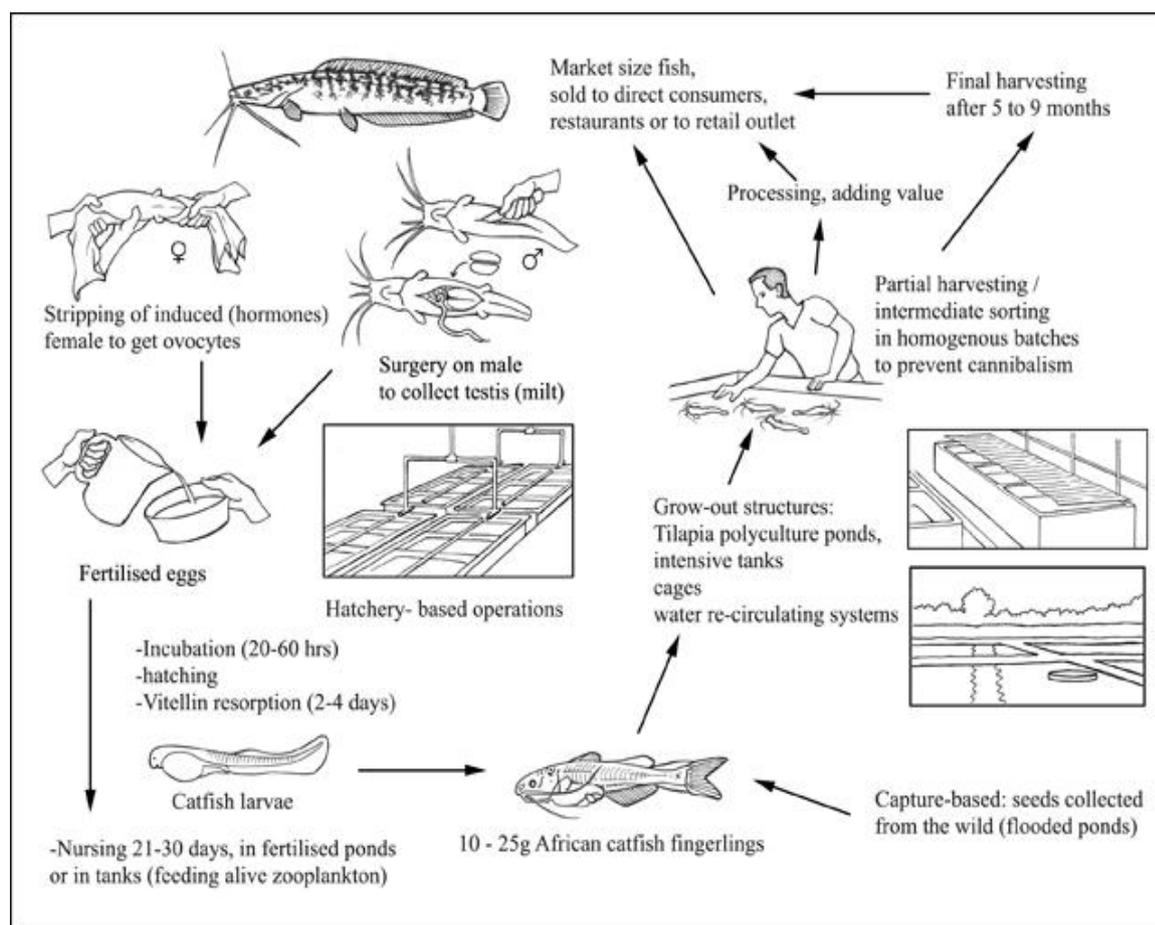


Figure 53 Production cycle of African catfish Source www.fao.org/fishery/culturedspecies/Clarias_gariepinus/en

Table 38 Time interval between injection and stripping in female African catfish (FAO, 1996)

Water temperature (°C)	Time between injection and stripping (hours)
20	21
21	18
22	15,5
23	13.5
24	12
25	11
26	10
27	9
28	8
29	7.5
30	7

thoroughly dried after which the testis is dissected and placed in a mortar or a teacup. The testis is rapidly cut into small pieces using a scissor and finally the milt is pressed out with a pestle or a teaspoon (see Figure 53). One testis of a mature male can easily fertilize the eggs of 10-15 females. The sperm is added to the stripped eggs, and the eggs fertilized by adding an equal volume of clean water. The water and egg mass are then mixed by gently shaking of the bowl. Eggs must be stirred continuously until they are placed in the hatching tanks as the eggs become sticky and without stirring will stick together into a clump.

Artificial incubation of fertilized eggs

The eggs can be either spread out on the bottom of a concrete basin with daily treatment of malachite green (0.1 ppm) to prevent fungal infection or spread on a screen (mesh size 1 mm) placed on the bottom of the concrete basin, with flowing water. Alternatively eggs are allowed to 'stick' to the roots of the floating water

Nursery production in earthen ponds

At yolk sac absorption fry should be transferred to nursery ponds. These can range in size from 100-150 m² and 0.8 m depth and should be clear of predators *i.e.* water insects or amphibian larvae and should be limed and fertilised with prior to filling in order to ensure a good zooplankton bloom that will provide the required live feed for the first feeding larvae. Catfish larvae can be stocked at 75-100 larvae/m² and daily, supplementary feeding must start immediately after stocking at a feeding rate of 1-2 kg of rice/wheat bran/100 m². In addition, 2 equal portions 6 days a week of formulated feed containing fishmeal should be fed starting at 0.50 kg/100 m²/day at incremental rates of 0.25 kg/100 m²/week until the fifth week. Growth after around 50 days can result in weight at harvest of . 3 g fingerlings (see Table 39).

Table 39 Average production figures for the nursery rearing of African catfish (FAO, 1996)

Production parameter	Results
Initial stocking density (#/m ²)	80.0±5.8
Rearing period (days)	48.3±4.6
Harvested fingerlings (#/m ²)	32.3±3.3
Survival rate (% of stocked total)	38.7±3.7
Weight at harvest (g)	3.1±0.5

A major factor which influences the success of the nursing phase is the length of the rearing period. In general, four to five weeks after stocking, two distinct size groups of catfish can be recognized within the pond consisting of a large group (80-90% of the biomass) consisting of small sized fingerlings (2-3 g) and a small group of fingerlings (10-20% of the total biomass) consisting of large fingerlings (8-10 g). Cannibalism will occur (*i.e.* the large fish will eat the smaller ones) if the two groups are not separated and only a small number of large fish will be harvested.

18.2.4 Technical requirements for on-growing of African catfish

Monoculture in earthen ponds

Monoculture of the African catfish can be carried out when suitable feed, with a high protein content is available. Growth of African catfish decreases with increased stocking rates while the standing crop remains more or less the same therefore the stocking rate depends upon the market size desired and varies from 2 to 10 fingerlings/m², which in turn corresponds to a market size of approximately 500 and 200 g, respectively after a 6 month rearing period. Some data on monoculture of African catfish are presented in Table 40.

Table 40 Biological data on monoculture of African catfish in the Central African Republic (FAO, 1996)

Week	Mean body weight (g)	Survival (%)	Biomass (kg/100 m²)	Feeding rate (%/biomass/day)	Feed (g/100 m²/day)
0	1	100	1	10	100
2	5	70	3.5	7.5	250
4	10	65	6.5	4.5	300
6	18	60	10.8	4.0	400
8	27	60	10.2	3.3	525
10	36	60	21.6	3.0	650
12	52	55	28.6	2.7	775
14	65	55	35.7	2.6	900
16	79	55	43.4	2.4	1025
18	102	50	51.0	2.3	1150
20	130	50	65.0	2.1	1350
22	160	50	80.0	1.9	4500
24	200	50	100.0	1.8	Harvest

Tanks and raceways

Although most farmers of African catfish are pond owners, African catfish can also be grown in peri-urban concrete tanks and raceways where there are fewer input availability constraints *i.e.* rearing infrastructures, power, seed, feeds, specialised manpower, market access *etc.* In the typical backyard 4 m x 3 m x 1.3 m concrete tank, 400 catfish fingerlings of 5-15 g are stocked, and fed with a balanced diet for 6

months. The water is renewed once or twice per week and a production of 300-600 kg/cycle is recorded, however this may vary according to the skill of the fish farmer.

Feed requirements

The African catfish has a relatively high dietary protein requirement, therefore feeding with a formulated feed is a prerequisite for intensive monoculture of the African catfish. The best growth rates and food conversions are achieved with diets containing 35-42% crude protein. Artificial formulated diets are generally composed of a mixture of vegetable and animal feedstuffs (usually agricultural and mill by-products) supplemented with vitamins and minerals. It is difficult to give standard formulation for a balanced diet for catfish since the composition of artificial diets will depend upon the availability and prices of locally available feedstuffs which in turn vary considerably between countries. Least cost formulation methods are used within the feed manufacturing. In most African countries, raw materials containing high amounts of animal protein such as fishmeal and blood meal are scarce and expensive. Hence, it is easier to meet the relatively high protein requirements for African catfish by using feedstuffs containing higher quantities of vegetable protein such as plant oilseed cakes and meals. These agricultural by-products are more common, cheaper and generally available in large quantities in the region.

Harvesting handling and transport

In order to prevent cannibalism, catfish ponds are netted using hauling seines during the production cycle and the fish are manually sorted and the larger fish are stocked separately. At the end of the rearing cycle ponds are completely drained and the pond bottom dried in order to prevent predation by remaining adult fish on the next batch of newly stocked fingerlings. Tanks, raceways and recirculation systems are partially harvested with grader bars to remove the largest fish. African catfish can stay alive for many days out of water. Harvested fish destined for local markets are loaded live into 40 L containers or in bags and transported in hauling pick-ups and taken to city markets where the fish are sold directly to consumers. Depending on fish size and market demand, the fish may be steaked, filleted or sold headed, gutted, and skinned.

Diseases and control measures

Catfish are susceptible to a range of diseases including bacterial *e.g. Aeromonas spp.*, fungal and parasitic *e.g. Gyrodactylus spp.* However, there are some observed diseases whose causative agents are unknown *e.g.* broken head syndrome that causes skeletal deformities, lethargy and a swollen or cracked head resulting in

death which can be avoided with proper management and a vitamin C supplement in feeds.

18.2.5 Market and trade potential for Namibian-grown African catfish

Global overview of catfish culture

The global catfish industry focuses on three major species e.g. the Channel catfish (*Ictalurus punctatus*) in the US, the Vietnamese catfish (*Pangasius spp.*) in Vietnam and the African catfish (*Clarias spp.*) in Africa. Global production of African catfish has shown considerable growth in the last decade (see Table 41). Nigeria is currently the main producer of African catfish at 75 662 tonnes in 2009 but the Netherlands, Hungary, the Syrian Arab Republic, Kenya, Ghana and Mali also produce significant quantities (Figure 54).

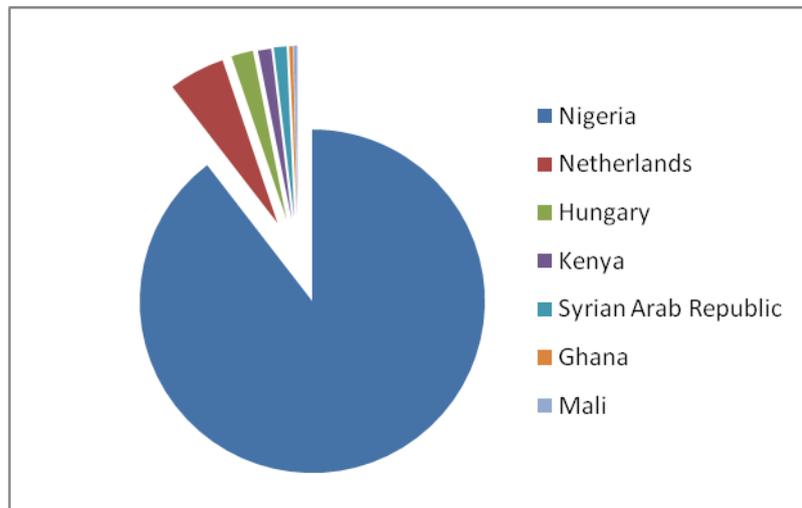


Figure 54. Main producers of African catfish by country in 2009 (FAO; FishStat, 2010).

Table 41 Global production of African catfish spanning two decades (FAO, 2010).

Species	Reported production (tonnes)		
	1989	1999	2009
African catfish	783	3 222	85 593

Prices of farmed African catfish

There are no prices to be obtained for the international market as none is traded internationally or possibly have been included in the 'other freshwater fish' statistics in the FAO Fish Stat databases

Potential target countries for export

There is good local demand for catfish particularly in Namibia's rural North West regions where the current selling price averages US\$ 3.5/kg. However, catfish products are still not as popular as tilapia in the regional export markets and prices are a little lower although the market in sub-Saharan Africa is seen to be developing. It is likely that catfish farmers cannot compete on the international export market with prices of African catfish fillets standing at US\$ 3/kg. Consequently their production and marketing will initially be confined to local markets, pending further market research and product development.

18.3 Culture and Market Potential for the Culture of the Giant Freshwater Prawn (*Macrobrachium rosenbergii*) in Namibia



18.3.1 Introduction

Macrobrachium rosenbergii (De Man, 1879), the Giant Freshwater Prawn or Giant River Prawn is indigenous to the whole of the South and Southeast Asian area as well as in northern Oceania and in the western Pacific islands. It is a freshwater species, preferring turbid conditions, however requires brackish water in the initial stages of its life cycle and therefore is found in water that is directly or indirectly connected with the sea. Although several species of the freshwater prawn have demonstrated potential as a candidate for aquaculture, it is the *Macrobrachium rosenbergii* that has emerged as the most suitable candidate for commercial culture.

Modern farming of this species originated in the early 1960's when FAO expert Shao-Wen Ling, working in Malaysia, found that freshwater prawn larvae required brackish conditions for survival. Larval rearing on an experimental basis followed and, by 1972, the Hawaiian team led by Takuji Fujimura had developed mass rearing techniques for commercial-scale hatchery production of prawn post larvae (PL) resulting in the development of commercial farms in Hawaii. The introduction of broodstock, initially from Hawaii and Thailand, into non-indigenous areas around the world began in the 1970s and the first major FAO project designed to expand the culture of this species began in 1978 in Thailand. Since then, giant river prawn culture has developed in every continent, particularly in Asia and the Americas.

18.3.2 Reproductive biology of the giant freshwater prawn and implications for aquaculture production

External morphology

All freshwater prawns have to regularly cast their 'exoskeleton' or shell in order to grow and this process is referred to as moulting and is accompanied by a sudden increase in size and weight. The body of postlarval and adult prawns consists of the cephalothorax ('head') and abdomen ('tail') (Figure 55) and are divided into twenty segments (known as somites).

There are 14 segments in the head, which are fused together and invisible under a large dorsal and lateral shield, known as the carapace. The carapace is hard and smooth, except for two spines on either side; one (the antennal spine) is just below the orbit and the other (the hepatic spine) is lower down and behind the antennal spine. The carapace ends at the front in a long beak or rostrum, which is slender and curved upwards. The front portion of the cephalothorax, known as the cephalon, has six segments and includes the eyes and five pairs of appendages. The rear portion of the cephalothorax, known as the thorax, consists of 8 fused segments which have easily visible pairs of appendages. These appendages consist of 3 sets of maxillipeds and 5 pairs of pereopods or walking legs. The female genital pores are at the base of the third walking legs.

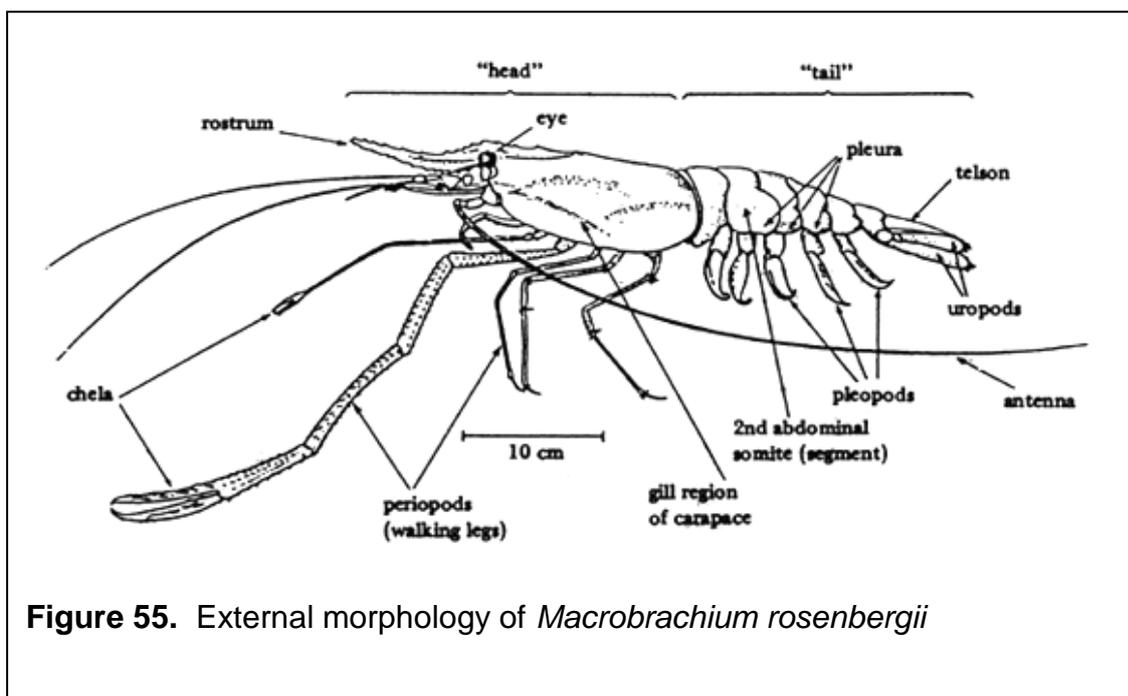


Figure 55. External morphology of *Macrobrachium rosenbergii*

The tail (abdomen) is very clearly divided into 6 segments, each bearing a pair of appendages known as pleopods or swimmerets. The first five pairs of swimmerets are soft and in females they have attachment sites for holding clusters of eggs within the brood chamber (Figure 56). In males, the second pair of swimmerets is modified for use in copulation. The sixth pair of swimmerets, known as uropods, are stiff and hard. The telson is a central appendage on the last segment and has a broad point with two small spines. The telson and the uropods form the tail fan, which can be used to move the prawn suddenly backwards.

Sexual dimorphism

Mature male prawns are considerably larger than the females and the head of the mature female and its second walking legs are much smaller than the adult male. A ripe or 'ovigerous' female can easily be detected because the ovaries can be seen as large orange-coloured masses occupying a large portion of the dorsal and lateral parts of the cephalothorax.

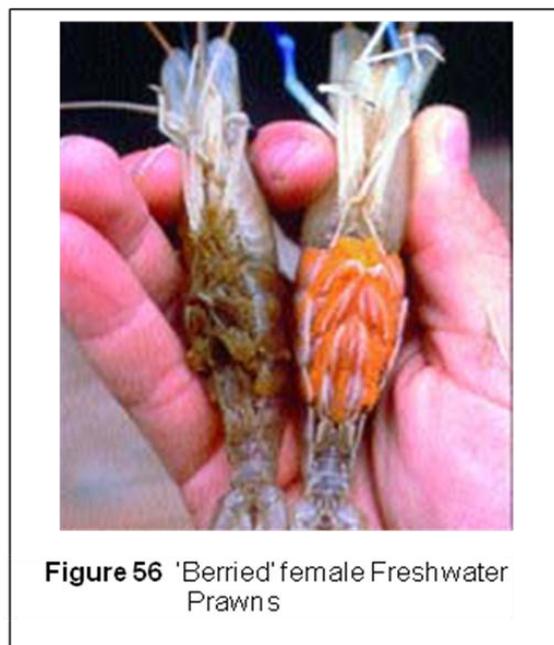


Figure 56 'Berried' female Freshwater Prawns

There are three major types of freshwater prawn males and are illustrated in Figure 56. The ability to distinguish between these forms is important in understanding the need for size management during the grow-out phase of culture. The first type consists of blue claw males (BC), which have extremely long claws. The second type has small claws and are called small males (SM) whilst the third type are known as orange claw males (OC). These OC males have golden coloured claws, which are 30 to 70% shorter than the claws of BC males.

Mating and egg deposition

The mating (copulation) of adults results in the deposition of a gelatinous mass of semen (referred to as a spermatophore) on the underside of the thoracic region of the female's body (between the walking legs). Successful mating can only take place between ripe females, which have just completed their pre-mating moult (usually at night) and are therefore soft-shelled, and hard shelled males.

All of the various types of males are capable of fertilising females but their behaviour is different. In tropical areas copulation and egg deposition coincides with the onset of the rainy season, whereas in temperate areas it occurs in the summer. Within a few hours of copulation, eggs are extruded through the gonopores and guided by the ovipositing setae (stiff hairs), which are at the base of the walking legs, into the brood chamber. During this process the eggs are fertilized by the

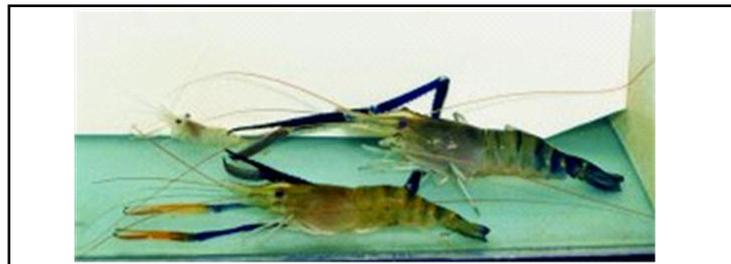


Figure 57. The major male morphotypes of *Macrobrachium rosenbergii* are called blue claw (BC), orange claw (OC) and small male (SM)

semen attached to the exterior of the female's body. The eggs are held in the brood chamber (stuck to the ovigerous setae) and kept aerated by vigorous movements of the swimmerets. Females normally become mature when they reach 15-20 g but berried females have been observed as small as 6.5 g. The number of eggs which are laid depends on the size of the female; between 80 000 to 100 000 eggs are deposited during one spawning at full maturity, however first broods (*i.e.* those which are produced within their first year of life), are often not more than 5 000 to 20 000 eggs. Under laboratory conditions, where a breeding stock of both males and females was kept, it has been noted that egg incubation time averaged 20 days at 28 °C (range 18-23 days). Ovaries frequently ripened again while females were carrying eggs.

Larvae

As the eggs hatch, a process which is normally completed for the whole brood within one or two nights, the larvae (free-swimming zoeae) are dispersed by rapid movements of the abdominal appendages of the parent. Freshwater prawn larvae are planktonic and require brackish water for survival. There are a number of microscopically distinct stages during the larval life of freshwater prawns, which lasts several weeks. Larvae eat continuously and, in nature, their diet is principally zooplankton (mainly minute crustaceans), very small worms, and the larval stages of other aquatic invertebrates.

Post-larvae (PL)

Freshwater prawns metamorphose into postlarvae (PL) on completion of their larval life. From this point onwards they resemble miniature adult prawns and become

mainly crawling rather than free-swimming animals. Postlarvae exhibit good tolerance to a wide range of salinities however they begin to migrate upstream into freshwater conditions within one or two weeks after metamorphosis and are soon able to swim against rapidly flowing currents they now utilize larger pieces of organic material, both of animal and vegetable origin. Postlarval freshwater prawns are omnivorous and, as they grow, their natural diet eventually includes aquatic insects and their larvae, algae, nuts, grain, seeds, fruits, small molluscs and crustaceans, fish flesh and the offal of fish and other animals. They can also be cannibalistic.

18.3.3 Technical requirements for mass seed production of giant freshwater prawn

Physico-chemical requirements

Although the larval stages of freshwater prawns require brackish water for growth and survival, hatcheries do not have to be located on coastal sites. Prawn hatcheries can be sited on inland sites and brackish water of 12-16 ppt can be obtained by mixing locally available freshwater with seawater or brine (and sometimes artificial seawater) which has been transported to the site. The brackish water should in addition have a pH of 7.0 to 8.5, and contain a minimum dissolved oxygen level of 5 ppm. Water of various levels of salinity is also required for hatching *Artemia* as a larval food. Both freshwater and seawater must be free from heavy metals (from industrial sources), marine pollution, and herbicide and insecticide residues (from agricultural sources), as well as biological contamination.

Obtaining 'berried females'

This species has the advantage of readily maturing, copulating and spawning under hatchery conditions. Female broodstock are usually obtained from grow-out ponds but also sometimes from capture fisheries. Normally, 'berried' females are only used once. The typical male to female ratio in broodstock holding systems is 1-2 BC males or 2-3 OC males per 20 females, at a total stocking density of 1 prawn/40 litres (see Figure 58). Within a few hours of copulation, fertilization occurs externally, as the eggs are transferred to the brood chamber beneath the abdomen. Between 5 000 and 100 000 eggs are carried, depending on the size of the berried female. Eggs are orange until 2-3 days before hatching, when they become grey-black (Figure 56). The eggs remain adhered to the female during embryonic development, which lasts about 3 weeks. At hatching free-swimming zoeae are produced.

Hatchery stage

First stage zoeae are just under 2 mm long and grow, through 11 larval stages, to almost 8 mm at metamorphosis into PL. Individual metamorphosis can be achieved in as little as 16 days but usually takes much longer, depending on environmental conditions. In commercial hatcheries, most larvae metamorphose by day 32-35 at the optimum temperature (28-31 °C) and pH 7.0-8.5. Larval rearing tanks can range in size from 100 L to 20 000. Rectangular concrete tanks are the most common although cylindro-conical fibreglass vessels may also be used. Rearing densities may range from 30-100 larvae/L. Larval rearing typically occurs in 12-15 ppt brackish water, and hatcheries are either flow-through (where a proportion of the

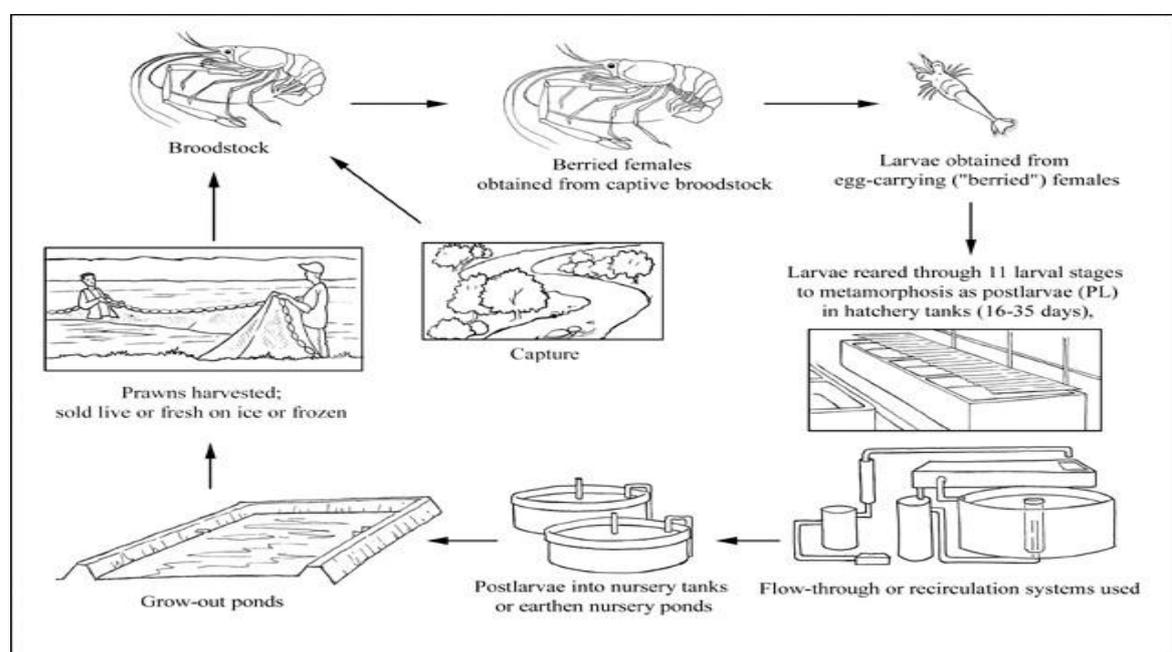


Figure 58 Production cycle of *Macrobrachium rosenbergii*. source: http://www.fao.org/fishery/culturedspecies/Clarias_bariepinus/en

rearing water is regularly replaced) or recirculating (where a variety of systems involving physical and biological filters are used to minimise water use) (Figure 58). Either type of hatchery may be inland or coastal. Some flow-through hatcheries use a 'greenwater' system, which involves fertilization to encourage the growth of phytoplankton (mainly *Chlorella* spp.), which is believed to provide a source of food for the brine shrimp (*Artemia salina*) and rotifers and thus increase larval survival; others operate a 'clearwater' regime.

Feeding systems vary widely but typically include brine shrimp initially fed several times per day then reducing to a single daily feed by larval stage 10. A prepared feed (usually an egg custard containing mussel or fish flesh, squid, or other

ingredients) is introduced at stage 3 and its feeding frequency is increased towards metamorphosis.

Nursery

Nursery rearing of prawns PL is usually carried out in concrete tanks can be stocked at densities of 1 000-5 000 PL/m² and held for between 7-28 days. Earthen ponds are also used at lower densities e.g. 20-25 PL/m² and harvested after 75-90 days. 100 PL/m² for between 30-40 days or 800 PL/m² for 30-50 days.

18.3.4 Technical requirements for on-growing of giant freshwater prawn

Culture systems

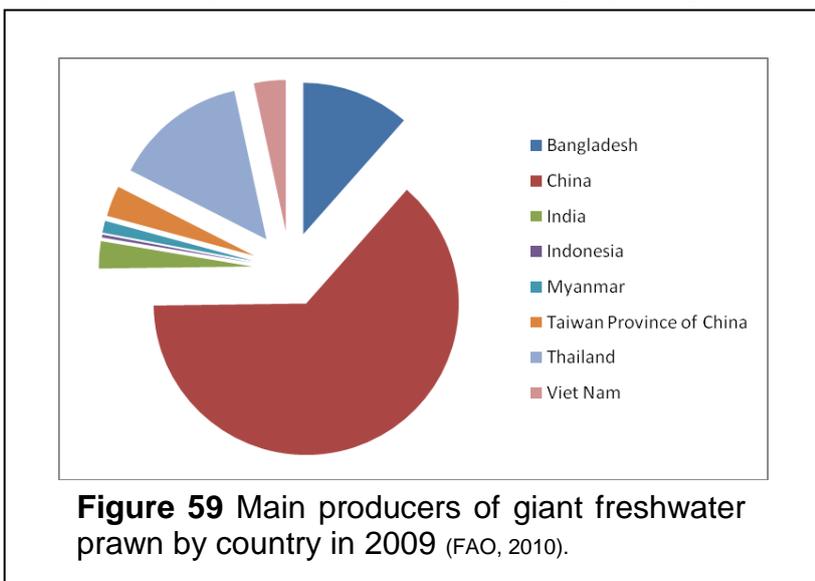
Freshwater prawns are reared in a variety of freshwater enclosures ranging from extensive to intensive systems, including tanks, irrigation ditches, cages, pens, reservoirs and natural waters; the commonest form being earthen *ponds* (Figure 58). For monoculture of prawns in ponds stocking densities vary according to the intensity of the system. In extensive rearing systems typically producing <500 kg/ha/year, PL are stocked at 1-4/m², in semi-intensive systems producing 500-5 000 kg/ha/year are stocked initially at 4-20 PL/m². Pond stocking densities in tropical monoculture vary widely. In extensive rearing systems (typically producing <500 kg/ha/year), PL or young juveniles are stocked at 1-4/m². Semi-intensive systems the most common (producing 500-5 000 kg/ha/year) are stocked at 4-20 PL or young juveniles/m². Rarely, some small intensive systems also exist, which stock >20/m² to achieve >5 000 kg/ha/year. In temperate areas with a limited rearing window of opportunity about 5-10 PL/m² or 4 juveniles/m² are stocked; levels can be increased in presence of substrates.

Diseases and control measures

In general the major disease problems affecting the freshwater prawn generally occur because of poor intake water treatment, poor husbandry, overcrowding, poor sanitation, and non-existent or inadequate quarantine procedures. They are susceptible to viruses e.g. MMV (Macrobrachium Muscle Virus) and WSBV (White spot Syndrome BaculoVirus), bacterial infections such as vibrio, pseudomonas and aeromonas causing melanised lesions that affect all life stages, fungal diseases and parasitic infestations. An array of antibiotics and other pharmaceuticals are used in the treatment.

Harvest, handling and transport

Ponds are harvested either by a total harvest when ponds are completely drained and all stock is removed or in a 'continuous' harvest where seine nets are used for regularly culling larger animals is carried out either. Care should be taken when handling during harvest as prawns may become crushed easily spoiling the final product. If they are to be sold live they should be transported in aerated water at 20-22 °C and then kept on ice for no more than 3 days. If they are to be sold frozen they should be killed in a mixture of water and ice at 0 °C immediately after capture, washed in chlorinated water and then quick-frozen at -10



°C and stored at 20 °C or below. Some farmed product is sold in the form of frozen tails however the processing yield is c. 40%, inferior to that of marine shrimp at 60-70%.

Feeds

Prawns can be fed 'farm-made' feeds which are usually single or mixtures of ingredients extruded through mincers and fed moist or sun-dried. In addition commercial feeds can be used and they usually contain 5% lipid and 30-35% protein with a FCR of 2:1 or 3:1.

18.3.5 Market and trade potential for Namibian-grown giant freshwater prawns

Global overview of freshwater prawn culture

Global production of the giant freshwater prawn has more than doubled in the last decade (Table 42) and the main producer countries can be seen in Figure 59.

Table 42. Global production of Giant Freshwater Prawn spanning two decades (FAO, 2010)			
Species	Reported production (tonnes)		
	1989	1999	2009
<i>Giant Freshwater Prawn</i>	26 483	101 509	229 417

Local and regional prices of farmed freshwater prawns and potential target countries for export

Domestic and international markets exist for the freshwater prawn and are expanding. Farmed prawns are usually sold shell-on/head-off from the main producing countries India, Bangladesh, Vietnam and Thailand.

18.4 Culture and Market Potential for the Culture of the Australian Red Claw Crayfish (*Cherax quadricarinatus*) in Namibia



18.4.1 Introduction

The native range of the red claw crayfish *Cherax quadricarinatus* (von Martens, 1868) comprises river catchments in northern Australia and south eastern Papua New Guinea. They are relatively large in size with a smooth, lustrous deep blue to green shell. Males, who exhibit bright red colouring on the margins of their large claws, can reach a maximum weight of 500 g whilst females can reach a maximum size of 400 g.

Since the early 1980s an interest in the culture of the Australian crayfish of the genus *Cherax* has arisen in light of the species' positive attributes such as an ability to withstand wide variations in temperature, pH and dissolved oxygen concentrations. Its texture and flavour compares very favourably with commonly eaten marine crustaceans and, having the appearance of a lobster, is positioned at the premium end of the crustacean market spectrum. The hardiness, flexibility in dietary requirement and fast growth rate of crayfish were attractive to the aquaculture industry and freshwater species such as the Red claw (*Cherax quadricarinatus*), the Marron (*Cherax tenuimanus*) and the Yabby (*Cherax destructor*) have been introduced worldwide as an economically important aquaculture and ornamental trade species. Production technologies are relatively

straightforward, and whilst still evolving, are at a stage where 'best management practice' methods have been identified.

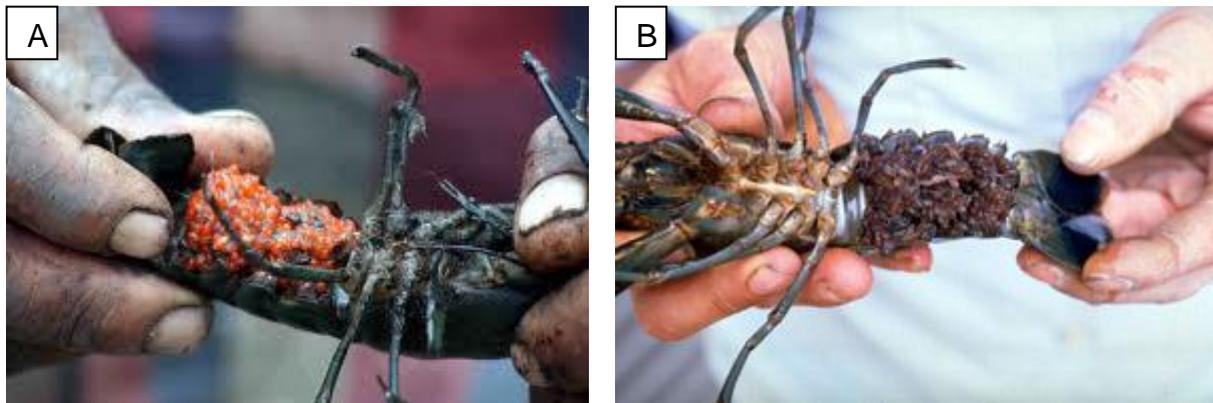


Figure 60 A) Eggs one day post-spawning and **B)** Eggs six weeks post-spawning ready for release

18.4.2 Reproductive biology and implications for aquaculture production

The red claw crayfish has a very simple life cycle requiring a low technology for culture. Broodstock are readily available from existing pond stocks enabling an easy selection. Queensland red claw usually mature at around six months of age, or 45-50 g, but it may be possible to select for later maturing animals when selecting for faster growers. Female red claw will stop growing at maturity when the ovaries develop and enlarge. Egg brooding lasts for six-ten weeks, depending on temperature and most females will produce between 300 and 800 eggs/brood. There may be between three to five broods during the breeding season. Hatchlings resemble the adult form and remain attached to the underside of the female for several weeks before progressively becoming independent (Figure 60). One disadvantage is the relatively low fecundity of freshwater crayfish, between 300-1,000/spawn; however, because of the ease with which broodstock can be obtained; it is of minor concern, especially as the female can be marketed after release of the juveniles.

18.4.3 Technical requirements for mass seed production of red claw

Physico-chemical requirements

The harsh climatic and geographical conditions that red claw crayfish has evolved in, such as poor water quality, low levels of dissolved oxygen (1 ppm) and alkalinity and a wide daily pH swings, have facilitated the development of broad tolerances to physical extremes. The red claw crayfish grows well within a wide range of

temperatures of 9-35°C, however optimum growth occurs between 26-29°C. Water should have a pH of 6.5-8.0, a hardness of >40 ppm and heavy metals such as iron and manganese not exceeding 0.1 mg/litre. Tolerance to salinities as high as 12 ppt for extended periods has been established, therefore extending the range of culture of this species to brackish water areas.

Seed supply and juvenile production

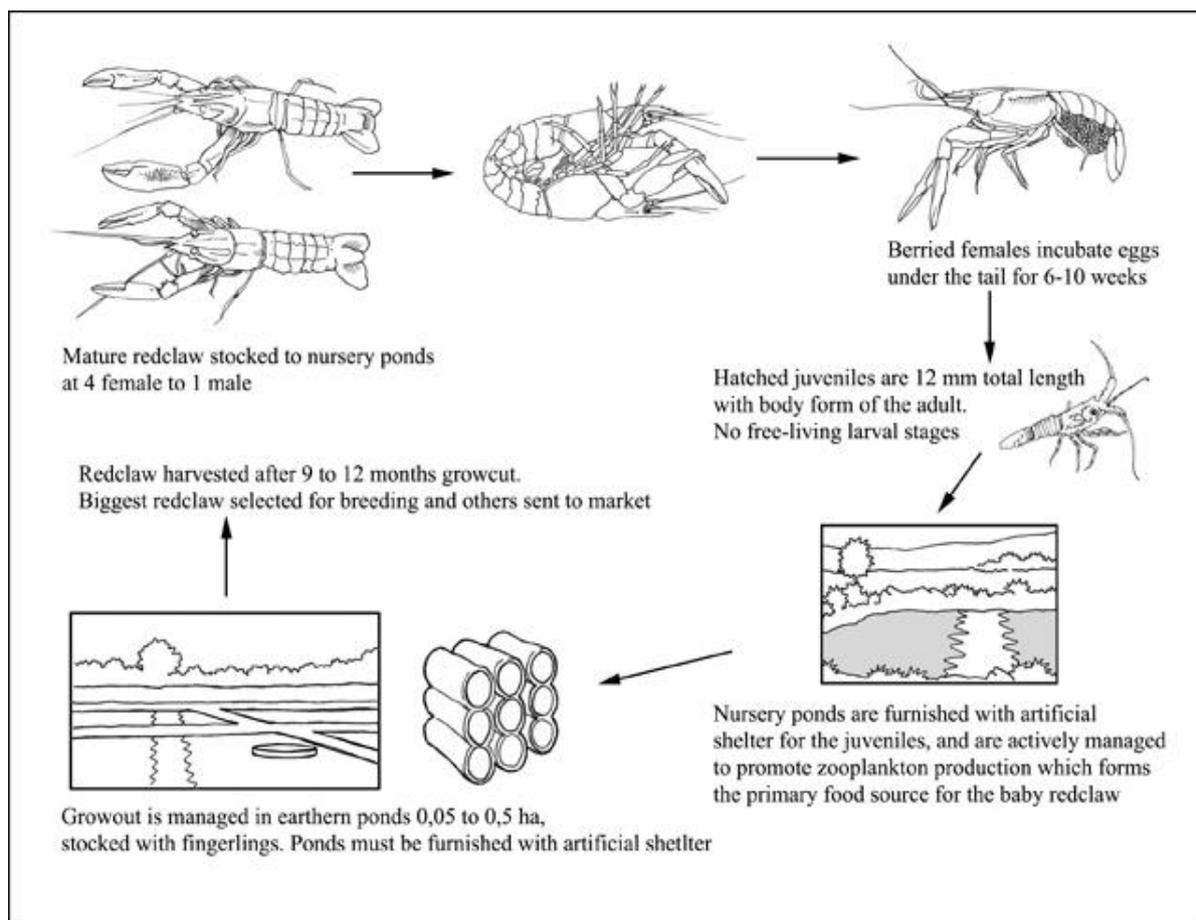


Figure 61. Production cycles of *Cherax quadricarinatus*. Source: www.fao.org/fishery/culturedspecies/Cherax_quadricarinatus/en

Selected 'berried' females or mature broodstock from the harvests of grow-out ponds are stocked into juvenile rearing ponds. Breeding and production of seed occurs naturally during the summer months, when temperatures are >25°C. No hatchery production is required as red claws are reared directly into the juvenile ponds (Figure 62).

Juvenile production

Typically juvenile ponds are stocked with mature females and males at a ratio of 4:1 and a density of 1 500/ha, carefully selected as the best of the stock available from

grow-out harvest. Under well managed conditions, 50-100 advanced juveniles will be produced per broodstock female, providing a yield of 60 000 to 120 000 juveniles/ha. Depending on temperature, a culture period of 3-4 months is required to achieve a mean size of juvenile of 5-15 g at water temperature >25 °C. The provision of adequate shelter is important and this is usually provided in the



Figure 62 On-growing ponds for Red claw crayfish

form of bundles of synthetic mesh, tied onto a line with a weight at one end and a float at the other. Arranged in this manner, these bundles extend from the pond floor up into the water column providing many spaces and surfaces for the juveniles to utilize. These mesh bundles are stocked at one every 5 m². Juvenile production ponds are carefully managed to provide an abundance of planktonic organisms that include both phytoplankton and zooplankton which the juvenile crayfish utilize as food. As they grow, they progressively consume less plankton and more of the detrital food that occurs on the surface of the shelter material and, more especially, on the mud surface. Maintaining high levels of plankton involves regular checking of water quality and periodic fertilization of the water with nitrogen and phosphorus (typically di-ammonium phosphate at 50 kg/ha). Harvesting of the juveniles is achieved by a number of methods. Sometimes individual mesh shelters are removed and the juveniles shaken out. However, the most effective method is to employ a flow trap (see Figure 63) from which they can be removed to tanks and sorted, counted and then stocked into the grow-out ponds.

18.4.4 Technical requirements for on-growing of red claw

Shelter

Whatever the on-growing culture system it is important that shelter is provided in abundance. Red claw, like all other crustaceans, moult or shed their shell as they grow and immediately after moulting the red claw are soft-shelled and are vulnerable to predation by their pond mates. The provision of shelter has been shown to improve survival substantially (from 15% with no shelter to 75% for the

best shelter types). Their shape, specification and positioning should permit water to drain out freely and completely as the pond is drained. Stacks of pipes have been found to provide the most effective shelter for red claw in the grow-out phase although mesh-type materials, such as onion bags or shade cloth may also be used.

Culture systems

Ponds

Typically red claw culture grow-out is carried out in ponds of 0.5-5 ha with a depth of 1-2.5 m. Aeration is essential and most frequently provided through airlift pumps, although other forms of aeration such as paddle-wheels and aspirators may be used. The aeration system should provide both oxygen input to the water and water circulation from bottom to top and around the pond. Fencing and netting over ponds is essential in areas where predatory birds and other species are prevalent (Figure 62).

Grow-out necessitates an active stock management approach. Because red claw breed so readily and profusely, the pond populations must be managed intensively. This includes stocking with known numbers of advanced juveniles of at least 5 g. Uniformity of size is very important. Maximum size at stocking should be 10 g. Stocking densities of 5-15/m² are recommended. Crayfish may be manually sexed and stocked into separate ponds, particularly those that are to be grown out to >50 g. Avoiding, or at least minimizing reproduction in grow-out ponds is important in effective management. The maximum grow-out period without grading should be six to nine months to minimize the possibility of un-managed reproduction. At each harvest, the stock must be size-graded and re-distributed as breeding stock, for marketing, for further grow-out or to be culled and discarded. The runts of each crop are unlikely to achieve market size in a reasonable time and it is best to remove them (and therefore their inferior genetics) from the farm population. The key factors for red claw grow-out are: maximize growth and survival, and avoid reproduction. If these principles are applied, an average yield of more than 5 tonnes/ha/crop should be achieved.

Grow-out ponds should be prepared with applications of lime, inorganic fertilizers and some organic material such as hay or manure. This initiates a plankton bloom, which provides additional, highly nutritious food and minimizes light penetration. The food used will have an important bearing on production. Commercial crayfish pellets are available and have proven to be effective. A feeding frequency of once per day is adequate, preferably at dusk when crayfish are active. Active management of the pond environment is essential to maximize yields. There should be weekly

monitoring of pH, dissolved oxygen and transparency (secchi disk) and monthly monitoring of hardness, alkalinity and ammonia. All measurements must be made at the water/soil interface on the bottom, and a contingency plan must be developed to counter poor water quality by applications of lime or fertilizer, or flushing of the pond with fresh water.

Tanks

There has been interest in the use of tank systems for red claw grow-out however they have not proved economically viable due to the fact that red claw obtains the majority of its nutrients from decaying matter and associated microbes in the pond bottom, and although manufactured feeds have been developed they have not achieved acceptable growth rates.

Feeds

Red claw are omnivorous and therefore highly adaptive with respect to nutrition. Supplemental feeding involves the distribution of a low-protein, high carbohydrate pellet diet in combination with organic matter that stimulates productivity of the detrital food chain. The supplemental pellets are either ingested directly by the red claw or are broken down by bacterial, fungal or protozoan decomposers and are subsequently consumed by other invertebrates. Commercial crayfish pellets are available in some countries, although in many cases pellets formulated for other species are used. The most effective have a protein content of ~25% and a lipid content of 8%, and are composed primarily of grains.

Harvesting handling and transport

Harvesting red claw is simple utilizing the red claws innate response to move towards an inflow of water as a water body drains and becomes shallower. This is exploited by farmers who slowly drain ponds over a 24 hour period and when the pond is two thirds empty a 'flow-trap' or box is introduced with an inflow of new water, into which the red claw will climb via a ramp and fall into a harvest box that is supplied with aeration (Figure 63).

The majority of red claw are sold live. A period of at least 24 hours in a tank with flow-through water supply or a recirculation system involving biological filtration to permit purging of the gut is recommended prior to packing for transport. Red claw can survive extended periods out of water provided they are kept cool and moist. Packing therefore involves insulated containers containing some moist packing material (foam rubber or wood shavings) and cooling packs



Figure 63 'Flow trap' system for harvesting red claw crayfish

Diseases and control measures

Several potentially disease causing organisms, including protozoans, bacteria and viruses, have been identified in red claw. All have been implicated at one time or another in some mortality or poor production from specific farms, although there has never been any documented widespread outbreak of disease. Farmers are well aware that careful quarantining and good health monitoring and management will minimize the risk of disease. By maintaining good culture conditions that maximize survival and growth, crayfish stress is managed and the threat of disease minimized.

18.4.5 Market and trade potential for Namibian-grown red claw crayfish

Global overview of crayfish culture

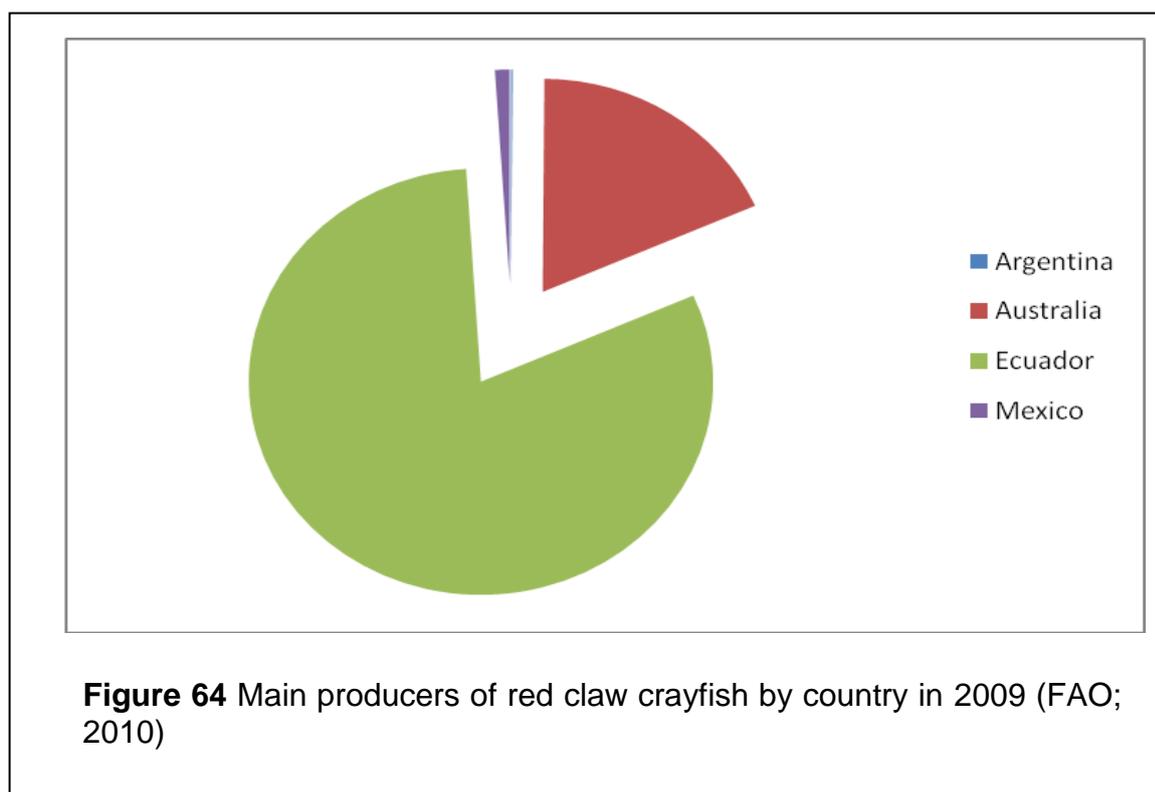
Global production figures of cultured species of freshwater crayfish are given in Table 43. The red claw crayfish has emerged as the species most suitable to culture and has been exported to many other countries where commercial production has now been established (Figure 64).

Table 43 Global production of major freshwater crayfish *spp.* spanning two decades (FAO, 2010)

Species	Reported production (tonnes)		
	1989	1999	2009
<i>Red claw</i>	166	142	372.3
<i>Marron</i>	7	52	87.9
<i>Yabby</i>	31	245	66.9

Local and regional prices of farmed red claw crayfish and potential target countries for export

Due to the fact that the texture and flavour of the freshwater crayfish compares very favourably with commonly eaten marine crustaceans and, having the appearance of a lobster, is positioned at the premium end of the crustacean market spectrum and can command high prices live. Prices for frozen crayfish are however considerably lower. They are commonly marketed at 30-50 g to > 120 g that range in prices from US\$9.50/kg to US\$18.00/kg. The main markets of cultured red claw crayfish are France, Spain and Italy (Table 44). However, there is also a good market for crayfish in the Scandinavian countries, but these markets are characterized by very seasonal demand as crayfish eating has traditionally been limited to the very short fishing season (August) in Sweden, Norway and Finland.



It is estimated that the red claw crayfish that is currently experimentally farmed at Eco-Fish Farm in Namibia should find a ready export market of air freighted live crayfish at prices of c. US\$40/kg in either in Europe or in Asia.

Table 44. Crayfish imports (all product forms) into key European markets Source: <http://www.globefish.org/homepage.html>

Country	Tonnes		% Change	Total imports EUR x 1000		% Change	Total imports unit price EUR/kg	
	2005	2006		2005	2006		2005	2006
France	3 900	3 300	-15%	81 300	81 100	1	20.85	24.58
Spain	3 800	2 800	-26%	48 300	42 600	-12%	12.71	15.21
Italy	1 600	1 600	-	22 900	21 400	-7%	14.31	13.38

19 RISK MITIGATION

19.1 Introduction

Aquaculture, being a relatively new non-traditional economic activity, is often cited as a contributing factor to the demise of global capture fisheries due to the large harvest of wild fish for fishmeal, a major feed ingredient for culture species. In addition, aquaculture is often held responsible for habitat alteration, genetic pollution, disease transmission, and wild seed stock collection. Such allegations, have caught the voting public's, (especially economically secure and mobile groups) imagination. These perceptions, promulgated by environmental pressure groups, although influential in a political sense, are not fully supported by scientific information and disregard the major advances and improvements in aquaculture technology, husbandry, hygiene, health and other good management practices.

All anthropogenic activity will have some effect on the environment and aquaculture is no exception. The magnitude of any environmental change associated with aquaculture development depends on the type and method of aquaculture, the level of production intensity and spatial concentration of activity. Generally, the majority of aquaculture operations around the world, especially in Asia and Latin America are small scale and are traditional and sustainable. It is acknowledged that to date, the majority of aquaculture practices have had few adverse effects on ecosystems (Barg, 1992) and any adverse impacts tend to be most severe in areas with poor water exchange (Midlen and Redding, 1998).

Large-scale farms, e.g. salmon farms in Europe, typically produce fish in the range of 10 000-15 000 tonnes/year and such single scale or clustered operations with measurable environmental impacts are unlikely in Namibia due to limited natural resources, sites and climate. Ultimately, the impacts of freshwater aquaculture in Namibia will have to be assessed against the national environmental legal regulatory framework (LRF) which specifically addresses mitigation of impacts that are deemed "significant" through an EIA process. Unfortunately, the LRF does not define what is a "significant" effect, leaving it open to interpretation by administrators (see Subsection 3.3.2).

19.2 Impacts of Freshwater Aquaculture on the General Environment

There is a significant body of information on environmental impacts of aquaculture (Midlen and Redding, 1998; Black, 2001; Pillay, 2004) and therefore this readily available information is not repeated here. Instead we assess actual potential

impacts that freshwater aquaculture could have on the Namibian and transboundary environments, if any. The following potential impacts of freshwater aquaculture (i) from effluent farm water on land and water, (ii) on fish biodiversity and biology, and (iii) on biosecurity and health. There are also other issues arising from other fish farming activities such as fish processing.

19.2.1 Potential impacts of effluent farm water

The relative impacts of freshwater aquaculture on the environment in Namibia are likely to be insignificant; farms will be small by global standards, scattered across the country due to water distribution and availability and suboptimal water temperatures. The potential risk could be pollution by effluent farm water which will eventually drain into rivers, reservoirs or ground. The production from the majority of potential fish farms in Namibia is unlikely to exceed 100-300 tonnes/year. Estimates of daily wastes generated from fish and uneaten feed on farms with production up to 500 tonnes/year are shown in Table 45. In the northern regions a 300 tonne farm unit will generate a total of 200 kg of dry waste/day. A total of 20 such farms across the northern regions will generate a total of 4 tonnes dry organic waste/day.

Table 45. Estimate of waste¹ from feed generated for varying farm production sizes

Annual fish tonnage	Feed used @ FCR 1.5	Kg of Feed use/day	Fish waste form feed (Dry weight, Kg)
100	150	167	67
200	300	333	133
300	450	500	200
400	600	667	267
500	750	833	333

¹ Assumed digestibility of feed 60%

19.2.1.1 Discharge of farm effluent into rivers

Discharging such organic loads directly into rivers should have no harmful impact given the huge catchment areas and flow rates of these river systems (Table 46). Discharge of a total of 4 tonnes organic matter/day in the northern regions over a total catchment area of 361 000 km² is unlikely to be of any environmental consequence. Moreover, it should be recognised that these wastes are organic and will biodegrade rapidly and will still have some nutritional value in the ecosystem.

Table 46. Main river basins catchment areas in Namibia and their and water flows¹

River Basin	Catchment area (km ²)	Flow (km ³ /yr)
Zambezi	17 426	40
Okavango	106 798	10
Kunene	17 549	5
Orange	219 249	11
Cuvelai system	199 718	-
Total Area	361 022	

¹Source adapted from http://www.fao.org/nr/water/aquastat/countries_regions/namibia/index.stm

19.2.1.2 Discharge on land to groundwater

Depending on location, water for fish farming may be abstracted from boreholes and aquifers and effluent may be discharged onto land to recharge ground water. The

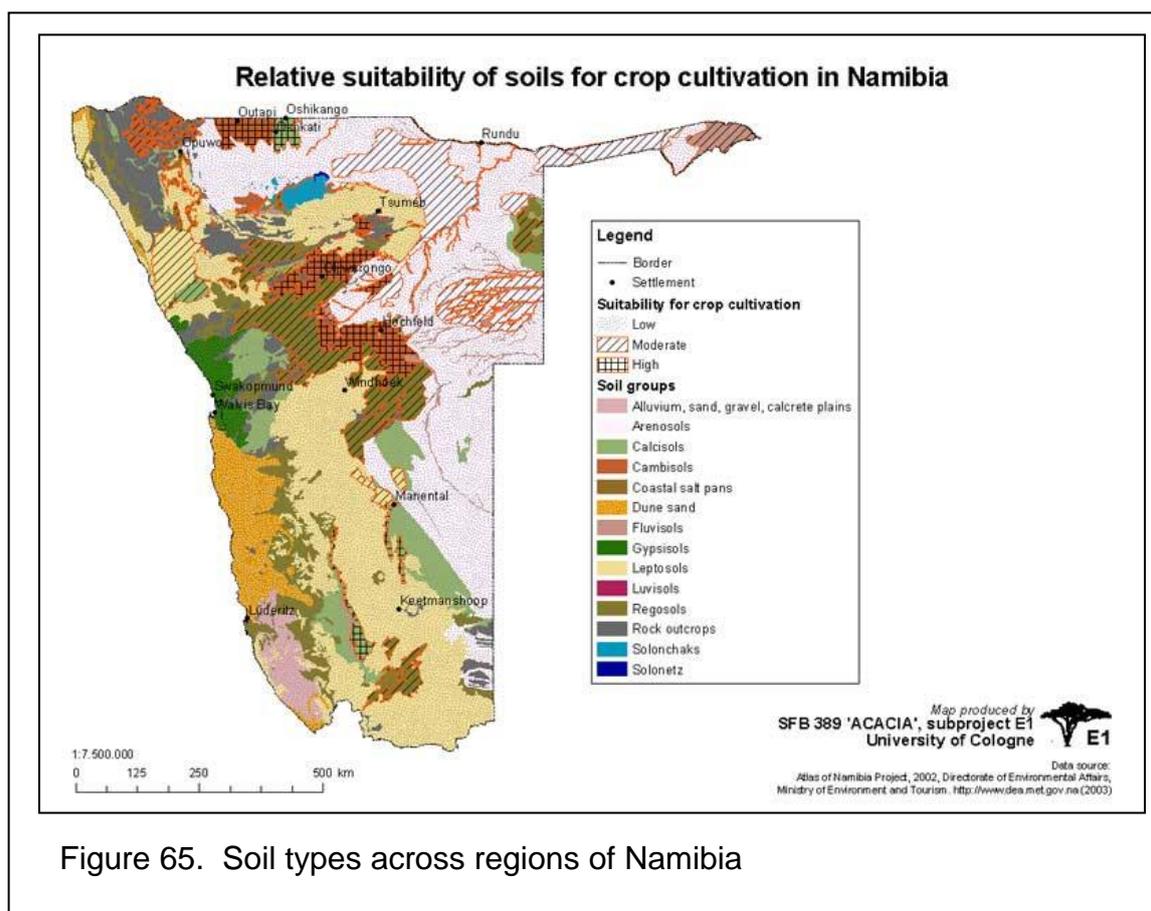


Figure 65. Soil types across regions of Namibia

soils in most regions of Namibia where freshwater aquaculture is likely to be practised are alluvial, sand and gravel soils (see light purple areas in Figure 65) and therefore prone to high seepage and can readily act as soak pits. It should be

deficient country where schemes for inter-basin water transfer is an historic practice dating back over a 100 years. Consequently, there has been continuous exchange of water and aquatic life, including fish, between these watersheds and basins.

The Calueque-Oshakati Water Scheme is an example of such a scheme that consists of an open channel of around 160 km from the Kunene basin to Calueque to Oshakati into the Cuvelai system and a pipe network of more than 2 000 km (Kluge et al., 2008). Further, NamWater manages an additional 14 bulk water transfer schemes across the country. Therefore the premise that fish species are isolated within their respective historic watersheds and basins is untenable.

Currently, *O. andersonii*, is farmed along its native northern regions and should pose no biodiversity risk. Additionally, current broodstock used for fingerling production are from the wild and as such only represent the F₀ generation (1st generation) and are not domesticated. Currently this species is not farmed in the south but could be used if it offers a comparative advantage with no additional risk than those of *O. mossambicus*, already present in these systems.

The debate that the use of introduced species such as *O. niloticus* should be discounted for farming in the north should be re-evaluated in the light of this species being already present in watersheds of most of the bordering countries such as Angola, Zambia and Zimbabwe and known to occur in South Africa.

South of these northern perennial river systems the exotic *O. mossambicus* is already present in all rivers and reservoirs. The use of another exotic such as *O. niloticus* should pose no additional risk.

19.2.2.1 Mitigation measures

There is no meaningful case for exclusion of species on the grounds of genetic contamination or dilution. Fish species have already been translocated between watersheds under historic water transfer schemes. However it may be prudent to first evaluate the performance of species such as *O. niloticus*, alongside natives such as *O. andersonii* to establish any comparative value. It should be noted that in 2009, Zambia is the only country to report production of around 3 000 tonnes of *O. andersonii* but 3 500 of ***O. niloticus*** was also produced.

The key purpose of any introduction is to farm a species that has an acceptable growth rate and is marketable. If a decision is taken **not** to introduce *O. niloticus* in the north, a broodstock selection programme for *O. andersonii* should be initiated to

mitigate against slow growth. There is an ample source of wild broodstock to ensure loss of stock vitality.

19.2.3 Biosecurity

With any farming activity diseases is a potential risk and farmers will have to ensure measures are in place to contain such outbreaks. In addition if diseases such as EUS are prevalent in natural waters farmers will have to vigilant to monitor such risks

Prevention is the best option to mitigate such risks. Farmers should be trained in good farming practices, including detailed record keeping and be competent in recognising signs of unhealthy fish. Farm designs should include anti-predator nets, disinfection foot baths into all entrances of rearing facilities and entry of persons into these facilities should be restricted.

19.2.4 General farm mitigation issues

Theft or larceny and their mitigation

Theft is the most significant external risk to freshwater fish farming in Namibia which, if not controlled at the outset, will cause enterprises to fail. This is a significant challenge in most other African countries and a reason why many farmers, for example in Nigeria, opted for backyard RAS which can be easily protected.

Given the investment, farmers will have to ensure that the farm site is securely fenced and guarded.

General and fish waste and their mitigation

Farms of the typical size envisaged are unlikely to generate significant wastes warranting specialised services or equipment. If packed in 50 kg bags a 300 tonne farm will have to dispose around 200 feed sacks and these can be recycled. Most of these farms will sell fish ungutted as whole fish and therefore in most cases farms will not generate any fish offal of note. Should farms gill and gut their fish then a similar sized farm will generate 3 tonnes of offal/month and mitigation measures may have to be put in place to process this waste.

Mitigation measures

The offal can be either dried or silaged. Offal waste should be minced and acid-stabilised and ensiled by the addition of formic acid into a high protein liquid that can be used as an additive to compost (in small volumes) or as an additive to animal feeds, especially for pigs.

If sundried, waste could be fed back to the fish. The offal should be first heated to remove fat and sterilise the offal, then dried and fed to fish.

20 CHALLENGES AND CONSIDERATIONS FOR PROMOTING THE NATIONAL FRESHWATER AQUACULTURE MASTER PLAN: Business Plan Model for Catfish Farm in Namibia.

20.1 Introduction

Although Namibia is classed as a semiarid to arid country it has abundant access to perennial rivers in the northern and western region and numerous ground water sources, some of which are geothermal. Subject to location, catfish farming could therefore be carried out using simpler systems. The African catfish a locally available species for which culture technologies are understood and is readily consumed in the region. The Namibian business is conducive to investment in fish farming providing encouraging tax incentives and government grants as part of social capital.

20.2 Catfish as a Proposed Candidate for farming



The African catfish as a potential candidate for aquaculture

Catfish has the attributes for profitable fish farming under Namibian conditions. It is a tradition fish widely consumed in Namibia and in consumed in various forms, such as fresh, smoked, sundried etc., creating the opportunity for value addition.

The African catfish (*Clarias gariepinus*) inhabits calm, static or slow flowing water bodies that range from lakes, streams, rivers, swamps to floodplains, some of which are subject to seasonal drying. The catfish have adapted to this environment by being able to respire through their air breathing organs, thus making it possible to

rear them at high densities at lower oxygen levels compared with other finfish species such as tilapia.

Under natural conditions, the maturation process of the African catfish is influenced by annual changes in water temperature and photoperiodicity and the final triggering of spawning is caused by a rise in water level due to rainfall. Reproduction begins, just after the start of the first heavy rains, Thereafter the oocytes start maturing gradually and become ripe again before the next rainy season..

Technologies for artificial breeding and rearing are well documented and relatively easy to perform. Therefore catfish seed and technology is readily available making it a target species for consideration under culture conditions. Catfish can be artificially spawned all year around on demand. Their adhesive eggs hatch in 20–60 hours, depending on temperature. The yolk sac is absorbed within 3–4 days when exogenous feeding commences.

Catfish are fast growers and under optimal farming conditions can attain 1kg in 6 months. Due to their air breathing habit they can be uniquely stocked up to ten times higher at densities most other marine and freshwater species. Under professionally manage systems catfish biomass densities of up to 600kgm³ can be attained.

The production systems proposed in this business plan is tailored to Namibian conditions to suit the technology and skills level available. A concrete raceway or pond semi flow through system is proposed which is less complicated than a full recirculatory system.

20.3 The Proposed Production System

Namibia is a water deficit country which enjoys over 300 days of sunshine but has suboptimal temperatures for all year round fish production. Coupled with this, are high evaporation rates up to 3 600 mm/yr which collectively makes outdoor aquaculture difficult. Therefore, many feasibility studies in Namibia to date have proposed indoor recirculatory Aquaculture systems (RAS). Such systems, however, are very capital intensive and, if effectively designed, will require **oxygenation** rather than the often proposed **aeration**. Such facilities will also require highly skilled staffs which are currently unavailable in Namibia.

This business plan proposed here is a concrete raceway system under greenhouses with waste water used secondarily to raise vegetables in green agricultural projects. The level of sophistication and therefore capital expenditure (CAPEX) will be influenced by the source of water and volumes available. If sufficient volumes of warm water are available a recirculation systems may not be necessary and flow through or a semi flow through systems can be employed, significantly reducing the utilities bill. Both these models are considered from a financial standpoint

The rearing facilities would need to be carefully considered. In most areas of Namibia, soils contain less than 5% clay and therefore unlined earth ponds are not practical and above ground structures such as tanks are more suitable. Ponds can be lined but this is capital intensive and more difficult to harvest. .

20.3.1 Recirculation aquaculture systems (RAS) under greenhouses

A combination RAS under polyethylene tunnel is amongst the most widely used system around the world where temperatures are suboptimal and evaporation rate high, ensuring best use of water resources. The system proposed is for a 225tonne/year farm.

At full production the proposed facility will contain four greenhouse units with each containing 2 sets of 6-80m³ cement raceways giving total rearing volume of about 3750 m³ at full capacity.

Great care will be required to put in place measures to ensure detailed understating on the functionality of such systems by floor staff. The high stocking densities of up to 100 kg/m³ will dictate the need for good health management of stocks and staff will have to be trained in fish health management. The production facilities will have water baths at points all points of entry into greenhouses.

Given the high densities a **standby generator** is essential to step in during power failures, both for the water pumps and air blowers.

Catfish farming is envisaged using good quality diet and other relevant good management practises, in particular feed management and grading. Fingerlings stocked at 20-30g are expected to reach a 1-1.2 kg in 8-9 months. Feed supply and utilization

Feed cost make up 50-60% of production costs irrespective of the type of system and therefore its sourcing, storing and utilization will have significant bearing on the profitability of the business

Complete diets with 25-30 protein should be used to ensure good growth and this could be reduced by feeding culled tilapia fingerlings sourced or produced locally in settling/sedimentation ponds etc. Feeds can either be in extruded (floating form) or sinking pellets. Sinking pellets produced at Onavivi are adequate provided correct feeding regimes are developed and used. Catfish are voracious feeders and the use of sinking pellets is acceptable and if correctly managed, uneaten feed is minimal.

In this model we anticipate, that with good management a food conversion ratio (FCR) is attainable. We have however been conservative, assuming that with time, diet quality and management will improve and therefore the FCR was gradually reduced from 1:7 in year 1 to 1:4 in year 10 in the cash flow analysis.

20.3.2 Harvest and post-harvest management

The core business of this business is on-growing and not processing and therefore the product value chain stops at harvesting and sold live or packed on ice for sales and distribution.

Fish harvested will be packed in 5 and 10 kg cool boxes and covered with flaked ice. A flake ice making machine is envisaged to provide adequate volumes of ice to cover fish to reduce the deterioration of flesh quality. Since the business will not engage in post-harvest processing there is no need for blast freezers, cold storage etc. nor get involved in any Hazard analysis critical control point (HACCP) procedures, except for staff trained in good handling practices of the harvested fish. We assume that the GRN will put in place a national marketing distribution chain.

20.4 Marketing Considerations

20.4.1 National markets

There is no accurate information on fish consumption in Namibia. The FAO estimates per caput consumption in Namibia to be around 10 kg/capita/yr. Some household surveys, however, indicate that this figure is around 5kg/person/yr.

Based on the FAO data and assuming that 60% of the population live in the north we estimate around 16000 tonnes of fish are required. Marine capture provides much of this market with cheap frozen horse mackerel. If aquaculture is able to capture 50% of this market a potential market of 8000 tonnes exists. If we assume a per capita consumption of 5 kg, an estimated of 4000 tonnes could be available. The government is actively promoting the fish consumption through its national campaign through the “Fish Promotion Trust”. No information could be located on the effectiveness of this initiative, but production in this model is based taking the view that through education and government promotion, fish consumption in all regions will increase with time.

The Northern provinces from Kunene to Caprivi which houses around 60% of the Namibian population are traditional fish eaters. Due to employment opportunities these populations are migrating to bigger cities especially in the south e.g. Windhoek, taking with them the fish eating habits of known species such as the tilapia and catfish to the south. This group may be prepared to pay higher prices for freshwater fish. We therefore assume that planned farming of a known species, such as catfish, will ensure a regular supply to urban and rural markets, to grow the market.

Such markets could be split into three groups, rural or urban communities with limited or no disposable income accepting smaller sized fish at a lower price, growing health conscious middleclass prepared to pay higher prices for larger more appealing fish and the tourist trade or accommodation establishments. Most restaurants do not have freshwater fish on their menu and we envisage government promotion initiatives to help grow consumption. Given that red meat and poultry range between \$50-70/kg, there should be opportunity to increase fish consumption with a well organised campaign.

INFOSA currently estimates that the potential market for tilapia in the north of Namibia amounts to some 1 500 – 2 000 tonnes per year.

20.4.2 Fish Prices

Currently the main producers of freshwater fish are government farms in the northern regions where fish are sold/given to public upon harvest at \$15-20/kg and at times higher. Private farms such as Ecofish sells scaled, whole gutted frozen

tilapia at N\$30 per kilo (5 kg boxes) whilst tilapia fillets are sold N\$50 per kg (5 kg boxes).

20.4.3 Regional market

The tilapia and catfish are well known in the region and fish is in short supply as landings from wild fisheries decline, creating more market opportunities in the region.

The populations around Namibia create a significant regional market of around 200 million people which require a constant supply of fish all year round. Currently INFOSA estimates a shortfall of 100 000 tonnes of freshwater fish in the SADC region thus creating a market opportunity for Namibia. The Market is nevertheless competitive. Companies such as Lake Harvest are selling whole gutted fresh/frozen tilapias into Zambia, Zimbabwe, and the Democratic Republic of the Congo from around US\$2.20 – US\$2.85/kg (N\$18-22/kg).

We do not envisage that this business will target the international markets.

20.5 The business model and system requirements

The business model is designed to produce 224 tonnes of catfish at full capacity starting with 56 tonnes in year 2 and 3 and stepping up 234 tonnes by year 10.. Ability to attain production targets and therefore profitability of the farm will depend on many factors, especially fish price, feed cost, cost of utilities and management and servicing of the facility.

The facilities will comprise as follows:

20.5.1 On-growing of catfish

Fingerlings 20-30g catfish fingerlings direct from fingerling producers and therefore will not rear any secondary stage fingerlings thus reducing infrastructure costs. We will, however, set aside appropriate number of isolated tanks to acclimatize and quarantine incoming catfish fingerlings.

Graded fish will be transferred into 23 m x 2.5 x 1.3 m concrete tanks at a rate of around 3200/tank at 30-50 g where they are expected to grow to about 1-1.2 kg in 7

months (assuming water temperature of 26-28 °C). In year 1 we expect to have tanks in operation each producing around 2500 kg of fish at harvest giving a final conservative stocking density of 50 kg/m³. With experience this can be raised to 100 kg/m³. Stocking of production tanks will be staggered to ensure all the year production.

20.5.2 Risks and mitigations

This is a very small production system by international standards and we not believe this operation will cause any significant harm to the environment. In fact, this project proposes integrating fish with plants and therefore we will add significant value to the water utilized. In addition, and in particular, the soils in Namibia are sandy and devoid of organic matter and therefore spreading of such waster water will help fertilize these and improve these poor soils. It should be noted that all such waste is organic and will decomposed quickly.

The species proposed is the local catfish available in Namibia and therefore poses no threat to wild stocks. Larceny, however, is a big threat and we propose to fence the site and employ gatepost guards to ensure no unauthorized entry. This will also be part of the biosecurity plan of the farm.

We propose using greenhouse structures but will consider improved insulated greenhouse covering capable of withstanding high winds.

20.5.3 Infrastructure requirements

In addition to six 100 x 15 m green houses the farm requires an administrative block, one two bedroom house for the site supervisor, a security port at the entrance and a feed store and storeroom.

Depending on sites we propose two systems subject to final evaluation on land suitability. The first scenario requires a RAS and the second using a flow-through system using currently available free-flowing river or borehole water.

20.5.4 Building of raceways

To generate local employment and build local capacity we propose to employ local tradesman to build under the supervision of a competent qualified aquaculture

consultant and out source the installation of the greenhouse with the agreed objective of building local capacity.

20.5.5 Human resource capacity requirements

- A farm supervisor/manager to oversee all farm activities
- A technician with skills in aquaculture to monitor the systems and follow up on production issues
- 8 farm hands. To attend to daily activities such as grading, sampling, stocking, feeding, harvesting etc.

20.5.6 Assumptions

- i. Domestic market available
- ii. Government assistance to secure site and access to land and water and licences
- iii. Suitable site location near river or high volume geothermal borehole
- iv. Water requirement/day 2000-4000m³, 0.5-1million m³/yr as a flow through system
- v. Effluent water discharged into river /ground via wetland ponds/soakway
- vi. A CAPEX and OPEX of N\$4 and \$1 million, respectively,
- vii. N\$3 million incentive grant from Government or taken as equity
- viii. N\$ 2 million as loan from Agribank @5% interest towards Capex and N\$1 millions for operational capital
- ix. 50% (Promoters) CAPEX depreciated and 50% recovered at end of 10yrs through Asset sale.
- x. Site location near river. Cement raceways proposed but good pond site could work and may reduce CAPEX. Ponds above ground must be drainable.
- xi. 48 – 78m³ raceways over 10yrs. A unit of 12 constructed under greenhouse in year 1. then a unit in year 3-4, 6-7 and 7-8
- xii. Cost of raceways provisioned at N\$950/m²
- xiii. Water pumped from river to raceways as flow-through to semi-flow through system - to be empirically established

- xiv. Low pressure air blowers and stand by generator in place.
- xv. Three phase electricity in place.
- xvi. Water temperature suitable for 8 months/year
- xvii. 20g Catfish procured at N\$1 eh
- xviii. Fish feed sourced form Onavivi @ N\$ 6/kg incl transport
- xix. Feed price stable and price increase is maintained to 5%/yr
- xx. Improving FCR achieved over 10years. 1.5 to year 2, 1.4 in yrs 3-6 and 1.3 in year 7-10 applied to estimate feed cost
- xxi. Labour: supervisor/manager and 9 staff
- xxii. Gate sale price of whole catfish N\$ 20, 21 23 and 25/kg

20.5.7 Cash flow and key Select Financial Indicators

The cash flow for the 224 tonne catfish farm shown in Table 46 reaches full capacity in eight but depending on resources can be achieved earlier. On this plan the business is in profit in year and by year four achieved a predicted net profit of N\$ 533 448.

Productivity makes a notable difference to key financial indicators. Increasing stocking density from 60 to 70kg/m³ increases the IRR from 22 to 33% (Table 47 and 48). At 60kg/m³ and a gate price of N\$20/kg an IRR of 22% could be achieved. By increasing stocking by 10kg/m³ the IRR can be increased to 33%. Increasing stocking density by 10kg/m³ also reduced the breakeven point by 13 percentage points providing a greater operation buffer.

20.5.8 Sensitivity analysis

Profitability was tested for the following:

Increase in fish price from \$20/kg to \$25/kg on

- Operating profit

Net profit and profit/kg fish produced.

The graphical presentations of these analyses are given Figure 67. The cost of feed is in the order of 70% of total operation cost and therefore most sensitive to feed price changes (Figure). The impact on profitability however is price dependant of fish. At a gate price of N\$20/kg operating profit and net profit is N\$5/kg and N\$4/kg, respectively, but double if fish prices increases to 25\$/kg.

Table 46. Cash flow of a 224 tonne catfish farm using a semi flow through raceway system

Description	PROJECTED FINANCIAL FEASIBILITY STUDY REPORT									
	Years									
	1	2	3	4	5	6	7	8	9	10
GROSS REVENUE¹										
Tonnes of fish	5	56	56	112	112	168	168	224	224	224
Revenue	100000	1117800	1117800	2235600	2235600	3353400	3353400	4471200	4471200	4471200
Annual increase in price at 5%			55890	58685	114714	117516	173546	176347	232377	235179
TOTAL REVENUE	100000	1117800	1173690	2294285	2350314	3470916	3526946	4647547	4703577	4706379
VARIABLE COST										
Fingerlings		60000	60000	120000	120000	180000	180000	238000	238000	238000
Fish feed	41250	461093	484147	903741	903741	1355612	1423393	1678377	1762296	1850410
Medication	10000	25000	25000	50000	50000	55000	55000	60000	60000	60000
Repairs and maintenance		30000	35000	35000	35000	35000	40000	40000	40000	40000
Electricity and fuel	10000	40000	40000	60000	70000	120000	130000	160000	170000	180000
FIXED COSTS										
Vehicle running and maintenance	20000	21000	22050	23153	24310	25526	26802	28142	29549	31027
Labour	235000	246750	258838	271279	284093	297298	310913	324959	339456	354429
Office and admin exp	10000	10500	11025	11576	12155	12763	13401	14071	14775	15513
interest	50000	50000	50000	50000	50000	50000	50000	50000	50000	50000
TOTAL OPERATIONAL COSTS	376250	884343	926060	1404749	1429300	1951198	2049508	2355548	2466076	2581379
Net profit before interest and depreciation	-276250	233458	247630	889535	921014	1519717	1477437	2291999	2237502	2124999
Opening loan balance	2000000	1833333	1650000	1485000	1336500	1202850	1082565	974309	876878	789190

Interest on loan	100000	91667	82500	74250	66825	60143	54128	48715	43844	39459
Depreciation	166667	183333	165000	148500	133650	120285	108257	97431	87688	78919
Net profit after Interest and depreciation	-542917	-41543	130	666785	720539	1339290	1315053	2145853	2105970	2006621
Taxation 20 %				133357	144108	267858	263011	429171	421194	401324
NET PROFIT AFTER TAX	-542917	-41543	130	533428	576432	1071432	1052042	1716682	1684776	1605297

Table 47. Effect of stocking at 60kg/m³ on key selected indicators

Indicators	Percentage at varying gate prices (N\$/kg)			
	20	21	23	25
Net profit/sales%	25.0	30.0	35.0	38.0
Internal rate of return	22.0	25.0	29.0	33.0
Break even point	73.0	67.0	58.0	51.0
Average return on equity	38.0	46.0	55.0	67.0
Pay back period	7yrs 9mths	7yrs 4mths	6yrs 4 mths	6yrs

Table 48. Effect of stocking at 60kg/m³ on key selected indicators

70kg/m³	Percentage at varying gate prices (N\$/kg)			
	20	21	23	25
Net profit/sales%	29.0	31	36	45
Internal rate of return	33.0	35	40	46
Break even point	60.0	51	47	40
Average return on equity	47.0	54	67	80
Pay back period	7yrs 1mths	6yrs 8mths	6yrs	5yrs 7mths

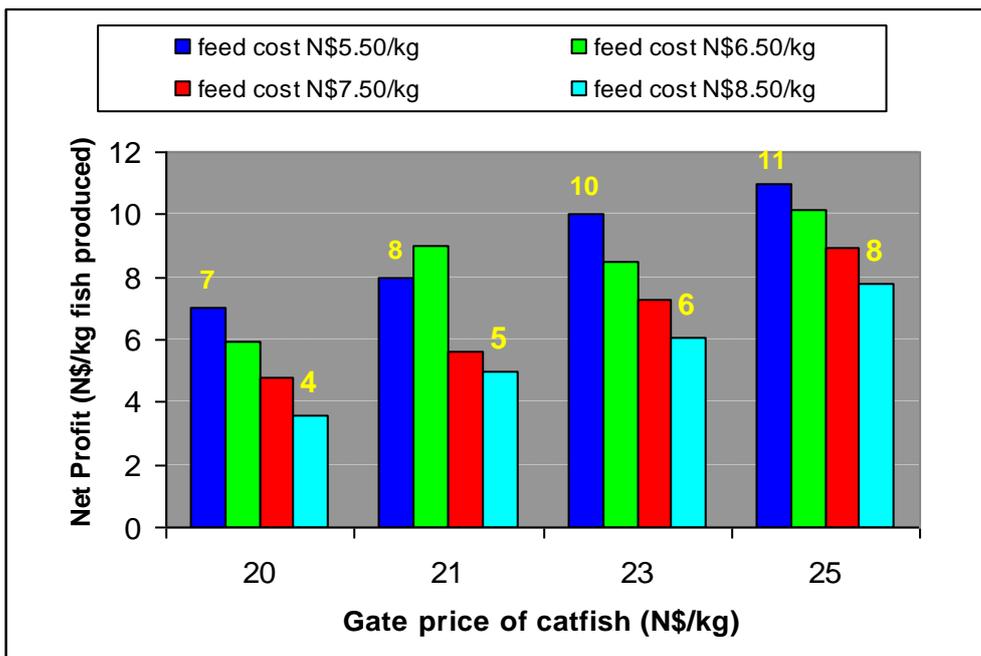
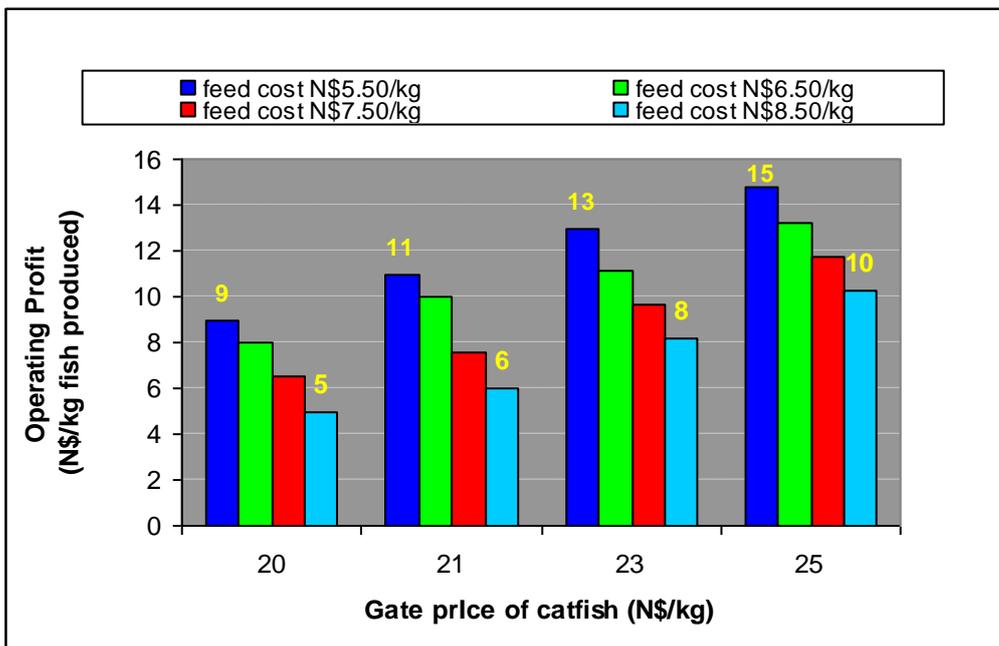


Figure 67. Effect of increasing gate prices and feed costs on the operating and net profit of a 224 tonne catfish farm.

21 OVERALL KEY CONCLUSIONS FOLLOWED BY RECOMMENDATIONS AND WAY FORWARD

To support the implementation process of the NAMP-FW an in depth situation analysis was conducted together with field visits to evaluate current government institutional and private initiatives, undertake stakeholder consultations and supporting assessments to access markets, human capacity and technological needs, potential production systems and identify potential candidates. The main conclusions and recommendations on the way forward is summarised below:

1. **On Regulations:** There are inconsistencies in some regulations which compromise freshwater aquaculture uptake and in some cases are premature in that government facilities are not in place for compliance.
2. Remove aquaculture from Schedule 1 to make transparent and comparable with other forms of livestock farming or gazette an EIA trigger of 250 tonnes/year allowing small-scale farmers to enter the subsector.
3. Specifically, allow species already introduced, such as *Oreochromis niloticus* and red claw (*Cherax quadricarinatus*) to be made more accessible for farming and promote other species advocated.
4. **On Namibia's Aquaculture Strategic Plan (NASP):** Overall, NASP has a clear mariculture focus due to its current economic significance. For freshwater aquaculture, its implementation appears limited and impact unclear.
5. The MFMR should review their management structure and conduct an analysis of the activities to identify how it can better achieve its targets.
6. The Fish Promotion Trust together with competent authorities and organizations should conduct a well-planned proactive marketing campaign to increase freshwater fish consumption.
7. There is a clear lack of human capacity to promote and develop freshwater aquaculture. We advocate MFMR conduct a training needs assessment study, which to our knowledge has not been done.
8. No structured research in freshwater aquaculture was apparent. We propose that MFMR develop a needs-driven freshwater aquaculture research strategy.
9. **On the Aquaculture Turnaround Strategy:** The MFMR inherited six community freshwater fish farms built by MTI in 2001 for local communities. These farms were deemed woefully unproductive. The MTI therefore commissioned a Turnaround Strategy (TAS) in 2006 to revive these ailing cooperative freshwater fish farms. To date there appears to be no successful resolution.
10. The draft TAS provides a comprehensive analysis/audit of all six farms, four of which (i.e. Mpungu, Likunganelo, Kalimbeza and Kalavo) were visited by the freshwater team. It is our understanding that the remaining two farms are now decommissioned.
11. The freshwater team largely concurs with the observations and constraints contained in the TAS, encapsulated in the SWOT analysis.
12. The ownership of the cooperatives MUST be resolved ASAP. We concur with the GRN, and propose a government (51%): cooperative (49%) PPP, provided good governance measures are in place.

13. A time-bound exit strategy (community buyout) should be put in place.
14. An integrated agri-aqua approach is advocated for all farms but more effective fish and plant farming practices are required.
15. A committed and adequately trained workforce must be put in place.
16. **On Private Farm Visits:** All initiatives showed signs of infancy of fish farming displaying limited knowledge and could have detrimental outcomes. Expectations from aquaculture are unrealistic.
17. Conduct farm-specific technical audits and guide and train farmers in improving facilities and production.
18. **On Government Inland Fisheries and Aquaculture Centres:** The GRN should be complemented on tremendous political goodwill through capital investment infrastructure development.
19. The line functions of these facilities are unclear. The MFMR should consider the strengths and delineate responsibilities in aquaculture and capture fisheries.
20. The GRN should make efforts to strengthen leadership at KIFI (Kamutjonga Inland Fisheries Institute) and other inland aquaculture centres.
21. Conduct a detailed audit of facilities and invoke remedial measures to optimize its facilities, especially at KIFI.
22. At Hardap, import new strains of *O. niloticus*, a species that already exist in Namibia.
23. **On Assisted 'Cooperative' Fish Farms:** Four of the six farms were visited. The flooding problems are known and some management practices can be put in place to ameliorate flooding on some farms. Until and unless the ownership of these operations is finalized, no meaningful progress can be made to improve these farms.
24. The farms, individually or together, should be rented or leased to committed locally established PPP companies who should operate the farm with technical support of MFMR and Ministry of Agriculture
25. Technical capacities of key staff on farms need to be upgraded urgently.
26. **On Evaluation of Potential Aquaculture Sites:** Rapid assessments were made on 17 sites and the way forward for each described. These sites were ranked.
27. The highest ranked site locations were at Kaoko Otavi, Oruvandjei, Warmquelle and Bernafay.
28. **On the Regional Stakeholder Consultations:** In total six regional workshops were conducted and the national SWOT (strengths, weaknesses, opportunities and threats) analysis was used to inform the NAMP-FW. The regional and collated national SWOT analysis are presented.
29. **On Assessment of Market Demand for Namibian Farmed Freshwater Fish:** An assessment was made based on secondary literature, household surveys and on demographics.
30. At national level around 75% of purchase transactions are conducted in cash, suggesting that there should be money in the economy to pay for fish, which is cheaper than red meat and poultry.
31. The current practice of MFMR producing and selling fish at N\$15/kg is untenable and comprises market development and opportunities for freshwater aquaculture uptake and should be re-examined immediately.

32. The national domestic demand for Namibian-grown freshwater fish is estimated at between 1 100 to 14 000 tonnes depending on the per capita consumption of freshwater fish. Gate sales revenue from this demand is estimated at N\$ 23 to 275 million/year at N\$ 20/kg.
33. A regional demand for freshwater farmed fish exists in neighbouring countries but the capacity to compete in this market will need to be assessed carefully.
34. The MFMR should conduct a detailed field study on the domestic market using innovative approaches to understand household consumption patterns of fish by regions.
35. The GRN should develop a national strategy and regional implementation plan for increasing the per capita consumption of freshwater fish.
36. **On Human Resource Development Requirements and Needs Profile:** There is a clear shortage of appropriately trained staff at all tiers of operation and across the whole value chain, including allied sectors in Namibia. Types of skills required for aquafarms were assessed.
37. There is a disjunction between infrastructure investment and human capacity development required to operationalize freshwater aquaculture development objectives.
38. Failure to address such shortages will compromise the GRN's infrastructure investment further.
39. Conduct an in depth TNA and use to design a suitable Namibian training programme that will enable MFMR and other local training institutions to provide appropriate training to the right people at the right place and at the right time using the right approach.
40. Collaborate with tertiary and vocational institutions in neighbouring countries to upgrade training capacity in Namibia.
41. Review all existing training curricula for the freshwater aquaculture sector and upgrade where necessary to include innovations and trends for freshwater aquaculture in Namibia.
42. **On Fish Feeds and Related Challenges in Namibia:** The MFMR together with assistance from the Spanish Government built a fish feed plant at Onavivi in 2009. The GRN should be complemented on this achievement. The plant has a capacity of 1 200 tonne/yr and can support around 600 tonnes of fish production/year.
43. The key issues with aquafeeds relate to pellet stability, consequent high dust levels and fast sinking rate of pellets.
44. MFMR should investigate if the feed plant can be upgraded to improve pellet stability and produce extruded feeds.
45. **On Potential Aquaculture Systems:** Six environment types in Namibia were considered suitable for development. These ranged from flood plains to groundwater. Additionally, a range of aquaculture production systems, from ponds in floodplains to recirculatory aquaculture systems, are suitable for Namibia.
46. Potential sites visits where such systems could be developed were identified.
47. Land in flood-prone and non-flood zones in the northern regions should be surveyed to identify suitable sites to create suitably sized dug-out ponds for freshwater aquaculture. A key consideration should be to ensure earliest possible receding of floodwaters to maximize the growing period.

48. Discuss with relevant authorities the possibility of using canals for direct stocking with fish and prawns for local communities.
49. Identify suitable reservoirs for cage culture using large juveniles (80g).
50. **On Estimates of Fish Farm Yields:** The yield under varying stocking models was assessed. Of the key factors determining fish yield in Namibia, initial size of fingerlings stocked, use of sex-reversed fingerlings, water temperature and mortality are most crucial.
51. Growth rates and therefore yields in all outdoor systems will be lower than indoor systems where water temperature can be raised. The only exception could be where large volumes of geothermal water are available.
52. Mortality significantly effects economic viability. Financial losses from fish mortalities are estimated to be over 60% from lost sales followed by 27-28% due to their feed costs and 8-12% due to fingerling costs.
53. It is imperative that MFMR immediately source annual water temperature data for the water bodies and initiate, implement and enforce simple protocols to routinely monitor water temperature in their facilities.
54. Immediately increase the size of fingerlings stocked in all on-growing rearing facilities and implement a programme for well-planned production of larger sex-reversed fingerlings, ideally *O. niloticus* and *O. andersonii*.
55. Conduct well-designed pilot trials (2/system) at predetermined sites for a selected number of on-growing systems and species described above to optimize fish farm yields for local conditions.
56. **On Assessment of Potential Candidate Species for Freshwater Aquaculture in Namibia:** Internationally acknowledged criteria, attributes and success factors were applied to identify potential farming candidates for freshwater aquaculture under Namibian conditions.
57. The tilapias had the highest aggregate score of 87 and offered the best chance for development followed by catfish (75), freshwater prawns (67), red claw (62) and carps (52).
58. The choice of tilapia species allowed for aquaculture is a matter of government decision. Currently, *O. andersonii* is farmed but other species such as *O. niloticus*, also available in Namibia, which may offer better growth performance should be seriously considered.
59. *Macrobrachium vollenhovenii* found in the Kunene region should be given high priority for development. This species offers an opportunity to develop a high value freshwater species for culture.
60. **On the Background and Potential to Culture Selected Freshwater Species:** Technical and cultural requirements for the four freshwater species identified for promotion is provided.

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