FISHERIES TRAINING PROGRAMME

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PLANNING AND MANAGEMENT FOR SUSTAINABLE DEVELOPMENT OF INLAND AQUACULTURE IN ANGOLA

Esperanza Justiz Silva
Institute of Development of Artisanal Fisheries and Aquaculture (IPA)
Ministry of Fisheries
Rua Jose Tuca 36/38
Luanda, Angola
justizsilva@yahoo.com

Supervisors
Geir Oddsson - University of Iceland - geiro@hi.is
Valdimar Ingi Gunnarsson - M. Sci. Fisheries - valdimar@sjavarutvegur.is

ABSTRACT

Responsible and sustainable aquaculture in Angola is one of the government's most important objectives as a means increasing food security and economic development. This study provides a clear understanding of the current status of aquaculture in Angola and describes different aspects that shall be considered for suitable and viable aquaculture development. In order to achieve this goal three objectives were developed. The study evaluated 11 native freshwater species, previously considered by Fishbase and selected as suitable for inland aquaculture in Angola. The evaluation process was carried out using three different phases. Growth performance, reproductive biology, feeding habits and market value were the criteria used to select the suitable species. However, there is a lack of information regarding the biological characteristics of most evaluated species. *Clarias gariepinus*, *Oreochromis andersonii* and *Tilapia rendalli* were selected as the best species for inland aquaculture. Suitable areas for rural and industrial aquaculture in Malange province of Angola were identified. Critical constraints in place and the main factors necessary for successful of aquaculture operation including social, economic, production technology as well as environmental aspects were considered for the future aquaculture development. The inland aquaculture checklist for Angola including, site selection, species source, business planning, environmental impact assessment and aquaculture licensing requirements was developed. This document provides information and assesses the different aspects required to develop an aquaculture project.

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1 INTRODUCTION

The development of aquaculture in Angola is necessary to offset the overexploitation of natural aquatic resources in the country. Aquaculture can also contribute to the diversification of industry especially in rural areas. Expansion and adaptation of sustainable aquaculture in rural areas by supporting integrated small-scale operations can increase food security, provide alternative means of income and thereby reduce poverty. A well-coordinated and planned development effort is needed to bring about significant increases in production. To achieve this, public investment will have to be made in infrastructure, in institutional frameworks, in extension and seed supply services, and in research and training programmes. The Action Plan for Fisheries and Aquaculture Development in Africa (NEPAD 2005) recognised the vital contributions of inland and marine fisheries to food security, poverty reduction and economic development in the African continent. This plan has also recognised the growing opportunities and emerging successes of aquaculture development. The Framework of the Comprehensive African Agriculture Development programme (CAADP) has identified the primary areas for investment in aquaculture as:

- Developing a sector-wide strategic plan at the national level for expansion and intensification of aquaculture.
- Supporting priority aquaculture zones.
- Encouraging private sector investment across the sector.
- Applying proven technologies to increase production.
- Maintaining the competitive advantage that Africa’s environment provides for aquaculture production.
- Harnessing opportunities for the development of small and medium sized enterprises provided by expanding domestic markets for fish, including growing urban demand.
- Supporting the emerging regional trade in aquaculture products.
- Harnessing the opportunity of expanding export markets for high-value products to increase investment in African aquaculture production and processing.
- Expanding the adoption of integrated small-scale aquaculture as a means of increasing rural productivity and food security.
- Exploiting the potential of aquaculture production to contribute to food security programmes.

Aquaculture production in Africa has increased by 60% over the previous decade; and contributes 0.4% of the world’s total production (Gupta *et al*. 2004). The trend in aquaculture production in Africa over the past decade, according to Fishstat (2005) is shown in Figure 1.

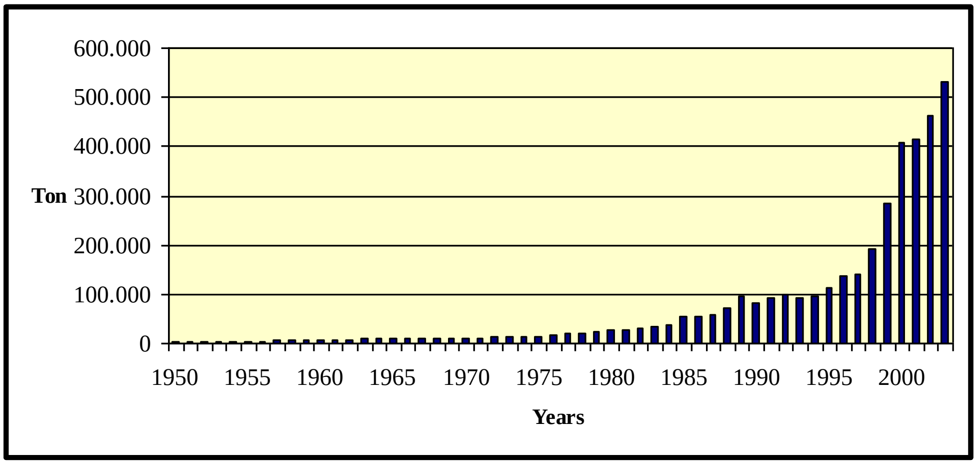


Figure 1: Aquaculture production in Africa (Fishstat 2005).

The greatest increase in production in Africa has been since 1998. Egypt is the most important aquaculture producer in Africa producing 445 mt in 2003. Nigeria and Madagascar are also important aquaculture producers with 30 mt and 9 mt respectively (Fishstat 2005).

The majority of the infrastructure used in African aquaculture was introduced through international technology development and transfer projects, but the current state of most research, development and extension in Africa is poor. Low levels of annual expenditure have rendered national and regional programmes more or less incapable of managing the growth of the industry. A large percentage of governmental aquaculture facilities are either abandoned or currently dysfunctional for various reasons (Gupta *et al*. 2004).

Many authors strongly suggest that governments should encourage aquaculture development based on native species first. If exotic species are to be introduced, governments should ensure that adequate safeguards are put into place (Stickney 2000). Research in the past was focused on the adaptation of the culture of exotic species to local conditions, but has since gradually moved towards the development of culture methods for native species (Van der Mheen and Haight 1994). Southern Africa has a wide variety of native fish species and several of these have been studied and tried for aquaculture production. The decision about which species to use in aquaculture depends mainly on the environmental conditions and scale of the aquaculture enterprise. Small-scale rural fish farmers mostly use species that are promoted by aquaculture authorities. However large-scale farmers have access to exotic species (Van der Mheen 1994).

Suitable fish selection for aquaculture is one of the most relevant aspects to be considered in the aquaculture sector. In Angola identification of native species appropriate for aquaculture is of great importance because some legal restrictions are imposed on the importation of aquatic species in order to safeguard native fauna and flora, protect habitats, and prevent the introduction of animal, plant and human diseases (Angola

Parliament 2004). The current status of native species of Angola is uncertain, there is an acute need to do research on native fresh water species and develop plans to conserve the species that are threatened (Vanden Bossche and Bernacsek 1987).

Environmental issues related to aquaculture and requirements for Environmental Impact Assessment (EIA) are defined in the Angolan Aquaculture Regulations. The general rule is that the establishment of new aquaculture enterprises is subject to an EIA. The Regulation states that any project proposing, amongst others, the cultivation of living aquatic resources, and the installation of plants for the processing of those resources is subject to an EIA. The negative environmental effect attributed to aquaculture has most often resulted from poor planning, inappropriate management procedures and lack of attention to mitigating environmental effects (Lucas and Southgate 2003). Haylor and Bland (2001) describe the benefits of integrating aquaculture into rural development. Environmental impact includes aquatic pollution, disease, mangrove deforestation, salt intrusion, impact on seed supplies, species introduction and reliance on exotics, concerns over biodiversity and genetics, negative environmental perceptions and pressure from lobby groups, and rapid and unplanned growth. Social impact includes exclusion of the poor from participating in, or enjoying the benefits of, aquaculture production (Lucas and Southgate 2003). Aquaculture requires a detailed study before decisions about major investments are made

1.1 Rationale for the project

The expansion of aquaculture in Angola will produce significant social and economic benefits and provide new employment. Although it is in the national interest to encourage both research and production, a careful review of developments is necessary to ensure optimisation of the national potential (Ministry of Fisheries 2003b). The existing legislation favours native species over exotic species to protect and conserve the aquatic biodiversity and the fish populations in the natural water bodies. To achieve this it is necessary to develop available technologies to cultivate native species with potential for aquaculture and create a rational framework to select appropriate native species. Research is required to determine optimal conditions for culture, and to improve local research capacities (Ministry of Fisheries 2004).

1.2 Objectives

This project focuses on the continued development of inland aquaculture in Angola. The overall objectives of this project are to:

1. Evaluate potential Angolan native species for aquaculture and select suitable species for inland aquaculture.
2. Identify the main criteria for the development of an initial checklist for inland aquaculture development.
3. Analyse relevant data from Malange province to identify and evaluate the areas that are most suitable for rural aquaculture by local communities and for industrial aquaculture facilities.

2 BACKGROUND

2.1 Angola

Angola is located in Southern Africa and has a surface area of 1,246,700 km^2. The country borders the Atlantic Ocean to the west with a coastline of 1,600 km. Angola has common borders with Congo and the Democratic Republic of Congo in the north, Zambia in the east and Namibia in the south. The country has 18 provinces; Cabinda province in the north is separated from the rest of the country by the Congo River (Figure 2).

Figure 2: Angola geographic location (Country Reports Org 2005).

The climate in Angola is tropical, with wet and dry seasons that vary little in maximum and minimum temperatures. While it is very hot and rainy along the coastal regions, the inland areas are milder. In the northern half of the central plateau there are humid tropical conditions and in the high regions of the south, a dry tropical climate prevails. The northern part of the coastal plain is humid, while the centre and the southern part are affected by the relatively cold Benguela current and gives a temperate character to the coastal regions. In the interior highlands, the rainy season lasts from November to April followed by a cool dry season from May to October. Rainfall is high in the north and in the central highlands (average 1,250-1,750 mm) and decreases rapidly along the coastal plain (average 250-1000 mm) (FAO 2004).

2.1.1 Angola freshwater system

Surface water resources are relatively abundant (Table 1). The major river systems in Angola are composed of the Zaire River Basin, where major tributaries include the Kasai and Kwango rivers, the Zambezi River Basin with the headwaters of the Zambezi and its tributaries and the Lungue and Kuando rivers, with some 20,000 km² of floodplain, the Okavango River Basin, with the Kuito and Cubango rivers, the northern coastal rivers, chief of which is the Kwanza River and the Cunene River Basin, including 15,000 km² of the Ovambo floodplain (Figure 1). The major rivers total over 10,000 km in length, not counting small streams (Vanden Bossche and Bernacsek 1987).

Table 1: Summary of inland freshwater potential in Angola based on information from FAO (2004).

Province	Number of main rivers	Number of lakes
Bengo	2	8
Luanda	2	6
Kwanza Sul	12	9
Namibe	3	2
Huíla	6	8
Kunene	4	2
Kuando Kubango	32	31
Bié	17	7
Moxico	13	22
Malange	7[1]	N/A
Lunda Sul	10	4
Lunda Norte	30	2
Kuanza Norte	2	30

[1](Ministry of Fishery 2003a)
N/A- No available data

Floodplains with numerous small lakes occur along the lower reaches of many of the rivers, discharging westward into the Atlantic Ocean (FAO 2004). There are no large lakes, but there are numerous smaller bodies of water associated with the floodplains of river systems in the south and east of the country (Vanden Bossche and Bernacsek 1987). The provinces of Kuando Kubango, Malange, Lunda Norte, Bié, Moxico and Kuanza Norte would seem to have the greatest potential for developing an active inland fisheries sector (FAO 2004).

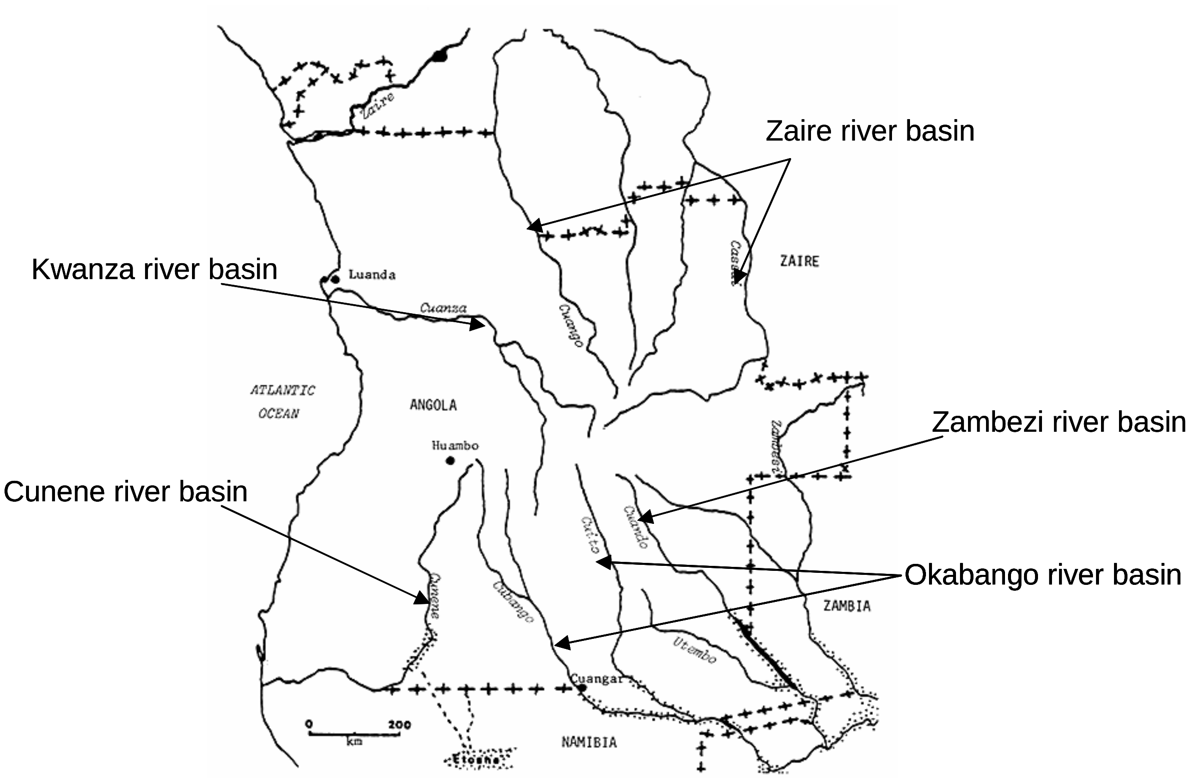


Figure 3: Main river basins of Angola based on information in Vanden Bossche and Bernacsek (1987).

2.1.2 Freshwater species

Angola has several fresh water species with high value in the local market, but very little knowledge on their potential for aquaculture. These species have contributed significantly to fish catches from Angolan rivers and smaller lakes. Fishbase (2005) offers information on more than 255 freshwater fishes for Angola in terms of their biology and geographical distribution. *Tilapia sp.* is the most important and abundant freshwater fish, and in terms of breeding has produced cheap animal protein from rural aquaculture. Other possible species include catfish (*Clarias gariepinus*) and fresh water prawn (*Macrobrachium rosenbergii*) (Ministry of Fisheries 2003a).

2.2 Overview of the aquaculture sector in Angola

The existence of abandoned aquaculture facilities in some provinces including Malange confirms that aquaculture started before independence, with rudimentary technologies and under initiative of the private sector (Ministry of Fisheries 2003a). Further the report of Vanden Bossche and Bernacsek (1987) confirmed that several fish-culture facilities existed in the last two decades. According to FAO (1994), there are no production records from the stations or the farms. In 1977 culture of common carp (*Cyprinus carpio*) and grass carp (*Ctenopharyngodon idella*) was attempted, without success. In 1992, five undrainable ponds were stocked with tilapia obtained from a river north of Luanda.

The aquaculture sector has experienced a number of difficulties and drawbacks in the past, mainly due to high cost of investment and inadequate training of personnel (Giudicelli *et al.* 1987 as quoted in Vanden Bossche and Bernacsek 1987). However, according to Vincke (1989 quoted in Vanden Bossche and Bernacsek 1987) there was some development of inland aquaculture for *Tilapia sparrmanii*. The only aquaculture production recorded since 1982 is 7 t in 1983 and 2 t in 1985.

In 2003 the responsibility for aquaculture was transferred from the Ministry of Agriculture and Rural Development to the Ministry of Fisheries. Since 2003 the Ministry of Fisheries has established a technical site visit programme in inland and coastal provinces to study and assess the potential for aquaculture development. At the national level, aquaculture development expertise from Israel, Yugoslavia and Vietnam has contributed. These experts carried out studies to identify the potential species and areas for aquaculture. However, technical services have recently been put in place by the government in the form of the Institute of Development of Artisanal Fisheries and Aquaculture (IPA).

2.3 Current situation of inland aquaculture in Angola

The Institute of Development of Artisanal Fisheries and Aquaculture (IPA), under the Ministry of Fisheries carries out biological studies and evaluations of potential environmental and social impacts of aquaculture developments and provides technical support to fish farmers. In 2005 the IPA conducted systematic surveys on the current status of aquaculture in Angola. Aquaculture in Angola is small scale and focused on inland fresh water aquaculture both by communities and the private sector. There is currently no development of mariculture. At the moment there is no statistical production data on aquaculture in Angola, probably because development has only been through small initiatives.

Rural fish farming with native species has been developed in some provinces of Angola (Cabinda, Luanda, and Kuando Kubango), but there is a shortage of technical expertise. Most aquaculturists employ rudimentary technology, using earthen ponds fertilised with locally available, low-cost agricultural by-products. In general production techniques are not very well mastered by fish farmers and there is a need to assist the farmers and further promote fish farming. The production is input-limited, both in terms of quality and quantity with low yield results (Silva 2005).

Commercial private sector aquaculture started in 2002 on the Bengo River in Kifangondo, Luanda province. The project is using the species *Oreochromis niloticus*, introduced from Brazil, and plans to produce 2 million larvae/month and 100 t/month. Currently the monthly production is 40 tons, which is marketed locally. A second aquaculture farm on the Kwanza River in Bom Jesus started in 2005 but is still in the development stages. They use exotic species including *Oreochromis niloticus* from Canada and *Oreochromis mossambicus* from Mozambique. The future yield is projected at 20 tons per month (IPA 2005).

The Proposal Plan for Development of Aquaculture in Angola (PPDA) is a strategic programme to combat hunger and mitigate poverty in Angola. The immediate objectives of this plan are to expand integrated small scale aquaculture as a means of increasing rural productivity, food security and harnessing the opportunities for small and medium sized enterprise development, provided by domestic markets, for high value products and to increase investment in aquaculture production and processing. The PPDA was conceived to have two basic phases, the latter depending on the success of the first. The first phase concentrates on implementing, in the short term, rural and industrial freshwater fish farms and in the second phase mariculture projects will be developed. In the development of inland aquaculture, priority will be given to the utilisation of existing natural resources of wild fry and juvenile fish and well known and tested environmentally friendly technologies, adapted to environmental conditions in Angola. Inland hatcheries, to provide further support to these industries, will be developed gradually (Ministry of Fisheries 2004).

An analysis of the strengths, weakness, opportunities and threats of developing the Angolan aquaculture sector was identified in the PPDA. The results are summarised in Table 2.

Table 2: SWOT analysis of the development of the aquaculture sector in Angola (Ministry of Fisheries 2004).

Strengths	• **Several agro-ecological zones and natural features.** • **Wide range of potentially suitable endemic freshwater species.** • **Low cost of fish feed production because of the availability of raw material for fish feed production.** • **High local demand for aquaculture products.** • **Good regulation support.**
Weaknesses	• Technical knowledge of suitable species specific to aquaculture practices is limited. • Hatchery capacity for seed-stock supply is non-existent at present. • There is a general lack of successful aquaculture demonstration sites for extension purposes nationally. • There is insufficient regionally based infrastructure specifically suitable for post-harvest handling and storage of aquaculture products.
Opportunities	• Aquaculture investment, development and associated socio-economic benefits are primarily regionally based and therefore of most benefit to rural communities. • Aquaculture provides the opportunity to diversify operations and so enhance economic security. • Any sustainable and responsible aquaculture production will reduce the pressures on already depleted wild fishery resources and will ultimately benefit aquatic biodiversity. • Increasing demand in local and international markets. • Presence of technology and knowledge on aquaculture worldwide.
Threats	• Inefficient Quality Assurance Programmes. • Lack of institutional infrastructure to facilitate aquaculture development. • Low technical level of fish farmers. • Lack of knowledge of the environmental impacts of aquaculture activities.

2.3.1 Policy and legislation to support the development of aquaculture activities

The Law on Aquatic Biological Resources of 2004 (LRBA) is based on sustainable conservation and use of fisheries and aquatic resources, and efficient development and management of aquatic resources. For aquaculture, LRBA Law guarantees the rational exploration of the aquatic biological resources inside the limits of biological sustainability and the protection of the aquatic environment. Furthermore establishing a sustainable aquaculture system in harmony with the environment and the local communities as well as conserving biological diversity. The LRBA Law also supports aquaculture development through research and development and the dissemination of environmentally friendly technologies (Angola Parliament 2004).

The aim of the National Aquaculture Policy is to promote sustainable aquaculture, management, protection and conservation of marine and inland ecosystems as well as the promotion and operation of aquaculture projects (Ministry of Fisheries 2004)

The Aquaculture Regulation establishes the rules to guarantee sustainable and responsible aquaculture development activities with observance of the Aquatic Biological Resources Law and other relevant legislations (Ministry of Fisheries 2005)

2.4 Malange province of Angola

The technical field trips in Angola in 2003 conducted by the Marine Research Institute identified 12 provinces with natural potential for aquaculture development. Namely, Luanda, Bengo, Lunda Sul, Lunda Norte, Malange, Moxico, Kuando Kubango, Kuanza Sul, Namibe, Huíla, Cunene and Huambo (Ministry of Fisheries 2003a). In the present study Malange has been proposed as a pilot province, because it has been prioritised by the government for aquaculture development for the next few years.

Malange province is located about 423 km from Luanda city (Figure 4). The population of the area is approximately 850,000. The province has an area of about 97,600 km^2 and has 14 municipalities (Republic of Angola 2005). The Kapanda hydroelectric dam is located in this province and will be a major provider of electricity for the country. Once the second phase of the hydropower project is completed, it will supply more power than all systems already in place in all of Angola’s Central and Northern provinces including Luanda. Upon completion the Kapanda hydropower project will attract more industry and foreign investment (Republic of Angola 2005). The Kapanda project is likely to enhance opportunities for government supported aquaculture development around the dam and reservoir.

Several of the major freshwater resources in Malange are the Kwanza River system (total length-960 km) and the Cuango River (Vanden Bossche and Bernacsek 1987). Others include Lucapa, Luando, Luchilo, Culamuxilo, and Camibafo Rivers (Ministry of Fishery 2003a). Some rivers in the Malange province have a significant number of native species with potential for aquaculture (Fishbase 2005). The region is suitable for the culture of carp, catfish and tilapia. The climate is humid tropical with tropical rain forests in the northern part and savannah in the southern. The rainy season lasts for 6 months from November to April with an average rainfall of 1000 – 1200 mm per year. Monthly mean temperature ranges from 9°C to 30°C (FAO 1994).

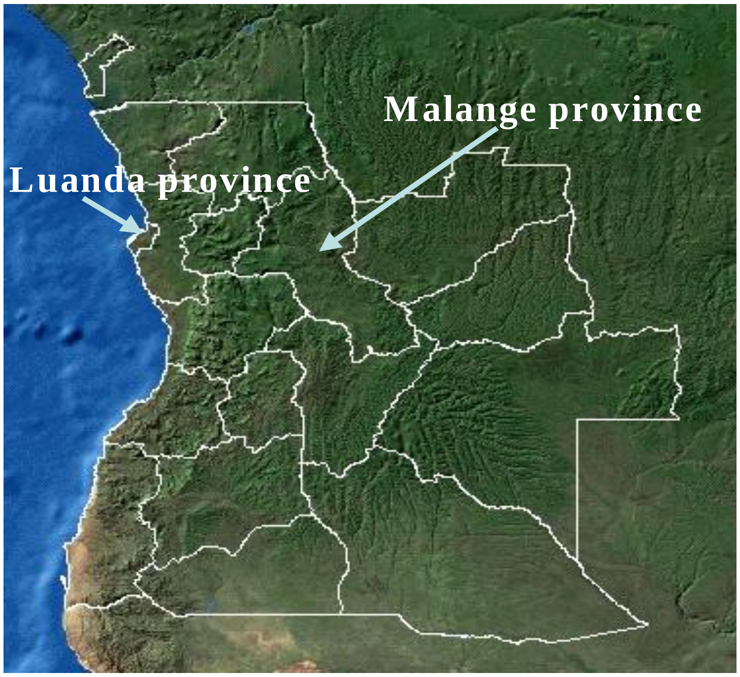


Figure 4: Malange province of Angola (FAO 2004).

In Malange province, fish culture was developed prior to independence. The proposal for the next years is the construction of hatcheries in this province in order to provide enough seedstock for the area, an aquaculture research regional centre and a feed processing factory, and the expansion of various programmes to build rural land ponds (Ministry of Fisheries 2004). The results from a preliminary report in 2003 are quite positive for the development of inland fish farming in Malange province. The report showed that both commercial and small-scale fish farming is possible over vast areas without serious constraints. The climate conditions and quantity and quality of water sources guarantee fish culture throughout the year (Ministry of Fisheries 2003a). Considering the fact that small water bodies could play a major role in supplying fish for food to rural populations it is necessary to define criteria for cultured fish species and the site selection for aquaculture operation in this province.

3 METHODOLOGY

3.1 Evaluation of data and criteria for selecting suitable native species for inland aquaculture in Angola

3.1.1 Data sources for native Angolan species

Fishbase (2005), which offers information on 253 freshwater fishes that occur in the Angolan river systems, was used as the main data source. From the total of 255 native species, Fishbase (2005) considered that 11 species were promising candidates for inland aquaculture, because they have been used for aquaculture and commercial purposes. This study started by evaluating these 11 recommended species.

3.1.2 Source for selection criteria

The selection of suitable freshwater species for inland aquaculture was based on several published aquaculture and biological studies, which contribute to a global knowledge on general species selection criteria. In this study the potential of native species is assessed from four critical criteria: growth performance in nature and in captivity, reproductive biology, feeding habits and market value. To evaluate growth performance, reproductive biology, and feeding habits, data were collected in the wild for comparison with the behaviour of these species in captivity. The market value criterion was estimated according to local market prices in Angola.

The species evaluation was done in three phases, namely first, second and the final evaluation. For the first phase, data from Fishbase (2005) on the main biological characteristics of wild fish was used. The definitions of these characteristics are described in Table 3.

Table 3: Definitions of main biological characteristics of interest for aquaculture (Fishbase 2005).

Maximum length	**The maximum length individuals of a certain species are likely to reach.**
Maximum weight	The maximum weight of an organism.
Average length at first maturity	Average length at which fish of a given population mature for the first time.
Age at first maturity	Average age at which fish of a given population mature for the first time.
Classification of fish	Fish are classified according to the position they occupy in the food chain. Primary producers, herbivores, detrivores, omnivores and carnivores[1].
Main food	Feeding type indicators.

([1]Pillay 1993)

The data to estimate natural growth rates using the traditional formulas does not exist for the species being evaluated in this study. Therefore average length and age at first maturity was used as an approximation of usual growth formula parameters. The formula used to estimate growth rate was:

$$\text{Growth rate} = \frac{\text{Average length at first maturity (cm)}}{\text{Age at first maturity (year)}} = \text{cm/year}$$

To evaluate the reproductive biology criteria, average length at first maturity in nature was used. The evaluation of the feeding habits, took into consideration the classification of fish according to the feeding types and trophic level. The main aspect to evaluate market value was the local market selling prices. Market prices both for formal and informal markets in Luanda province were surveyed by the IPA in 2005.

To be able to compare objectively the different species it was decided to give each species a score on the scale of 1-3 for each selection criteria. Table 4 represents the score of each of the four criteria used in this study for the first stage. Species that had an average score of more than 2 were selected.

Table 4: A rational framework for aquaculture species selection (score used to evaluate the suitable species for the first stage).

CRITERIA/SCORE	1	2	3
GROWTH PERFORMANCE			
Growth rate (cm/year)	10 <	10 – 20	>20
Maximum length (cm)	40<	40 – 50	>50
REPRODUCTIVE BIOLOGY			
Average length at first maturity (cm)	1 5 <	15 – 30	> 30
FEEDING HABITS			
Classification of fish by feeding types	Carnivorous	Omnivorous	Herbivores and Detrivores
MARKET VALUE			
Market demand (Local selling price – USD/kg)	< 5	5 – 10	>10

For growth rate the maximum score was given for species that grow more than 20 cm/year. This was based on the selection of species that grow faster before attaining first maturity and, also species that take a short time to reach the market size. This means that species that reached 20 cm/year before the attainment of first maturity should be suitable especially for industrial aquaculture. For the maximum length species than showed a length more than 50 cm obtained the maximum score. For this aspect the capacity of species growth in nature was taken into account. This size (50 cm) looks profitable from the point of view of the market. For the second criteria, reproductive biology was evaluated. For the average length at first maturity, considerations such the growth performance were estimated. The significance score was given to species that attained an average length at first maturity of more than 30 cm. For the feeding habits criteria the herbivorous and detrivores fish received the maximum score. For inland aquaculture purposes these species are considered less hazardous than carnivorous fish, because of the possibility of improving the quantity of natural food through organic fertilisation as well as inorganic. Omnivorous fish received the middle score, because these species exploit a wide variety of food items. Carnivorous fish in aquaculture generally need a high protein diet , which is generally considered more expensive produce (Pillay 1993). For the last criteria the maximum score was given to those species with a selling price over 10 USD/kg, because of the relevance of the freshwater fish in Angola.

The species with an average score of more than 2 are of major interest, because of the need to select the best species to start industrial aquaculture in Angola. These species can also be used in rural aquaculture, using simple technology.

The second phase of species evaluation uses only relevant information regarding critical aspects of interest for inland aquaculture. Firstly, the species are characterised by important factors such as, how fast they grow in captivity, fecundity and frequency of spawning, age at first maturity (only for ongrowing[1] stage), as well as capacity for feeding on supplementary food in captivity. For the last phase or final evaluation, the results of the second phase are used.

3.2 Evaluation of the potential for aquaculture in the Malange province of Angola

In Malange province three districts, namely, Malange, Cacuzo, and Kalandula were visited. The sites visited included rivers, lakes, two hydroelectric dams, irrigation dams, abandoned aquaculture infrastructure, reservoirs and small water bodies (Ministry of Fisheries 2003a). Information on the potential resources for aquaculture development in Malange province was obtained from a report on the technical site visit programme in the inland and coastal provinces to study and assess the potential areas for aquaculture development in 2003. A total of nine places in three districts were visited. Information on the possible past and current aquaculture activities was obtained though a questionnaire survey from competent authorities in local communities. Additional information was taken from local authorities and direct observation. Questionnaire surveys from local communities were used for different objectives. This information shows species composition of the catches, local names of freshwater fish species, several fishing seasons etc. Constraints in place for initial aquaculture development were identified mainly based on their importance in the efficiency of aquaculture.

[1] Ongrowing refers to hatchery fish that have been transferred to tanks, ponds or cages.

4 OVERVIEW OF INLAND AQUACULTURE

4.1 Sustainable aquaculture

Van (2001) introduced a definition of aquaculture as 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.

FAO (1997) defines sustainable development as the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable.

Aquaculture cannot be considered only from the technical aspects in isolation from social, economic and environmental contexts. The system approach to promote sustainable aquaculture practices is shown in Figure 5. The system approach is required to adequately understand and promote the development of aquaculture in general, and integrated aquaculture in particular. Sustainability is first defined in general terms and then specifically in relation to aquaculture in terms of production technology, social and economic aspects, and environmental aspects (Edwards *et al.* 1997).

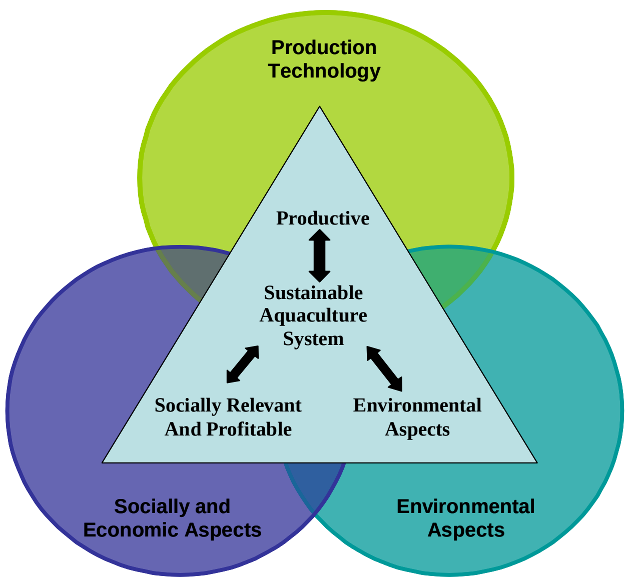


Figure 5: The three inter-related aspects of the sustainability of an aquaculture system, production technology, social and economic aspects, and environmental aspects (AIT 1994 quoted in Edwards *et al.* 1997).

Sustainability may be expressed in terms of three interrelated aspects (Figure 5): Production technology, social and economic aspects, and environmental aspects. An aquaculture farming system needs to be sufficiently productive to make it an attractive option to alternative or competing uses of resources (land and water, capital and labour, and farm by-products). Social and economic aspects of aquaculture have received relatively little attention compared to production aspects and are major constraints to development through aquaculture. Environmental aspects are only now beginning to receive the attention they require to prevent humans from exceeding the global carrying capacity for our species.

The main details of the three interrelated aspects are described below (Edwards *et al.* 1997):

- Production technology: Production technology may be subdivided into three main aspects (cultured species, culture facility and husbandry). The choice of species influences the type of facility and also the type of methods. Husbandry may involve various methods (monoculture or polyculture), use of different feeds (natural, supplementary or complete feed), management of substrate and water quality, and disease prevention and therapy.

- Social and economic aspects: Low unit cost input system may be most appropriate for the limited resource base of most poor subsistence farming, and low production costs mean that fish can be sold at a relatively low market price and be affordable to poor consumers.

- Environmental aspects: Aquaculture should be environmentally friendly. The environment is defined as being external to the aquaculture system and includes the natural resources used for aquaculture development such as land, water, nutrients and biological diversity. Technology needs to be adjusted to the limited resource base of the poor. Resources that may be used more productively in other ways shall not be used.

4.2 Freshwater fish

The freshwater species can be herbivores, detrivores, omnivores and carnivores and are often cultured together as complementary species (Lucas and Southgate 2003). The most important species to rural aquaculture are carps and tilapia. These are low value species that are low in the food chain and require little supplementary input of feeds (Edwards and Demaine 1998). Studies carried out by Hecht and Moor (2004) defined the most popular cichlids species (*Oreochromis andersonii*, *O. niloticus*, *Tilapia rendalli*, *O. macrochir*, *O. aureus* and *O. mossambicus*), other species include catfish species, *Chrysichthys nigrodigitatus*, and African catfish, *Clarias gariepinus*, which is widely cultivated throughout the world and particularly in Asia but does not rank highly as an aquaculture species in small scale farms in Africa. Traditional inland aquaculture practice is considered less hazardous with the use of herbivorous and omnivorous fish species. The quantity of natural food can be improved through fertilisation and water management (Black 2001).

Aquaculture with freshwater fish has been development by small-scale farming households or communities, usually by extensive or semi-intensive low-cost production technology appropriate to their resource base (Edwards and Demaine 1998). Lucas and Southgate (2003) described the extensive aquaculture method as a method that uses the natural environment, where the stock generally are obtained from a hatchery, although in some cases wild spat or juveniles may be collected, and placed into a position where they can obtain all their needs from an unmodified or minimally modified environment. However a semi–intensive aquaculture system is described more as supplementation of the natural system. Supplementation may take many forms, including additional aeration to guarantee adequate dissolved oxygen, addition of inorganic or organic fertiliser to improve natural productivity and addition of prepared feeds for supplemental feeding.

4.3 Use of native species for aquaculture

Regulation No. 39 of 2005 on Aquaculture defines native species as the animal and plants species that occur naturally in Angola (Angola Parliament 2005).

In an extensive review of small-scale aquaculture in sub-Saharan Africa, Hecht and Moor (2004) concluded that Africa has many native species with aquaculture potential. However, little is known about them and there is a need for a concerted research effort to identify suitable species for small-scale fish farming in Africa. Culture of native species has both advantages and disadvantages (Table 5). However many of the disadvantages associated with the use of native species can be overcome by means of intensive research.

Table 5: Advantages and disadvantages of native fish species for small-scale aquaculture based on information from Hecht and Moor (2004).

Advantages	Disadvantages
Do not pose a threat to the environment since they are already an integral part of the natural ecosystem in the surrounding region.	The technology for their artificial propagation is often not well developed.
Do not have the potential to introduce alien parasites, which are often accidentally imported in association with alien species.	The genetics of many of these species is not well known and fast-growing strains have not been developed.
In many instances local people are already familiar with the native species and prefer them to alien species.	Growth performance under aquaculture conditions is not well known.
Broodstock can often be obtained from natural waters, and in some instances fingerlings can be collected from natural waters.	Complex environmental cues, which are not well understood and may be difficult to replicate under hatchery conditions, may be required to initiate spawning. Cichlids are an exception to this rule
Fingerlings of many species, particularly the cichlids, can be harvested from production ponds.	
Sophisticated hatcheries are therefore not necessary.	

The main native freshwater fish used in aquaculture in Africa includes large Cichlidae species (*Tilapia sp*. and *Oreochromis sp*.) and Claridae (Table 6).

Table 6: Native freshwater fish farmed in Africa based on information in Changadeya *et al.* (2003).

SPECIES	COUNTRIES
Clarias gariepinus	Malawi, Nigeria, Rwanda, South Africa, Tanzania, Zambia.
Oreochromis andersonii	Zambia
Oreochromis aureus	Côte d'Ivoire
Oreochromis macrochir	Zambia
Oreochromis mossambicus	Malawi, Mozambique, South Africa, Swaziland
Oreochromis niloticus	Congo, Egypt, Gabon, Ghana, Kenya, Mozambique, Senegal, Tanzania, Uganda, Zambia
Tilapia rendalli	Malawi, Swaziland, Tanzania, Zambia
Tilapia zilli	Uganda

In southern Africa aquaculture research in the past has mainly focused on the adaptation of the culture of exotic species to local conditions, but has since gradually moved towards the development of aquaculture methods for native species (Van der Mheen 1994). Study on industrial aquaculture in Malawi shows that the main species cultured are from the genera *Tilapia* and *Oreochromis* (Ambali 2001). The Malawi Government put a ban on the import of exotic species, which have been domesticated and selected over native species. Research into new species for aquaculture therefore has been conducted with native species and some studies have shown that wild populations grow faster than domesticated populations.

In southern Africa *Clarias gariepinus* has been recognised as a candidate aquaculture species since 1970, but the first commercial *Clarias gariepinus* farms were not established until 1984 (Hecht 1994). In South Africa the *Clarias gariepinus* is a good example of freshwater native species for which culture techniques were successfully developed (Vuren *et al.* 1994). Several native species offer potential as ornamental fish and have commercial potential in South Africa (Vuren, *et al*. 1994). In Zimbabwe the native species, *Oreochromis mossambicus*, *O. macrochir*, *O. andersonii*, *Tilapia rendalli* and *Clarias gariepinus* are being cultured successfully (FAO 1994).

4.4 Suitable fish species for aquaculture

In a biological and technical evaluation of marine and anadromous fish species for cold-water mariculture, Le Francois *et al.* (2002) listed over 45 native fish species of potential commercial interest. The procedures used in the study included studying complete life cycles, stock enhancement and ongrowing of juveniles. The individual species were then submitted to the evaluation of its respective potential through a two-stage selection process using three criteria. Quémemer *et al.* (2002) proposed a new selection method for fish species as candidates for aquaculture development, based on a three-phase procedure, settlement of the mother population, the geographical case/elimination and the geographical case/classification. The study started with 20,000 species. In the first phase species were eliminated for the following reasons, systematic, dangerous or non-eatable species, electronic activity, environment, salinity, minimum weight, minimum length, threatened species. In the geographical elimination some species cannot be selected whatever their geographic distribution. In the last stage remaining species were classified into groups. For the first and second phases, species were selected using ACCESS 97 software and for the third phase the selection was carried out using Electre III Software. As a result cod was selected as the first candidate for aquaculture development in the northern parts of France.

Species with well-known and proven aquaculture performance and known breeding and growing techniques are obviously preferred by aquaculture operators (Van der Mheen 1994). Different criteria have been used to select the appropriate species for aquaculture. Species have be selected according to the objectives of culture, for example to increase protein supplies to the poor, export to earn foreign exchange or waste recycling in a polyculture system (Pillay 2003). Lucas and Southgate (2003) define the choice of aquaculture species as balance between the biological knowledge and economic considerations of the species (Figure 6).

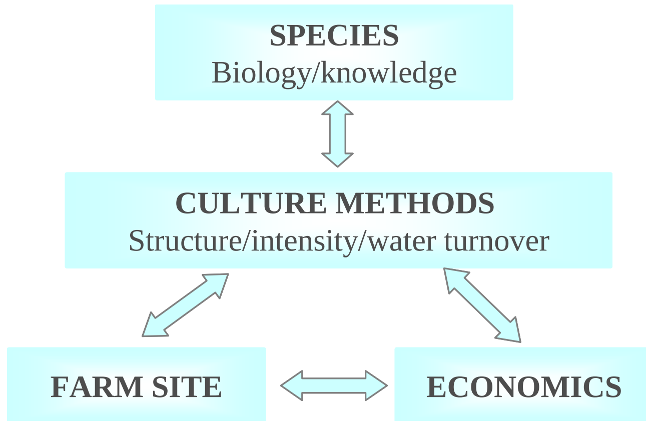


Figure 6 : The interrelationship between cultured species, culture methods, farm site and economics in aquaculture practices (Lucas and Southgate 2003).

Figure 6 shows the interrelationship between cultured species, culture methods, farm site and economics, choosing species for aquaculture practices. Choosing a site for aquaculture is strongly influenced by intensive of culture, the quantity of water exchange required and the biological characteristics of the selected species. The method of culture depends on the availability and characteristics of farm sites. The culture facilities, site and species selected for aquaculture will depend on the economics of the operation. Aquaculture businesses frequently fail as a resulted of inadequate understanding of all facets of the biology and economics of the targeted species, so prior to starting aquaculture operations, it is necessary to be aware of these inter-related components.

Avault (1996), quoted by Lucas and Southgate (2003), listed the main issues to be considered when selecting an aquaculture species, namely, water quality conditions, performance of species under culture conditions (growth rate, reproductive biology and feeding habits) and marketing.

Each species has specific requirements for various water quality parameters. These parameters included temperature, dissolved oxygen, salinity, ph, and ammonia/nitrite/nitrate nitrogen. From these parameters is important know not only the tolerance ranges, but also the optimum levels for growth, survival and reproduction.

Rates of growth and production under cultured conditions are major characteristics that determine the suitability of species for aquaculture. Species showing rapid growth to reach market size are preferred in aquaculture. However, slow growing species can also be candidates for culture because of their market value. In this case species can be grown to the size most preferred by consumers (Pillay 1993).

Reproductive biology is also an important consideration. Is preferable that species reach marketable size before the attainment of maturity, so that, most of the feed and energy is used for somatic growth. Early maturity can be considered an advantage by breeders for hatchery operations, but early maturity before the species reach marketable size is a great disadvantage for aquaculture, as is often for the tilapia species. For species that mature more than once a year it should be possible to have several harvests of seed. High fecundity and frequency of spawning can be an advantage in aquaculture. High fecundity helps offset the high cost of maintaining and spawning broodstock. The size of eggs and larvae is another important factor. Small eggs and larvae can be difficult in the hatching aquaculture operations. A shortened incubation period and larvae cycle often contribute to lower mortality of larvae and greater survival. Larvae that accept artificial feeds would be easier to breed in hatcheries (Pillay 1993).

In aquaculture feeding is one of the major elements in the cost of production, so feeding habits and feed efficiency in terms of growth conversion rates and production then become important criteria for selection of fish for culture (Pillay 1993). Avault (1996) quoted by Lucas and Southgate (2003) divides feeding habitats according to production stage, hatchery/nursery, juvenile and growout phases. Individual fish species are often categorised by feeding habitat, herbivorous feed largely on living plant material, carnivores feed on animal matter, detribores feed on detritus, and omnivores consume a mixed plant an animal diet (Lucas and Southgate 2003).

The feeding habits of fish are important in certain types of aquaculture in particular in warm-water polyculture, in which a combination of species is used, each occupying a different ecological niche (Lucas and Southgate 2003). In culture supplemental feeds are commonly given to fish. Manure may serve as a food source for some fish by supplementing the nutrition available from natural food organisms in the pond. A wide variety of agricultural by-products may also serve as supplemental feed. When fish are fed, ponds can be stocked at higher rates. Stocking bottom-feeding fish such as common carp prevents sinking foods from being wasted. Some of the low trophic level feeders can also be highly selective in their feeding, as in the case of filter-feeders that require plankton of a particular size and form. Carnivorous species are mainly used in intensive aquaculture. However these species command higher market prices and generally have greater export markets and therefore attract substantial investments (Pillay 1993). Is important to identify the best market for the product and access the market value of the product prior starting aquaculture. The market price and demand should be considered before a fish species is chosen for culture. When two or more fish can fill the same feeding niche in culture, the choice should be based on which will maximise economic returns to the farmer. Aquatic farming is of special significance in fish marketing strategies, the production can be organised according to market demand, in respect of quality, size, colour, preservation and processing (Pillay 1993). Some species may also have several marketing opportunities; certain fish species may be sold as fingerlings for restocking into the wild. Sustainable aquaculture for the local market sale is an important even for the development of subsistence fish farm. The relationship between the population density and the occurrence of fish farming is another important factor. In Africa the local market potential is an important criterion for fish farming where transport systems are not well developed and where transport is expensive. The importance of local markets pertains not only to commercial fish farms, but also to subsistence fish farming (Kapetsky 1994).

4.5 Impact of aquaculture

4.5.1 Negative environmental impact of aquaculture

Aquaculture may have a diverse range of effects, both negative and positive, on the environment and also on the communities. Environmental impact assessment should be carried out before the promotion of rural aquaculture (Edwards and Demaine 1998).

The negative impact of aquaculture on the habitat can be minimised through the use of good operational techniques and better farm management practices. Lucas and Southgate (2003) describe the serious environmental impact of effluent discharged from land-based aquaculture. The environmental impact of untreated effluent into surrounding bodies of water increases with the production and intensity of aquaculture operations, and depends strongly on species, culture methods, stocking density, food composition, feeding techniques and hydrographic conditions. Intensive cage farm operations are not limited in their environmental impact. The generation of wastes from cages can be viewed as a simple input - output process (Figure 7)

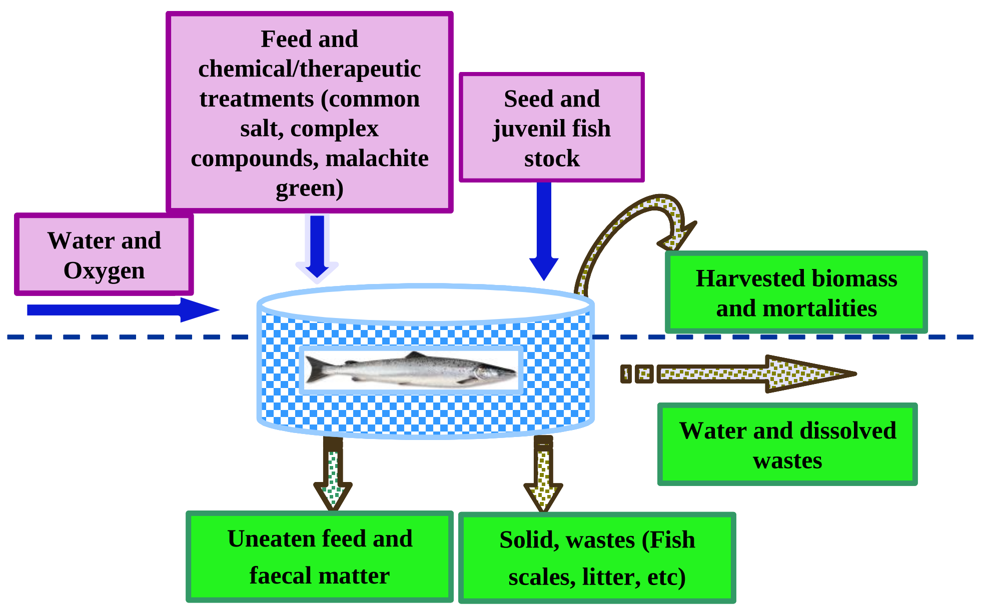


Figure 7: Schematic representation of the environmental impact of cage culture.

The main inputs are seed stock, feed and water, and the major outputs are solid waste (faeces and feed) and dissolved waste. Chemical compounds used in cage culture also resulted in output from the cages. Cage culture can also introduce disease and parasite transmission in the natural water bodies. The major impacts include destruction of natural habitats, eutrophication and sedimentation in natural bodies of water and negative effects on native fisheries and biodiversity. The introduction of exotic species in aquaculture is also a contentious issue because it can alter the diversity of the natural flora and fauna (Black 2001).

4.5.2 Positive environmental impact of aquaculture

Polyculture systems and integrated agri-aquaculture systems (IAAS) can also have positive effects on the environment (Black 2001). Polyculture and integrated aquaculture systems are environmentally friendly aquaculture methods. These methods can raise diverse organisms within the same farming system, where each species utilises a distinct niche and distinct resources within the farming complex (Stickney 2000). One option for sustainable aquaculture is the development small scale integrated agriculture-aqua-culture systems. Integrated agriculture-aquaculture offers special advantages over and above its role in waste recycling and its importance in encouraging better water management for agriculture and forestry. Fish are efficient converters of low-grade feed and wastes into high-value protein. In integrated farming, the wastes of one enterprise become input to another and, thus, optimises the use of resources and lessens pollution. The system refers to the production, integrated management and comprehensive use of aquaculture, agriculture and farm animals, with an emphasis on aquaculture (Figure 8).

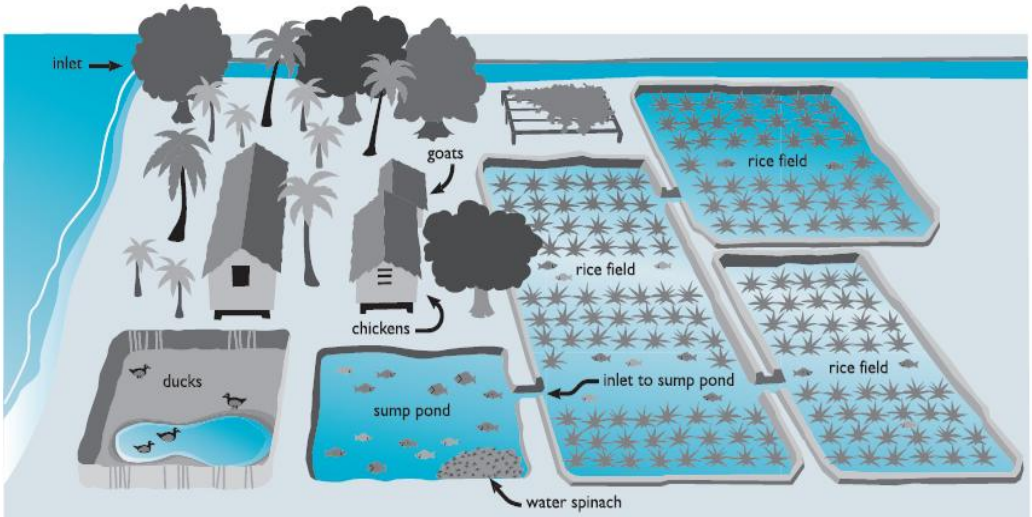


Figure 8: Typical integrate freshwater aquaculture system (FAO 2001).

Positive effects include the recycling of nutrients and organic wastes (Black 2001). Integration involves growing a variety of aquatic species, water re-use, and integration of aquaculture with other farm production (Figure 9). The basic premise of IAAS is the multiple use of water for both traditional terrestrial farming and aquaculture in a profitable and ecologically sustainable manner (Edwards 1998).

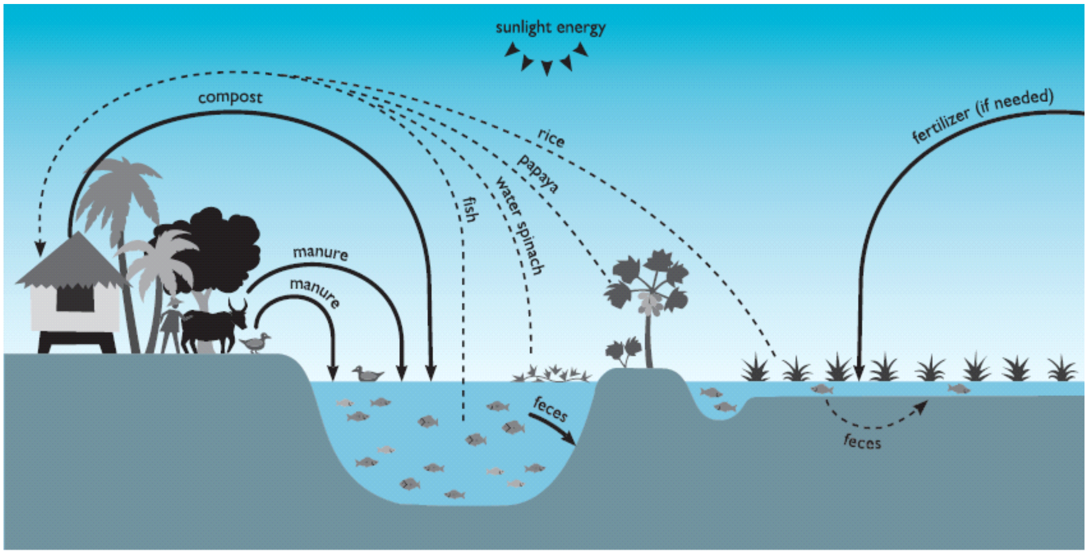


Figure 9: Recycling of nutrients and organic wastes in a traditional polyculture system (FAO 2001).

A variety of aquatic plants can be used as supplemental feeds in fish production, among these is the water hyacinth frequently found in Angola water bodies. Large-scale terrestrial animal farms produce large amounts of excreta which, are used as fertiliser pond water to support the growth of fish. The pond humus can then be used as manure for plant cultivation, thus, the productivity of both fodder grasses and phytoplankton can be utilised. The example shown in Figures 7 and 8 can be applied on large scale state farms, where component enterprises were designed and managed to optimise production, and the required labour force could be appropriated as needed. The example is also widely used in small scale, family-operated fish farms (FAO 2001).

The IAAS has been practiced with success for many centuries in many parts of the world in many developing and developed countries. In Israel IAAS are highly developed and make optimal use of the available water. In Asian countries, fish, rice, crops and ducks have been integrated to better utilise available water, land and nutrients. In developed countries, such the USA, Australia and in Europe IAAS technology has been limited to small-scale system linked to irrigation farming (Huazhu *et al.* 1994 quoted by Lucas and Southgate 2003).

Traditional polyculture systems (Figure 10) describe the deliberate culture together of complementary species (species occupying complementary niches especially in regard to their food and feeding).

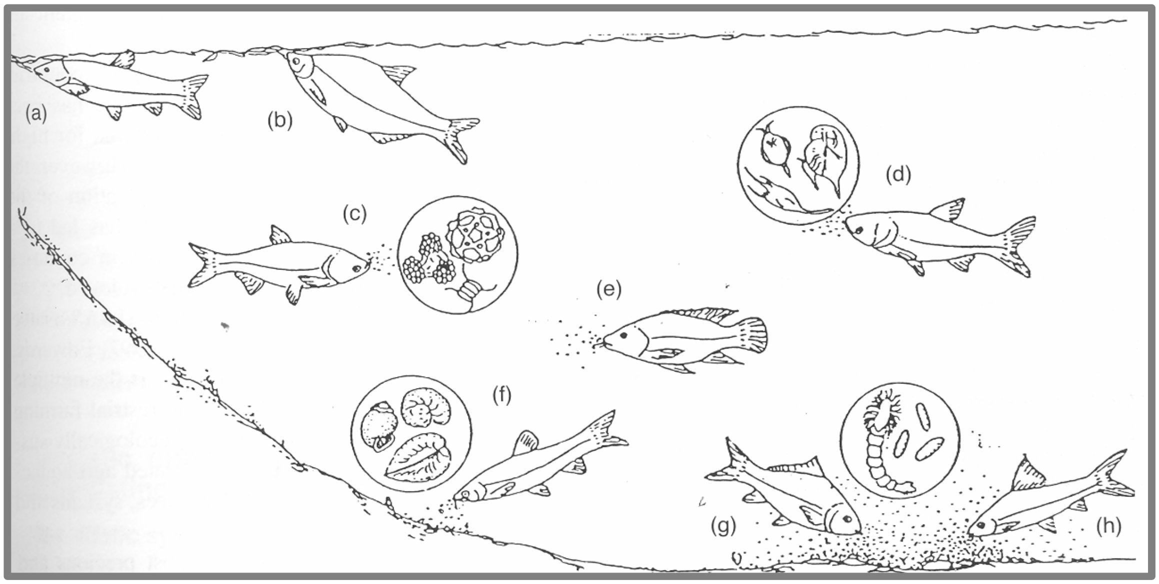


Figure 10: Typical polyculture system with the major fish species cultivated in Chinese ponds (Lucas and Southgate 2003).

Figure 9 shows the relationship between different species, grass carp (a), wushang fish (b) feed upon terrestrial vegetation and aquatic macrophytes; silver carp (c) graze upon phytoplankton; bighead carp (d) consume zooplankton; tilapia (e) feed upon both kinds of plankton, green fodders and benthic organic matter; black carp (f) feed on molluscs; and common carp (g) and mud carp (h) consume benthic invertebrates and bottom detritus. This system not only restores the quality of the effluent water, but also produces a commercial crop from the effluent treating organism (Figure 11).

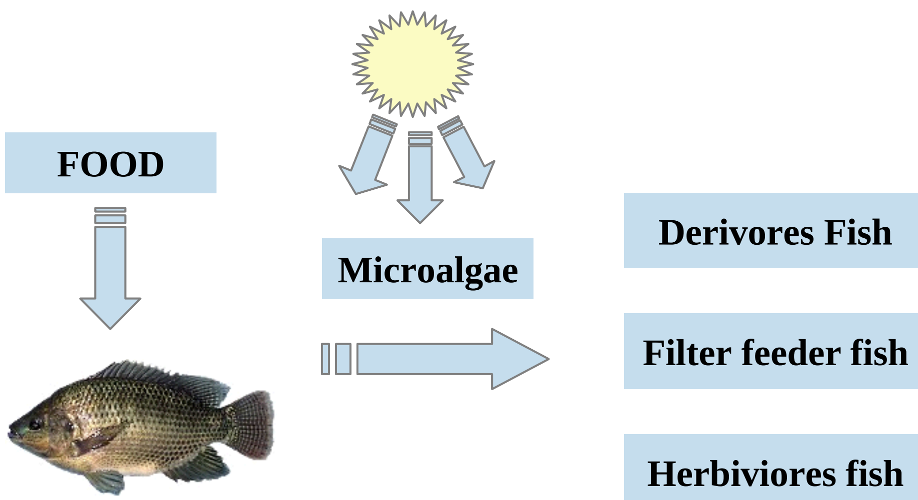


Figure 11: Diagrammatic representation of the uses of effluent from fish culture to provide nutrients for algae culture.

Figure 11 shows how fish effluent from culture provides nutrients for algae culture that are use as a food source for a variety of other culture animals such as detribores fish, filter feeders bivalves etc. (Lucas and Southgate 2003).

According Black (2001) the intensive cultivation of broodstok as supplier egg and juveniles for restocking programmes where native stocks are extinct or unviable may also be a positive aquaculture benefit. The stock-enhancement has been successful and already contributes in commercial or recreational fisheries (FAO 1999 quoted in Pillay 2004). A good example of the role of fish propagation is the recovery of salmon stock in river systems in countries in the northern hemisphere, through environmental improvements and stocking or re-populating with hatchery production (Pillay 1993).

4.5.3 Social aspects

Aquaculture development has a number of advantageous social impacts, particularly in rural areas. Small-scale aquaculture in developing countries is often given priority as it offers opportunities for employment, which help in sustaining rural populations and reducing the drift of populations to urban centres (Pillay 1993). This employment includes production processing, transport and marketing. However, aquaculture development can also result in social problems such as:

- Displacement of traditional local industries like captures fisheries;
- Reduction in employment because of intensive and relatively skilled aquaculture activities;
- Depletion in the seed required for aquaculture;
- Changes in traditional water use and consumption;
- Reducing the possibility of other uses;
- Increased farm intensity, which may lead to differential increases in income and social stratification;
- Competition for spaces, traditional fishing;
- Restriction of access to land;
- Reduction in property values;
- Reduction in the amenity value of freshwater for recreational fisheries, recreation and tourism; (Lucas and Southgate 2003)

Before implementing an aquaculture project, priority has to be given to the study of local communities. For appropriated project design it is necessary to know about the level of human, economic and infrastructure development, and the cultural and political context. The technology or the farming system to be adopted has to be carefully selected, not only on the basis of the climatic and hydrological conditions of the area, but also on the skills and educational background of the target population and their socio-cultural system (Lucas and Southgate 2003).

4.5.4 Economic aspects

Economic considerations play an important role in the survival and development of aquaculture. An aquaculture venture will be economically viable if a fish or fisheries product can be produced at a cost, which is competitive with other animal protein sources and can be sold at a reasonable profit. Economic considerations can be divided into demand, finance, production, and marketing. Product demand involves the relationships between the quantity of product that consumers will get, the selling price, the price of competing products, the size of the consuming population, and the income of the consuming population Financing and capital for aquaculture are a very important economic consideration. Production economics involve various direct costs, which can be divided into systems costs, production costs, and processing costs. Systems costs include the initial facilities investment, maintenance, taxes, and interest of working capital. Production costs focus the culture techniques used and the cost of inputs to the production process such as feed, fish stock, water quality management, additional fertiliser antibiotics, labour, harvesting, and transport facilities. Processing cost is also an important factor, and involves direct cost to the producer and transport to the processing facilities. Processing can be considered a production cost if there are existing processing facilities (Helfrich 1997).

Marketing involves the movement of goods from the producers to the consumers. The marketing network for food items involves processors, distributors, and outlets. Marketing of new aquaculture products can be difficult especially in the absence of appropriate marketing networks. Profitability is influenced not only by the market but also by the costs of production. Production costs vary according to whether the business is involved in the hatchery phase, the growout phase or both (Lucas and Southgate 2003).

4.6 Aquaculture checklist

Environmental inventory is a complete description of the environment as it exists in an area where a particular proposed action is being considered. The environmental inventory is compiled from a checklist of descriptors for the biophysical (physical/chemical and biological) and manmade (cultural and socio-economic) environment (Oddsson pers. com. 2005). The aquaculture checklist is a document that provides questions to be considered among many various aspects at the beginning of an aquaculture business. The Western Australia Department of Fisheries (2000) created a pond checklist to assist new entrants to develop a sustainable and viable commercial aquaculture. The list describes step-by-step of different criteria and processes required to develop aquaculture projects, site selection, and choice of species and licence requirements.

- Site selection

The right site selection is probably the single most important factor that determines the feasibility of aquaculture operations (Pillay 1993). Sites selection depends on the species, the technology to be used and the culture system to be adopted (Lucas and Southgate 2003). Site selection for small scale aquaculture includes available access, meteorological and hydrological information about the area, such as range and mean monthly air temperature, rainfall, evaporation, sunshine, speed and direction of winds, floods, water table etc. (Pillay 1993). The basic data for aquaculture site selection taking into consideration the environmental conditions according to Pillay (2004) are local environmental sensitivity, land user patterns, composition of discharges from the farm, the pattern of water exchange and the bottom dynamic conditions.

- Land use

According Black (2001), one of the issues involving inland aquaculture is conflict over land use. For freshwater pond farms, the land available consists mainly of swamps, unproductive agricultural land, valleys, streams and river beds exposed due to changes freshwater courses (Pillay 1993). The other important factors to be considered are the existing and future sources of pollution and the nature of pollutants, so it is necessary to obtain information on development plans for the neighbourhood areas (Western Australia Department of Fisheries 2000).

- Water source

Provision of water of adequate quantity and quality is a primary consideration in both site selection and aquaculture production management (Lucas and Southgate 2003). The amount of water supply for both the initial facility and any planned expansions, depends on several factor such as species, density, management practices and production technology (Timmons *et al.* 2001). The quantity of water is a particularly important aspect for land-based aquaculture systems (Pillay 1993). Surface water should never be used in intensive recirculating aquaculture systems due to the higher risk of contamination by pollutants, fish eggs, insect larva, diseases, microorganisms, and wide seasonal temperature variations (Timmons *et al.* 2001).

According Meade (1989) various sources of fresh water are used for aquaculture and each of these has advantages and disadvantages (Table 7).

Table 7: Characteristics of freshwater sources for fish culture based on information in Meade (1989).

WATER SOURCE	ADVANTAGES	DISADVANTAGES
Lakes and reservoirs	1. Large volume available for special or seasonal needs. 2. Intakes at two levels give temperature control.	1. Susceptible to climate changes and pollution. 2. Predators, competitors and pathogens may be present from the wild population.
Streams or shallow springs	1. Temperatures are usually optimum for native fish. 2. Usually have high oxygen content.	1. Highly variable chemical quality and sediment load due to climatic influences. 2. Susceptible to pollution. 3. Pathogens may be present.
Deep springs	1. Nearly constant flow, quality, and temperature. 2. Usually sediment free. 3. Little effect of drought.	1. Oxygen may be low. 2. Supersaturation of nitrogen.
Wells	1. Small area needed for development. 2. Advantages similar to those of deep springs.	1. Yield difficult to predict before development. 2. Pumping cost: power support required. 3. May deplete groundwater resources. 4. Supersaturation of nitrogen.

Groundwater sources (springs or wells) are most commonly used for intensive culture. Groundwater refers to water that is contained in subsurface geological formations. To move a large mass of water for the farm needed for fish culture any great height or distance requires energy. This will always be more costly than water that is free flowing or shallow, and also will have a great impact on the economic viability of the aquaculture business (Stickney 2000). However the impact of the farm depends on many factors related to species and site selection.

Freshwater surface waters include, streams, rivers, lakes, canals and wells, because they are exposed to the atmosphere and typically support diverse and abundant biological ecosystems. Surface water can be fed either by rain and groundwater or both and water quality parameters will be somewhat dependent on this source. In addition, biological processes lean to change water quality and add competing organisms, pathogens and predators. Water temperature follows seasonal and local weather patterns; therefore surface water is more variable than groundwater (Stickney 2000). Each source has unique water quality parameters associated with it (Table 8).

Table 8: Quality parameters characteristics for freshwater sources based on information in Stickney (2000).

Water source	Salinity	Temperature	Suspended solids	DO	Other dissolved gasses	Metals	Ph
Groundwater	Fresh to full strength seawater	Stable over the short term, can vary seasonally	Low	Low	Carbon dioxide, and argon can be high depending on geology	Iron and manganese may be problems in water with low DO.	Depends on geology
Rivers, streams and lakes	Fresh	Variable in short term and seasonally, varies more than groundwater	Varies, can be high during runoff event	Low to high variable	Generally low, but carbon dioxide can be high and variable if there is a lot of respiration	Depends on industrial and domestic discharges in proximity to inflow lines.	Depends on geology and source of water

According Timmons *el al*. (2001) water temperature is of great importance in the economic viability of commercial aquaculture operations. Temperature directly affects the physiological processes, such as respiration rates, efficiency of feeding and assimilation, growth, behaviour, and reproduction.

- Topography and soil characteristics

Topography surveys can be utilised to reduce pumping costs, collect and store water from natural sources and also to provide sites for building (Lucas and Southgate 2003). Gravity fed is an important aspect especially in rural inland aquaculture where electrical power supply is lacking or erratic, taking into account that the provision of pumping is expensive in both capital construction and running costs. Free flowing springs and artesian supplies eliminate pumping costs, the risk of pump failure, and the power support requirement (Meade 1989).

The quality of soil is an important aspect in pond farms, not only because of its influence on productivity and quality of the overlying water, but also because of its suitability for dike construction. According to Pillay (1993) the appropriate soil investigations can be carried out through simple visual and tactile inspections or detailed sub surface exploration and laboratory tests. To determine the nature of the soil, it necessary to examine the soil profile, the most important physical properties to be examined are texture and porosity. Soil texture depends on the relative proportion of particles of sand, silt and clay. It is therefore essential carry out the appropriate soil surveys when selecting sites for pond farms, to know the ability of the pond to retain the required water levels.

- Aquaculture licensing requirements

One of the first problems that an aquaculture entrepreneur faces is in obtaining the right to establish and operate a farm in a suitable area (Pillay 1993). The Angola Ministry of Fisheries is responsible for licensing aquaculture operations. The Ministry of Fisheries through the Department of Aquaculture is strongly supporting the project approach and licensing requirements for aquaculture development. In accordance with the Angola Parliament (2005), aquaculture licenses are divided into three types, depending on the purpose of the aquaculture.

1. Communal or subsistence aquaculture license
2. Commercial aquaculture license
3. Research aquaculture license

When aquaculture is in the form of small scale operations as an integral part of rural development that uses artisanal methods, no authorisation is required, but local authorities have to take responsibility for these and monitor, inspect and report on the aquaculture operation (Angola Parliament 2005).

5 RESULTS AND DISCUSSION

5.1 Analysis of data for species selection

The list of native freshwater species for this study and natural geographical distribution in the Angola river system is shown in Table 9. The list is predominated by species of the family Cichlidae, followed by Claridae and one species of the family of Bagridae.

Table 9: Native Angolan species included in this study for the evaluation (Fishbase 2005).

Species	Family	English common name	Local common name	Occurrence records for Angola
Chrysichthys nigrodigitatus	Bagridae	Bagrid catfish	Bagre[1]	Occurrence records only for place name not for water bodies (Cabinda province).
Clarias gariepinus	Claridae	African catfish	Bagre[1]	Bengo (Quifangondo), Cunene, Cubango, Kwanza and Cuango rivers, Kilunda lagoon.
Clarias ngamensis	Claridae	Blunt-toothed African catfish	Bagre[1]	Cubango, Kwanza, Cunene river, Okavango rivers; Catete lagoon.
Heterobranchus longifilis	Claridae	Banded jewelfish	Bagre[1]	Luachimo and Dundo river (Lunda Norte province).
Hemichromis fasciatus	Cichlidae	Vundu	Cacusso[1]	Cuango, Kwanza, Lucoge, Chicapa, Luachimo rivers, and Chiloango lake.
Oreochromis andersonii	Cichlidae	Three spotted tilapia	Cacusso[1]	Panguila lagoon, Bengo, Okavango river, Cunene (Sacaala) river bassin, Kwanza (Gangassol – Lucala) river basin, Malange Irrigation Dan, Loge river (Uige province).
Oreochromis macrochir	Cichlidae	Longfin tilapia	Cacusso[1]	Panguila lagoon, Cunene river (Sacaala, Capelongo, Matala, Mulongo, Ruakana), Cutata, river (Lagunen), Luembe river (Lumbona) and Loge river (Uige province).
Serranochromis angusticeps	Cichlidae	Thinface cichlid	Boca larga[2]	Cunene River (Capelongo)
Tilapia guineensis	Cichlidae	N/A	Cacusso[1]	Kwanza and Bengo rivers,
Tilapia rendalli	Cichlidae	Redbreast tilapia	Cacusso[1]	Cunene (Capelongo, Sacaala, Matala), Okavango, Luembe, Cuabango, Cuchi, Cukimaala, Cutato rivers
Tilapia sparrmanii	Cichlidae	Banded tilapia	Cacusso[1]	Kwanza, Cunene, Cuango, Cubango, Cuchi, Luembe, Longa, Cueve, Cukimala, Okavango, Bengo river, Kasai, Kwanza river (Malange province), Dundo, Luachimo rivers (Lunda Norte province)

[1] - Angola local name (FAO 2004)
[2] - Angola local name (Ministry of Fisheries 2003a)

5.1.1 First phase of selection

The most relevant information regarding biological characteristics of the 11 species under study is shown in Table 10. The first phase of evaluation was carried out using this data.

Table 10: Critical aspect data from freshwater fish of Angola (Fishbase 2005).

Species	Classification	Age at first maturity (year)	Average length at maturity (cm)	Optimal growth temperature	Maximum length (cm)	Maximum weight (Kg)	Main food
Chrysichthys nigrodigitatus	Omnivore	1.3	27.5	23-26 °C	65.0	2.4	Plants/detritus, animals
Clarias gariepinus	Omnivore	2-3[1]	70.2	25-30°C[2]	170.0	60.0	Nekton, mainly animals
Clarias ngamensis	Omnivore	1.6	29.2	N/A	73.0	4.0	Nekton, mainly animals
Heterobranchus longifilis	Carnivore	5.5	59.7	22-23 °C	150,0	55.0	Detritus, mainly animals
Hemichromis fasciatus	Carnivore	0.6	13.1	23-25 °C	20.4	0.3	Zoobenthods, mainly animals
Oreochromis andersonii	Detrivore	2.3	26.6	18-33 °C	61.0	4.7	Mainly plants detritus
Oreochromis macrochir	Detrivore	2.9	23.2	18-35 °C	27.1	1.4	Mainly plants, detritus
Serranochromis angusticeps	Carnivore	1,1	21.1	N/A	41.0	2.5	Nekton, mainly animals
Tilapia guineensis	Herbivore	0.9	12.7	22-26 °C	30.0	N/A	Zoobenthods, plants, detritus
Tilapia rendalli	Herbivore	N/A	27.3	24-28 °C	45.0	2.5	Mainly plants, detritus, animals
Tilapia sparrmanii	Herbivore	1.5	14.9	22-25 °C	23.5	0.45	Mainly plants, detritus, animals

([1]Pillay 1993)
([2]Stickney 2000)
N/A - Not available data

The outcome from the first stage of evaluation is shown in Table 11. The first stage of selection resulted in the rejection of five species (*Hemichromis fasciatus*, *Oreochromis macrochir*, *Serranochromis angusticeps*, *Tilapia sparrmanii* and *Tilapia guineensis)* out of a total of 11 evaluated that showed an average score less than 2. The species were rejected with average scores ranging from 1.6 – 1.8.

Table 11: Evaluation process of selected species for the first stage.

Species	Growth in nature		Reproduction biology	Feeding habits	Market value	Average
	Grow rate	Maximum length	Length at first maturity	Classification of fish	Local selling price	
Chrysichthys nigrodigitatus	3	3	2	2	N/A	**2.5**
Clarias gariepinus	3	3	3	2	3	**2.8**
Clarias ngamensis	2	3	2	2	3	**2.4**
Heterobranchus longifilis	2	3	3	1	3	**2.4**
Hemichromis fasciatus	3	1	1	1	N/A	**1.5**
Oreochromis andersonii	2	3	2	3	2	**2,4**
Oreochromis macrochir	1	1	2	3	2	**1.8**
Serranochromis angusticeps	2	2	2	1	N/A	**1.8**
Tilapia guineensis	2	1	1	3	2	**1.8**
Tilapia rendalli	N/A	2	2	3	2	**2.2**
Tilapia sparrmanii	1	1	1	3	2	**1.6**

The evaluation in the first phase positioned *Clarias gariepinus* as the best species with an average score of 2.8, followed by *Chrysichthys nigrodigitatus* (2.5), *Clarias ngamensis* (2.4), *Heterobranchus longifilis* (2.4), and *Oreochromis andersonii* (2.4).

The results calculated of growth rates of the Bagridae, Claridae and Cichlidae families are represented graphically in Figures 12 and 13. Because of lack of data and accessible information related with the age at first maturity of *Tilapia rendalli*, it was impossible to calculate the growth rate for this specie. The positive results from maximum length reached in nature were used instead. The average score for *Tilapia rendalli* (2.2) was also considerate positive in this phase.

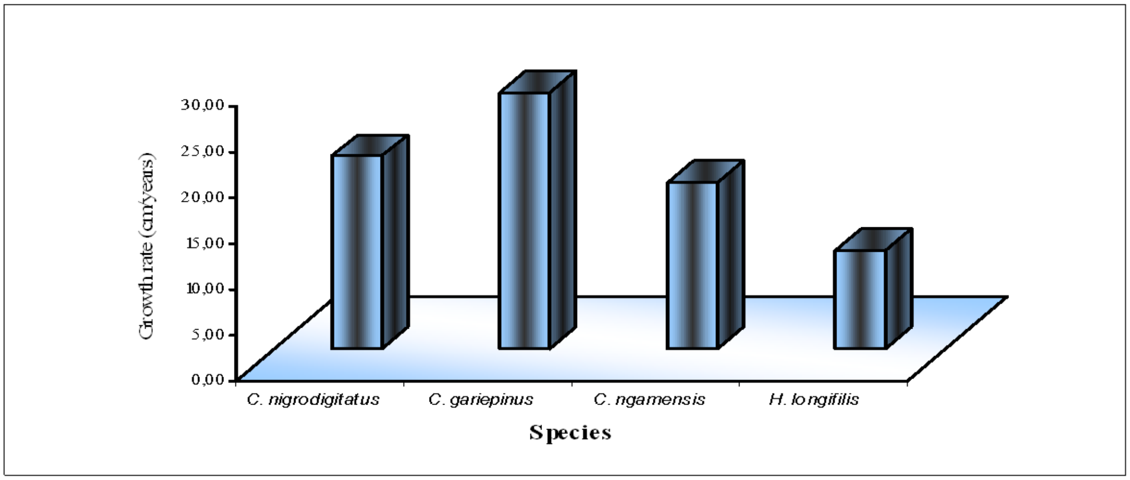


Figure 12 : Growth rate (cm/years) for *Bagridae sp*. and *Claridae sp*. evaluated in this study.

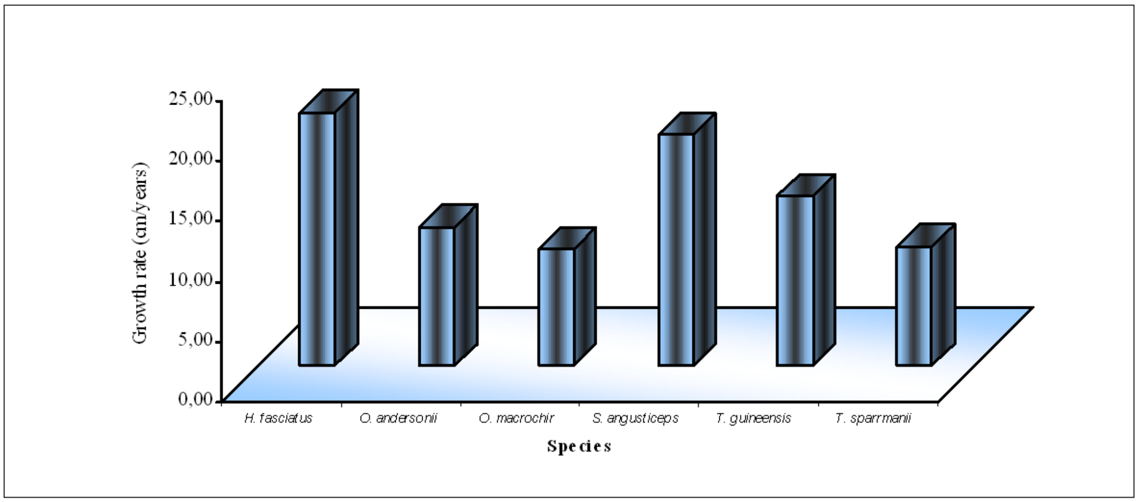


Figure 13: Growth rate (cm/years) for *Cichlidae sp*. evaluated in this study.

Hemichromis fasciatus was rejected in the application of the four criteria. This species grows faster to first maturity but the maximum length reached is under 25 cm. The average length at first maturity is lower than 15 cm. *Serranochromis angusticeps* also was rejected because of the third and fourth criteria applied. *Hemichromis fasciatus* and *Serranochromis angusticeps* species are carnivorous fishes, in their natural environment they feed on shrimps, insects and small fishes. Carnivorous species in aquaculture generally need a high protein diet so they are considerate to be more expensive to produce (Pillay 1993). For both species available data and information about market price, specifically for Angola was not found. *Hemichromis fasciatus* can be stocked together with tilapia to control the overpopulation and increase fish yields (tilapia control use), because it does not grow to a large size (Fishbase 2005)

Oreochromis macrochir was rejected because of the first criterion. The results for this specie showed significant differences in growth rate and maximum length reached when compared with *Oreochromis andersonii*. Maximum length data showed that *Oreochromis macrochir* grows slower than *Oreochromis andersonii* in natural conditions, so *Oreochromis andersonii* looked the most promising and presented much better conditions results than *Oreochromis macrochir*. The last two species rejected in the first stage were *Tilapia guineensis* and *Tilapia sparrmanii*. Despite the fact that these species are herbivore fishes, they were rejected because of the maximum length reached and average length at first maturity criteria. *Tilapia sparrmanii* was also rejected because of the growth rate criteria. This species exhibits slower growth rates than *Tilapia rendalli* and has a maximum length under 30 cm. The average length at first maturity for both species is smaller than *Tilapia rendall.,* It is a disadvantage for aquaculture operations when the species attain first maturity before reaching a marketable size (Pillay 1993). The maximum weight data for *Tilapia guineensis* is not available in Fishbase (2005).

The species with high market potential value were represented by *Claridae sp*. *Clarias gariepinus* markets have been established in Germany, Italy, and the United Kingdom (Stickney 2000). *Clarias gariepinus* is in some African countries considered as a high consumer preference (Shilo and Sarig 1989). In Angola, especially the local name "bagre" is considered important for food value and is widely accepted by the population in general. It can be sold mainly dry and smoked and the cost varies in accordance with the type of market (Table 12).

Table 12: Typical prices for "bagre" products sold on the Angola market (IPA 2005).

Bagre	Supermarket ($/kg)	Informal market ($/kg)
Whole smoked fish	12.00	6.00
Whole dry fish	10.00	4.00

Tilapia that has been represented by *Oreochromis andersonii* and *Tilapia rendalli* as the best in the first stage also has good market potential. The types of market depend on the type of aquaculture system (Table 14). All tilapia (cacusso) produced in Angola through aquaculture and inland rudimentary catches are use for local consumption. In Angola traditionally these species are popular and are processed in a number of different ways in accordance with consumer acceptance. Tilapia can be sold fresh, frozen, salted or smoked in formal and informal Angolan markets. Table 13 show the different forms and current prices of tilapia in the Angola market.

Table 13: Typical prices for tilapia products sold on the Angola market (IPA 2005).

Cacusso	Supermarket ($/kg)	Informal market ($/kg)
Whole fresh fish	6.00	3.00
Whole frozen fish	5.00	Not been sold
Fillets (import)	9.00	Not been sold
Whole dry fish	10.00	6.00
Whole smoke fish	10.00	6.00

5.1.2 Second phase of selection

The results from the first stage of selection narrowed the evaluation down to only six species in the second stage. The remaining species were characterised using the different criteria but based on aquaculture potential. The evaluation of these species is described bellow.

- In-depth information regarding selected species

The *Chrysichthys nigrodigitatus* (Figure 14) is an omnivorous fish, which feeds on seeds, insects, bivalves and detritus. Feeding becomes specialised with age and size; larger fish may feed on decapods and fish (Fishbase 2005). The occurrence records for *Chrysichthys nigrodigitatus* in Angola are only for place name not water bodies. For this species no information was found on growth under artificial conditions and breeding biology in captivity.

Chrysichthys nigrodigitatus is considered suitable for culture in both fresh and brackish water ponds in Nigeria. Studies in brackish water ponds in monoculture systems showed that this species is harvested after nine months of stocking. *Chrysichthys nigrodigitatus* is a highly valued food fish in Nigeria and other West African countries (Ezenwa 1982).

Figure 14: *Chrysichthys nigrodigitatus* freshwater fish (Fishbase 2005).

Clarias gariepinus (Figure 15) has excellent characteristics for tropical and subtropical pond fish culture (Pillay 1993). *Clarias gariepinus* is an extremely hardy adaptable animal. This is an omnivorous fish and can be successfully fed a range of plants and animals including fish, birds, frogs, snails, crabs and shrimp based protein sources; also detritus (Pillay 1993). This species can efficiently exploit a wide variety of food items and is able to survive adverse environmental conditions and habitat instability. Under optimal conditions, it can attain a weight of 0.8-1.0 kg in 8–10 months (Hecht and Moor 2004)

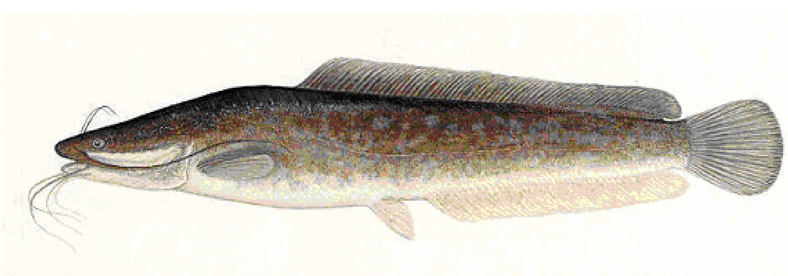


Figure 15: *Clarias gariepinus* fish (Hecht and Moor 2004).

According to Gravendeel (2001), the seasonality of spawning is a major problem in the reproduction of *Clarias gariepinus* as it has a restricted spawning season beginning at the start of the rainy season (Shilo and Sarig 1989). The spawning season varies between regions, for example in Egypt and Central Africa it is between July and September and in West Africa in April and May (Pillay 1993).

Clarias gariepinus does not spawn naturally in captivity, therefore reproduction has to be induced (Gravendeel 2001). This can be an advantage or a disadvantage for aquaculture operation. It is an advantage because uncontrolled reproduction can lead to an overabundance of fish, which may reduce the yield of marketable fish (Lucas and Southgate 2003). However hatchery requirements for fingerling production can also be a disadvantage in communities with poor infrastructure, but this problem can be overcome by means of good marketing and the construction of hatcheries (Hecht and Moor 2004).

Clarias gariepinus are easy to spawn, and large numbers of fry are readily obtained using simple methods (Lucas and Southgate 2003). Under pond conditions *Clarias gariepinus* mature in about 7 months, when they have attained a weight of 200-300 g. For induced spawning, brood stock from natural habitats or culture ponds can be used. Ovulation in females can be induced by injection of the hormone product desoxycorticosterone (DOCA). Ripe females in captivity range in size from 28-65 cm, weighing 0.175 – 1.6 kg (Pillay 1993). The fecundity is relatively high between 20,000 – 25,000 eggs/kg. In large fish one million eggs have been recorded (Hecht and Moor 2004). Embryonic development is completed in about 24 hours after fertilisation at a temperature around 26°C (Gravendeel 2001). A shortened incubation contributes to lower mortality of larvae and greater survival of hatcheries. The larvae start feeding when they are about two to three days old before the yolk sac is completely absorbed (Pillay 1993).

Clarias gariepinus is also an attractive fish for rural aquaculture because it shows high degrees of hardiness. The most common system of culture for this fish is in pond farms, either in monoculture or polyculture in combination with tilapia (Pillay 1993). The fish normally live on the natural productivity of the ponds, which may be enhanced by the addition of small quantities of fertilisers (Lucas and Southgate 2003).

Clarias ngamensis (Figure 16) is an omnivorous fish, which feeds on molluscs, terrestrial and aquatic insects, shrimps, crabs and fish (Fishbase 2005). Although it has similar characteristics to *Clarias gariepinus*, there is a lack of additional biological information and a relevant background about use in aquaculture.

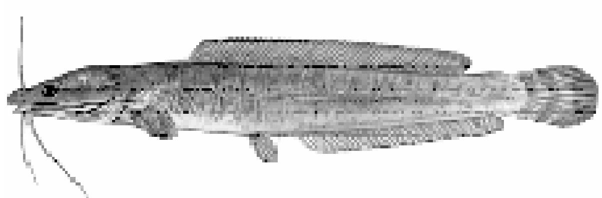


Figure 16: *Clarias ngamensis* fish (Fishbase 2005).

*Heterobranchus longifilis***Error! Reference source not found.** is a carnivorous fish feeding on any available food, including invertebrates and insects when small, fish and other small vertebrates when large (Fishbase 2005).

No information was found about the reproductive biology in captivity of this fish nor on its use for aquaculture proposes.

Figure 17: *Heterobranchus longifilis* fish (Fishbase 2005).

Among the tilapias, members of the genus *Oreochromis* are favoured in aquaculture because of their performance under culture conditions. The genus *Oreochromis* is differentiated from other genera of tilapia by the way they brood their eggs and larvae (Lucas and Southgate 2003). The main problem in growing *Oreochromis sp.* is their early and uncontrolled reproduction in culture systems. According to Stickney (2000) several methods (hand-sexing, stocking the tilapia pond with predatory fish, and rearing tilapia in cages placed in ponds) in semi-intensive and intensive aquaculture have been development to avoid the problem of early spawning and overpopulation of stunted fish in ongrowing ponds as well as to improve the productivity. In culture conditions reproductive control is necessary (Table 14). However, the fact that this species is able to spawn in ponds eliminates many problems associated with the procurement of fingerlings (Hecht and Moor 2004).

Table 14: Characteristics of the tilapia culture system based on Lucas and Southgate (2003).

	Extensive	**Semi-intensive**	**Intensive**
System type	Rice fields, earth ponds, communities ponds, reservoirs and tanks for irrigations.	Ponds built specifically for fish farming.	Small ponds, tanks, cages, raceways.
Reproductive control	None	All male stock may be used	All male stock
Source of seed (fingerlings for stocking)	Wild fish, by products of culture	Commercial hatcheries	Own hatchery
Feeds	None except occasional farm by-products and household wastes.	Farm by-products such as rice bran, oilseed cakes or supplementary compound feeds.	Complete, compounded feeds.
Culture duration	Seasonal	6 – 9 months	4 – 6 months
Market	Producers own consumption and local, rural markets	Local and national markets	Urban, high - value, export markets

Reproductive control is mainly used in semi-intensive and intensive aquaculture systems. To control reproduction in captivity hormonal sex reversal in fish is used. The most commonly used protocol is to incorporate 17α-methyltestosterone (MT) into the fry diet at 40-60 ppm and feed it to the fry from the first feeding stage for 21-30 days (Lucas and Southgate 2003).

The typically breeding of *Oreochromis sp*., according Lucas and Southgate (2003), is shown in the Figure 18. When a mature female is ready to spawn, she goes to the breeding arena or lek. The breading lek consists of several males that form well-defended, individual nests. After brief courtship, the female lays her eggs while the male simultaneously fertilises the eggs. The female then picks up the fertilised eggs in her mouth for brooding and leaves the arena. Intensive parental care continues until the fry are sufficiently large to be on their own. The female stands guard over the free-swimming fry. Mouth brooding lasts for 5-10 days, during which time the females eat little. Finally, the hatched fry are relaxed in shallow waters. The female then resumes active feeding, which allows maturation of her ovaries and after 14-30 days, she is ready to spawn again.

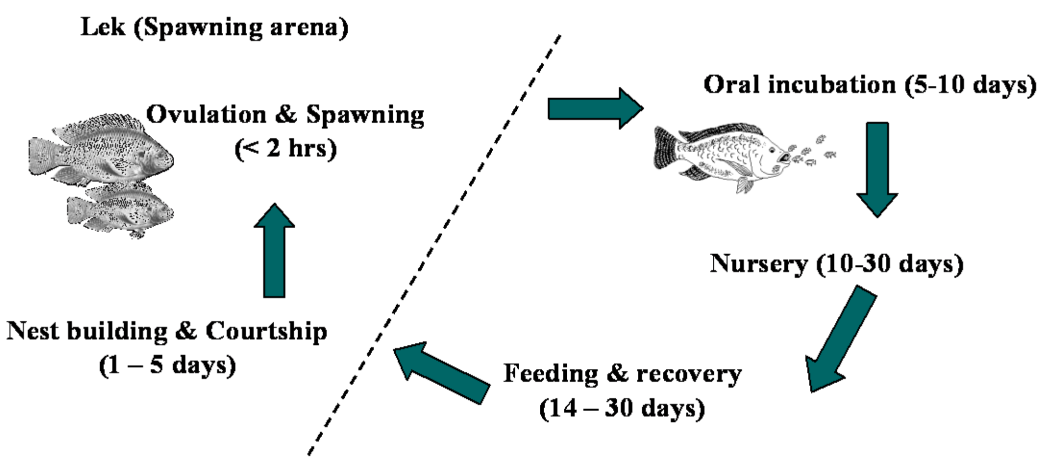
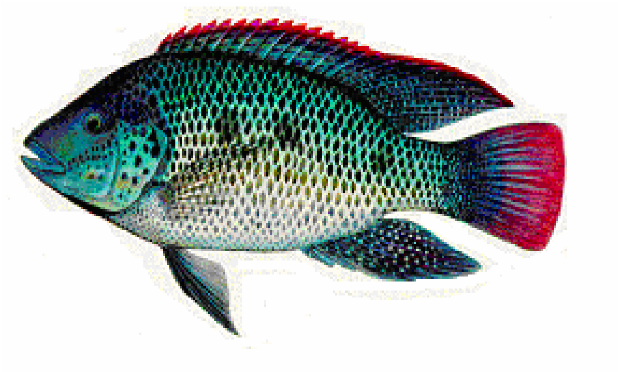


Figure 18: Schematic representation of the reproductive cycle of *Oreochromis sp*. based on information in Lucas and Southgate (2003).

Oreochromis andersonii (Figure 19) have considerable importance for commercial aquaculture (Pillay 1993). The growth potential of this species has been demonstrated to be much better under semi-intensive culture and also in integrated farming systems compared to other species of tilapia and research has demonstrated that *Oreochromis andersonii* is appropriate for economically viable fish farming (Cayron–Thomas 1994).



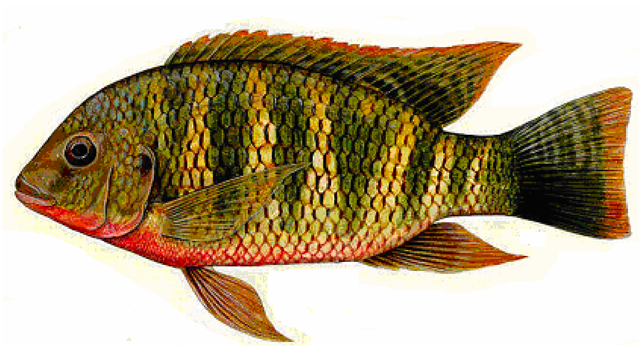
Oreochromis andersonii is a detrivore fish, the main foods are mostly detritus, very fine organic material, blue-green algae and diatoms (Fishbase 2005). *Oreochromis andersonii* can eat algae and detritus naturally produced in culture systems for example in rural farms there should be manufactured feeds where the raw material is mainly ingredients derived from plants.

Figure 19: *Oreochromis andersonii* fish (Hecht and Moor 2004).

This factor makes these species ecologically suitable and economically important for aquaculture operations (FAO 2001). The type of feed is different in accordance with the method of culture used (Table 14).

This fish is often cultured in polyculture systems together with *Tilapia rendalli* (Hecht and Moor 2004). *Oreochromis sp.* can be grown in a wide variety of aquaculture systems (Table 14). They reach typical market size (500-600 g) in about 6 – 8 months under optimum temperature conditions for growth (20-35^{o}C) (Lucas and Southgate 2003).

Tilapia rendalli (Figure 20) is predominantly herbivorous and tolerant of a wide range of temperature (11-37°C) (Hecht and Moor 2004). This species presents a high growth capacity (Lucas and Southgate 2003).



In comparison with other cichlids this species has high fecundity, approximately 5000-6000 eggs under suitable environmental conditions (Hecht and Moor 2004). According Lucas and Southgate (2003) *Tilapia* species lay eggs on a substrate, both parents care for the eggs until hatching, females fan and clean the eggs while males guard the territory.

Figure 20: *Tilapia rendalli* fish (Hecht and Moor 2004).

The fact that tilapia feed relatively low in the food chain is one of their main attributes as culture species (Stickney 2000). *Tilapia rendalli* is considered ideal for rural fish farming because it is easy to breed in captivity, tolerates high stocking density, poor water quality and is relatively disease resistant (Lucas and Southgate 2003). It is adaptable to many types of culture systems (Table 14). The most common and widely practiced system of culture of tilapia is in earthen ponds, tanks, cage culture, raceway culture, ricefield culture and polyculture; compatible species include carps and *Clarias gariepinus* (Pillay 1993). Tilapias are frequently cultured with other species to take advantage of many natural foods available in ponds to control tilapia recruitment. Another polyculture system that shows potential consists of culturing tilapia together with freshwater prawns *(Macrobrachium rosenbergii).* The description of the remaining species has led us to define the best species for inland aquaculture. Table 15 gives us the outcomes of the description process examining the potential for aquaculture.

Table 15: Summary of the aquaculture potential of species in the second selection stage.

SPECIES	**AQUACULTURE POTENTIAL**
Chrysichthys nigrodigitatus	- Growth in captivity – N/A. - Reproductive biology – N/A. - Feeding habits – omnivorous fish
Clarias gariepinus	- Growth faster in captivity conditions - Reproductive biology; easy breeding, does not spawn naturally in captivity, easy spawn in hatchery, high fecundity. - Omnivorous fish, wide food spectrum.
Clarias ngamensis	- Growth in captivity – N/A. - Reproductive biology – N/A. - Feeding habits – omnivorous fish
Heterobranchus longifilis	- Growth in captivity – N/A. - Reproductive biology – N/A. - Feeding habits – Predatory fish. - Tilapia control used in aquaculture.
Oreochromis andersonii	- Growth faster in captivity conditions; reach market size in short time in semi-intensive and intensive aquaculture systems. - Reproductive biology; easy to hold and breed in captivity environments, able to spawn in ponds; high fecundity and also high frequency of spawning. - The type of feeding is favourable to be maintained on a low-quality diet based on agricultural by-products.
Tilapia rendalli	- High growth capacity; easy to hold and breed in captivity environment. - Able to spawn in ponds; high fecundity and also high frequency of spawning. - The category of feeding is favourable to be maintained on a low-quality diet based on agricultural by-products.

N/A - Not available information

5.1.3 Final evaluation of the selection process

Because little is known of the aquaculture potential of some evaluated species the final selection was carried out on four species (*Clarias gariepinus, Oreochromis andersonii*, and *Tilapia rendalli*). These species were selected as the suitable species for inland aquaculture in Angola. During the evaluation process these species showed better aquaculture potential when compared with the other evaluated species. The selection of *Oreochromis andersonii* in the present study coincides with the soaring interest in aquaculture of this type of fish in many countries in Africa. Different studies carried out in Zambia clearly indicate that *Oreochromis andersonii* was the best candidate for integrated fish farming as an industry. Previous research has shown that *Oreochromis andersonii* is the most promising tilapia for pond culture (Cayron-Thomas 1994). In polyculture and monoculture systems it was demonstrated that *Oreochromis andersonii* is appropriate for economically viable fish farming. *Tilapia rendalli* has dominated inland aquaculture and is one of the most important species for industrial aquaculture (Pillay 1993). In Malawi the dominant tilapia cultured species is *Tilapia rendalli* (Petr 2000).

Clarias gariepinus has been recognised as a candidate for aquaculture in different countries. In Central Africa, *Clarias gariepinus* have been reared in ponds heavily fertilised with pig manure and fed on different locally available feedstuffs (Pillay 1993). *Clarias gariepinus* are farmed extensively all over Asia. At present, most Indian fish farmers have directed their attention towards *Clarias gariepinus* due to the opportunity for short-term profit, faster growth and cheap modes of feeding, irrespective of the potentially disastrous effects of this exotic fish escaping (Hecht and Moor 2004). Aquaculture in Malawi has successfully cultured *Clarias gariepinus* in fertilised ponds, research shows that it converts feed into growth better than tilapia and the growth rate to market size is more rapid than of Cichlids in general (Ngwira 1994). Much more basic research on *Clarias gariepinus* is needed before its use can be accurately evaluated. Research should include natural and cultured growth rates, reproductive biology, nutrition and diseases. In Angola hatchery development *Clarias gariepinus* can be supplied gradually with seeds for rural farms or seeds taken from the wild. The final evaluation resulted in the rejection of three species (*Chrysichthys nigrodigitatus, Clarias ngamensis* and *Heterobranchus longifilis). Clarias ngamensis* and *Heterobranchus longifilis* were rejected because no adequate aquacultural background was found. *Chrysichthys nigrodigitatus* has been cultivated in Nigeria and other West African countries, but there is insufficient knowledge regarding its reproductive biology. For the next years specific research on these species is necessary.

5.1.4 Use of species selected in rural and industrial aquaculture

Species selected from this study will be used in both rural and industrial inland aquaculture. To build models that combine the criteria described in the preceding sections species are selected for the development and operation of rural and industrial fish farming. It is necessary to know that the use varies between the types of aquaculture, and also according to the intensity of industrial fish farming. The main considerations to take in consideration for the culture of these species in both types of aquacultures are show in Table 16.

Table 16: Main comments for the use of species selected in rural and industrial aquaculture.

	COMMENTS	
SPECIES SELECTED	**RURAL AQUACULTURE**	**INDUSTRIAL AQUACULTURE**

Oreochromis andersonii and *Tilapia rendalli*	• The culture duration is seasonal
	• Lower stocking density normally with small tilapias harvested from the wild.
	• In pond culture, attain maturity early, with high level of uncontrolled reproduction.
	• Tilapia in culture produces larges seed so this possibility avoids the collection of the seed from the wild.
	• No reproductive controls are used. Culture of male and female together results in reproduction before market size.
	• The solution is the practice of polyculture in which small carnivorous fish are introduced to reduce tilapia recruitment.
	• Not intentional fertilisation. Some times organic fertilisers are used to increase primary productivity and promote a succession of organisms within the aquaculture pond.
	• The fish are able to utilise natural foods.
	• Limited to own consumption and local markets
		• The culture duration depends on the type of aquaculture system
		  ○ Semi – intensive system: 6 - 9 months.
		  ○ Intensive system: 4 - 6 months
		• High stocking densities
		• Use reproductive control. Early maturities do not represent a problem because reliable technologies are available to control reproduction (monosex culture).
		• Early maturity would ensure easier availability of breeders for hatchery operations, so this permits hatchery production of seed in adequate quantities to guarantee seed for restocking and selling.
		• Improved seed quality.
		• Semi-intensive and intensive systems require artificial feeds with high protein content.
		• Formulated feeds are used according the target species for the minimum possible cost.
		• In semi-intensive systems manure and inorganic fertiliser is applied.
		• Wide market opportunities.

Clarias gariepinus	• Do not reproduce in captivity. • Do not spawn naturally so, seed supply may be a problem in the future. • Limited only for own consumption and local markets.	• Maintenance of broodstock in hatchery. • Do not reproduce in captivity, which is an advantage for intensive aquaculture. • Artificial reproduction has to be induced in hatchery. • Simple methods for broodstock and fry rearing management. • Wide market opportunities.

The growth capacity in captivity is associated with the culture and how it is carried out. *Tilapias sp* are considered ideal for rural aquaculture, because the favourable characteristics described above. But some of these advantages proved to be real constraints to profitable fish farming, particularly the abundant breeding. In Table 16 the strategies carried out by industrial aquaculture to reduce the overpopulation of tilapia in culture are described. Culture using only males or sex reversed can increase the yield per pond. However mixed culture in extensive systems has been obtaining higher average sizes in the harvest time.

The species selected in this study are very easy to reproduce, which minimises dependence on external supplies of fingerlings. The growth of the aquaculture industry greatly depends on the capacity of the hatchery operators to supply high quality fry or fingerlings at a reasonable price that would permit growout operators to sustain their operations.

Feeding and the quality of feed also depend on the culture system. Feed containing higher values of protein is more expensive, which is appropriate for intensive systems that generally have greater export markets. Adequate feed must be selected to reduce costs and increase the probability of obtaining profits from species production.

Species selected can provide a wide range of market opportunities such as sport fishing seeds for lake and river stocking, human food consumption and domestic and international markets. Demand for freshwater species has especially been increasing in the local market. Tilapia, also known as cacusso, and catfish, also know as bagre, dominate the wild catches in Angola (FAO 2004). However the Angolan fishing industry does not adequately satisfy such demand, so harvesting from farms could be a solution to meet this demand.

5.2 Inland aquaculture checklist

The criteria for the aquaculture checklist inventory for aquaculture activities depend on the type of aquaculture system that is being used. A checklist to develop inland aquaculture in Angola involves mainly five aspects: site selection, species source, business planning, environmental impact assessment and aquaculture licensing requirements. A complete analysis of suitable sites and appropriate species is the main factor to developing any aquaculture project.

The site selection aspect is the first decision and most important consideration. Under site selection parameters to be considered is the range of temperature around the site, water quality and quantity, the size of the site, soil quality, topography survey, accessibility to the main electrical power and conflict with neighbours. The analysis of site selection takes into consideration the potential for future environmental damage and the appropriate bio-physical conditions for the species to be cultured.

Each species and type of culture system has special requirements that must be satisfied by the site; if not efficient culture will not be possible. A thorough planning process prior to implementation that includes assessment of which species are most appropriate under given circumstances is necessary. Promoting aquaculture where the biology of the species and the requirements for technology are not well known is a risk. The best target species for investment are those whose culture technology has already been demonstrated. The final checklist model for inland aquaculture in Angola is shown in Appendix 1.

5.3 Evaluation of the potential for aquaculture in Malange province

5.3.1 Preliminary assessment from site visits

Natural potential for inland aquaculture development in Malange province was assessed during the technical trip in 2003. The preliminary report described some characteristics regarding water resources, water body classification, and other important aspects concerning aquaculture. The number of water bodies, lakes and rivers is high, which is suitable for aquaculture development activities. There are many medium and small lakes in the province with about 1-2 ha. These lakes have different origins and can be classified as lakes that receive their water supply from rivers and lakes that get water from rain, only available in the rainy season. Other water bodies include artificial ponds or lakes constructed for reservoir purposes for storage and regulation of water for community use and a small number constructed for agriculture and domestic use. Most of the rivers and lakes fishing activities are simple, that is fishing by net and angle. Lakes and rivers have not yet been polluted from industrial development, urbanisation and waste from human activities. However, in some places local people are starting to pollute the lakes and surrounding areas by throwing rubbish into them or, washing their cars, clothes, etc., for example at the Malange dam.

In the most of the visited areas several issues such as poor infrastructure, bad roads, no electricity and poor information infrastructure (post office, internet) were identified, that should be limited to future sustainable development.

5.3.2 Identification of suitable areas for farm development

5.3.2.1 Rural fish farming

There are a number of small dams in the Malange district (“PRODECA” irrigation dam, Gaiato I, Gaiato II, Malange dam), used mainly for cattle and wildlife watering, water supply coming from the Culamuxilo River. A pilot programme on integrated aquaculture can be introduced with success into this province. Polyculture and integrated aquaculture systems, have multiple advantages for local communities and also a positive impact on the environment (Black 2001).

Communal fish cultivation is most commonly carried out in small ponds. These ponds additionally provide water for household use, watering vegetables and livestock and trapping wild fish. This can serve as the focus for aquaculture diversity by supporting the production of crops, leading to increasing sustainability in social as well as in environmental terms (Edwards *et al.* 1997). The irrigation dam and pond should be stocked with juveniles of tilapia and *Clarias gariepinus* previously selected in this study. This species can easily be fed with numerous plants, and different kinds of waste. The culture of tilapia for example must be used as much as possible, using artificial feeding based of vegetable products of little value such as leaves from banana trees and cassava, rice bran, palm, sweet cassava and cotton seed.

5.3.2.2 Industrial fish farm

In Kalandula district the Kalandula waterfall was visited, there are excellent road conditions, with in easy access points. The major inflowing rivers are Lucala, Luando and Luchilo, the water is good quality. This area was proposed for the construction of a big hatchery centre in order to provide enough seeds for the large areas.

Near Kapanda Dam there are potential sites (lake, small reservoirs) with appropriate conditions that may be adapted to implement an intensive cage culture system. In order to be successful, it is necessary to choose a site that avoids a number of factors that could directly or indirectly affect the viability of cage culture.

The abandoned tanks in the Forest Development Institute (IDF) in Malange district have good potential for aquaculture production but require considerable engineering work to provide adequate water supply and drainage. This area can be upgraded and a new infrastructure built in order to establish an intensive research programme.

5.3.3 Type of aquaculture best adapted in this province

Taking into consideration the main objectives of the government (expanding the adoption of integrated small scale sustainable aquaculture through the implementation of rural and industrial freshwater fish farms) and the results of this study, the types of aquaculture best suited in these provinces are:

- Semi-intensive systems

The semi-intensive aquaculture system is appropriate for industrial aquaculture operation. Culture is almost exclusive to ponds and permits an increase in the stocking density of fish. This system requires additional aeration, addition of inorganic and organic fertiliser and addition of prepared feeds as a supplemental feeding.

- Extensive systems

This system generally involves low technology and is most commonly carried out in small land ponds with little cost. The ponds additionally provide water for household use, watering vegetables and livestock and trapping wild fish. They essentially function as a farm reservoir. This can serve as the focus for aquaculture diversity by supporting the production of crops, leading to increased sustainability in social as well as in environmental terms. *Tilapia sp*. is often favoured for extensive systems because of its tolerance of poor water quality and facilities of feeding. This system usually is developed by small families organised in groups or cooperatives. This is an advantage for the rural communities especially in developing countries because the group can work together to gain some purchasing and marketing opportunities.

- Integrated agri-aquaculture systems

The integrate aquaculture systems is environmentally sustainable because it promotes species diversification and nutrient recycling in ponds. Integration involves a variety of aquatic species, water re-uses for successive aquaculture, by-products generated from agriculture as well as animal manure. This system as an extensive system also usually occurs on family farms in which there are plant crops, animal rearing and aquaculture. This system shall be planned through demonstrative projects using the local available resources.

- Polyculture

This method of culture is usually associated with extensive and semi-intensive farming systems. This system has great advantages for aquaculture because it involves culturing a number of species together with different trophic and complementary feeding habits. This leads to reduced demand for food and avoids serious problems in the farming pods such as declining DO levels and waste increment. Small carnivorous fish can also be used as components in order to control excessive numbers of small fish such as of *Tilapia sp*. resulting from early spawning. Polyculture systems may also be practiced with terrestrial farming (vegetable and animal wastes). In this case the design of the system is an important aspect to consider.

5.3.4 Critical constraints in place

There are different problems and constraints that are considered important to develop aquaculture systems relating to the lack of strong aquaculture research, seed and fingerling supply, feed formulation and electricity costs. The analysis of these critical constraints led to the identification of several main priority aspects to aquaculture development in this province.

- Extension

Extension, for the purposes of this study, is defined as the overall structure which can develop high quality aquaculture training programmes and disseminate information for farmers through seminars, workshops, journals and different publications that involve aquaculture knowledge.

- Seed and fingerling supply

Planning capacity hatcheries for establishing seed production units and ensuring seed quantity and quality, and also sound broodstock management are of great importance for suitable aquaculture development. The building of small-scale hatcheries for the Government sector to produce high quantity and quality seed for the expansion of fingerlings for fish farms, can encourage the aquaculture activity. To achieve good results prior research in quality seed technology will be developed. Starting with species that are easy to grow, but which will not reproduce in the pond during the growout cycle such as Clarias sp. (*Clarias gariepinus*), and mono-sex tilapia (*Oreochromis sp*.), is advantageous for suitable aquaculture development.

- Feeds

Feeds are one of the more important aspects in aquaculture operations and an assurance of quality in economically viable aquaculture. The Government proposed the implementation of a feed processing factory in Malange province. Currently there are two fish meal factories in Angola that could support the supply of sufficient raw material for feeds. Also, this province has several agriculture activities that should be an important factor to consider in feed processing mainly for rural aquaculture.

- Electricity cost

The northern electricity system of Angola supplies electricity to the Malange provinces. Due to a lack of electric power, diesel generators are used as the main sources of electricity so the electricity costs increase as the cost of fuel increases.

5.3.5 Considerations for successful of fish farming operations

To analyse the above, it is necessary to develop a checklist for inland aquaculture to do an inventory of the area before building aquaculture infrastructures, according to the requirement parameters. Critical factors such as economic, social, biologic and legal issues need to be considered for the development and operation of rural and small-scale industrial fish farming aquaculture activities. These factors are summarised in Table 17. In establishing an intensive aquaculture operation, there are many requirements that have to be considered.

Table 17: Important factors for rural and industrial aquaculture operations.

FACTORS	RURAL AQUACULTURE	INDUSTRIAL AQUACULTURE
Aquaculture methods	- Extensive system - Polyculture - Integrated aquaculture system	- Intensive - Semi-intensive system - Polyculture - Hatchery
Economic	- Special finance by the government for aquaculture development. - Development of a small-scale pilot project model for calculating financial and economic feasibility of the project for rural aquaculture.	**The feasibility of the project** - Source of finance management - Product demand - Production economic costs: • System costs ○ Initial facilities investment ○ Maintenance • Production costs directly related with the farm production ○ Fish stock (eggs, fingerlings) ○ Inorganic fertiliser ○ Chemicals ○ Feed ○ Labour ○ Water pumping ○ Oxygenation system ○ Fuel ○ Harvesting • Processing costs ○ Processing parameters ○ Economic parameters - Sufficient market for aquaculture products. - Distance from the farmed fish to the urban market centres
Biologic	- Water supply of high quality - Source of species for culture - Source of seed supply	- Water supply of high quality - Choice of a suitable species for culture • Knowledge about reproductive biology, • Survival • Nutrition • Disease - Source of seed supply, fingerlings, broodstok available for aquaculture operations
Social	- Cultural aspects - Poverty alleviation - Improved purchasing power of the population - Better standards of living - Employment opportunities - Elementary education and extension services - Technical assistance	- Human resources - Labour force - Education and training programme development
Legal	- Law, regulations and legislation in place to support aquaculture development (Rural aquaculture does not require authorisation/licence for aquaculture development)	- Examine law, regulations and legislation in place to support aquaculture development. - Permits and procedures for aquaculture licence requirements necessary for aquaculture operations.

The main factors to be taken into consideration for both rural and industrial aquaculture development were described in sections 4.1, 1.2 and 4.5.

5.3.5.1 Regional Inland Aquaculture Centre for breeding production and training

The construction of a Regional Inland Aquaculture Centre for breeding production should be an important aspect to support the growing national small-scale aquaculture industry. The Centre shall conduct multidisciplinary research and development programmes as well as extension of services by providing practical training courses for local farmers, and by providing information in the form of operational manuals and guidelines. The multidisciplinary research shall include the following programmes:

- Developing under pilot scale conditions, different culture systems and where necessary adapting them to local environmental conditions
- Water and environmental monitoring
- Fingerling production
- Broodstock selection programmes
- Restocking of lakes and other small-water bodies
- Ongrowing (pond management)
- Artificial fish production and propagation
- Training of technicians and fish farmers

To minimise the potential risk associated with the culture of aquatic organisms, specialised training programmes need to be developed. The immediate aquaculture training includes, water management, parasite and disease control, nutrition and feeds, cultural techniques, marketing and processing skills.

6 CONCLUSIONS AND RECOMMENDATIONS

During this study different criteria and factors were considered for the successful development of sustainable aquaculture in Angola. The selection of the native species suitable for inland aquaculture, the development of an aquaculture checklist model to inventory aquaculture issues, and the evaluation of Malange province of Angola for the implementation of rural and industrial aquaculture in small scale were the main objectives.

Great care was exercised in the selection of fish species for the different forms of aquaculture. The evaluation process was accomplishment using two selection phases. Growth rate, reproductive biology, feeding habits and market value of the species were the main criteria used. The final results identified three species with potential for inland aquaculture development. *Clarias gariepinus*, *Oreochromis andersonii,* and *Tilapia rendalli* were selected as the most suitable. The main outputs of the evaluation were:

- Angola has native freshwater fish with appropriate potential for aquaculture, so it will not be necessary to introduce exotic species.
- The species selected are suitable for hatchery aquaculture and are very easy to reproduce which is an advantage in aquaculture.
- The selected species have the cultural characteristics for extensive, semi-intensive and intensive aquaculture systems.
- The selected species are also on demand in the local market. However, the selling market price is relatively high especially in the capital of the country, but the cost should be less in some regions. This scenery should change in the future with the increase of aquaculture production.

During the selection process, constraints, such as important biological aspects that were not available in Fishbase (2005), were found as well as insufficient data regarding the aquaculture potential of some of the species. Furthermore, some data provided by Fishbase (2005) regarding the wild life history of the evaluated species were not very clear. This made the evaluation process in the species selection difficult.

The species that were not selected in this study: *Chrysichthys nigrodigitatus, Clarias ngamensis, Heterobranchus longifilis, Hemichromis fasciatus, Oreochromis macrochir, Serranochromis angusticeps, Tilapia guineensis* and *Tilapia sparrmanii* should be researched in the near future in order to evaluate their suitability for aquaculture after accurate research. To achieve the best results in the future the first priority will be to develop biological studies regarding aquaculture potential of these species under different culture systems and also to research hatchery propagation. This research is necessary to extend to other freshwater native species that were not considered in this study, taking into account that Fishbase (2005) has reported on 250 native freshwater species that occur in Angola. The criteria for the selection of species in this study will help develop future research to find others suitable for aquaculture in Angola.

The checklist provides questions to help consider the many varied aspects of starting an aquaculture business and determine whether a fish farming enterprise is feasible for a particular situation. The checklist represents the first step in the development of an aquaculture project. To create a checklist model different aspects such as site selection, species sources, business planning, environmental impact assessment (EIA) and aquaculture licensing requirements were taken in consideration. The gathered data regarding the site and species selection is considered an important aspect to guide inland aquaculture. It can also be used as a guideline to promote sustainable rural and industrial aquaculture for the efficient management and protection of natural resources. Selecting the best species and the most appropriate sites to culture that species increases the probability that the aquaculture venture will be profitable, and also guarantees environmental sustainability.

Others aspects taken in consideration in the aquaculture checklist such as the EIA process, feasibility study and aquaculture licensing requirements also play important roles in the future of an aquaculture project. This checklist was adapted to Angolan conditions and will be used in diverse farming systems including, open water systems, land-based systems and integrated farming systems.

The present study has provided an overview of the potential for aquaculture in the Malange province of Angola. The information from the visited sites helped to identify the critical constraints in places and adjust the development for both rural and industrial aquaculture. Identifying the critical constraints in place also helped to indicate the number of ways in which the future of aquaculture could be improvement. From the visited sites identification of the suitable areas for rural and industrial farms was made. The province provides potential sites that should be available for aquaculture. In the evaluation, the main economic, social, biological and legal factors for successful rural and industrial fish farming operation were considered. Finally, the Regional Inland Aquaculture Centre was evaluated as a possible centre for breeding, production and training. The aim of this centre will be to develop research needs or strategies to address the identified issues for aquaculture development in Malange province.

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APPENDIX 1

CHECKLIST FOR INLAND AQUACULTURE

YES **NO**

Aquaculture activity is permitted in the local purpose?

- To avoid conflicts between different land users is restrict or not allowed the practice of aquaculture, intensive agriculture or horticulture in determinate areas.

ACTION: Contact the local authorities (traditional) to determine if approval is required for aquaculture activities.

1. Site selection

YES **NO**

Do you know the water source for the proposed site?

- Determine the likely range of water temperatures at the purposed site, so as to ascertain the potential duration of the "growth season" the species that will be cultivate.
- A profile of the source of water should be complete prior to the construction of rearing aquaculture facilities. The following information shall be provided for each water source;
    - The minimum flow available
    - Maximum flow required
    - If the water source will be pumped

ACTION: Describe the source of water that will be used for the aquaculture activity. The result can be submitted to the National Department of Aquaculture Offices, Ministry of Fisheries for evaluation.

YES **NO**

Do you know how much water is necessary for aquaculture operation requires?

- Quantity of water varies according to the species that will be cultured and method of aquaculture that will be use.
- Estimate the sufficient water supply available in the dry season.
- The pond water requirement for a given month depends on the climatic conditions of that month (temperature, wind, humidity)
- An annual water budget should be calculated for a potential farm site operation so that the supply is adequate for existing and future needs.

ACTION: Estimate how much water will be needed on a monthly basis, for aquaculture operations. If you are unsure about of type of aquaculture system that will be use, contact the Institute of Development of Artisanal Fisheries and Aquaculture, Ministry of Fisheries, for further details.

YES **NO**

Do you know the water quality for the proposed site?

Water testing requirements →

- **Temperature**
- **pH;**
- **Conductivity;**
- **Cations – sodium, potassium, calcium, magnesium;**
- **Anions – chloride bicarbonate, carbonate, sulphate;**
- **Heavy metals;**
- **Cadmium;**
- **Toxic metabolites;**
- **Turbidity;**
- **Productivity – calcium;**
    - **total hardness, total alkalinity**
- **Gases (in situ, specify the temperature)**
    - **Dissolved oxygen**
    - **Dissolved nitrogen**
- **Pesticides (water and soil)**

- Determining the quality of the water available at the proposed site is very important for the success of the proposed aquaculture operation.
- It is advisable to locate the operation in an area that offers the most favourable climatic conditions for growth of the intended aquaculture species.

ACTION: Send a water sample to accredited laboratory. The result can be submitted to the Institute of Development of Artisanal Fisheries and Aquaculture, Ministry of Fisheries for interpretation and evaluation.

YES **NO**

Have you had your topography survey in site for Aquaculture activities?

Topography survey →

- **Describe the area for the proposed site and provide topographic map**.

- Topography surveys help to provide suitable sites for aquaculture farm building and also can reduce the pumping cost.

ACTION: Carry out a topography survey before starting an aquaculture project.

YES	NO	Is the proposed site suitable for pond construction?

Sub-soil survey → **Clay content**

- It is important to know the previous land use for the proposed site. If the land has been used for agriculture the soil needs to be tested for pesticide residues.
- Soil needs a good clay content to facilitate pond construction (Ideally the soil clay content should be greater than 20%)

ACTION: Soil analysis conducted by a soil scientist or other competent individuals or authorities.

YES	NO	Is the proposed site suitable for cage culture?

Parameters for considerations →
- **Topography**
- **Wind force**
- **Wind direction**
- **Current velocity**
- **Water depths**
- **Water quality**

- Potential sites for inland aquaculture includes lakes, reservoirs, ponds and dam
- The design of cages varies depending upon their use and location

ACTION: Carry out a responsible survey before starting an aquaculture project.

YES	NO	Is the proposed site of adequate size?

Estimate if the site is sufficiently large for future expansion of aquaculture operation:
- Expansion in on-growing ponds
- Additional storage of water supply
- Additional sediment tanks

ACTION: Contact and discuss with the National Department of Aquaculture Offices, Ministry of Fisheries.

YES	NO	**Have you arranged for power supply in the proposed site?**

Access to electricity is essential for aquaculture operations, the electricity is needed for:

- Artificial aeration to prevent stock mortality during periods of low dissolved oxygen.
- Pumping water supply

YES	NO	**Do you need to clear land?**

- By Law, the area proposed for aquaculture activities shall comply with the duties and obligation established by Regulation No. 39 of 2005 on Aquaculture, land Conservation Law and other relevant national regulations and legislation as National Aquaculture Police.

ACTION: Contact the National Department of Aquaculture Offices, Ministry of Fisheries for further details.

YES	NO	**Could neighbouring activities be a source of a conflict (dust, noise, spray, drift, pollution, odours, etc.) with your operations ?**

Other land uses? → **•The separation distance between aquaculture and another land uses varies in accordance the type of aquaculture.**

- It is necessary to assess any existing or potential areas of conflict with neighbours before start of aquaculture operations.

ACTION: Discuss alternatives and measures to avoid futures conflicts, preferably with neighbours and other stakeholders.

YES	NO	**Have you had your site surveyed for farm building?**

Farm layout →

Be sure to arrange the service of a properly qualified eartth mover, experienced in aquaculture farm contruction.

- **Desing the aquaculture facilities needs the assistence of professional surveyors and engineers.**
- **The proposed site for ponds construction should be slope at less than 5%, ideally between 1 and 2%.**

Check that the plants include:

- **Accommodation**
- **A processing building**
- **Feed silos**
- **A farm vehicle**
- **A workshop**
- **Ponds/tanks**
- **Gravity drainage outles on ponds/tanks,**
- **Effluent treatment plant**
- **Space for vehicle access**
- **Power lines**
- **A back-up power supply**
- **Support poles for overhead pond covers**

- Determined expenses for construction or improvement of the aquaculture facilities are very important.
- Explored the different production technologies available and identified one that satisfied your interests and resources.
- An aquaculture operation also needs available equipments, reagents, feed and other essential supplies.

ACTION: Contact professional surveyors and engineers for aquaculture facility design. Contact the National Department of Aquaculture Offices, Ministry of Fisheries, for further details.

2. Species source

YES	NO	Is the species you plan to farm native to Angola or exotic?

Regulation No. 39 of 2005 on Aquaculture →

- **Is the species for culture is not native you shall seek the written approval or authority of the Ministry of Fisheries to cultivate the species.**
- **The regulation defines the culture of exotic species in accordance with the type of aquaculture and region proposed for aquaculture development.**

ACTION: If you are unsure, contact the Institute of Development of Artisanal Fisheries and Aquaculture, Ministry of Fisheries.

YES	NO	Do you know how to grow the selected species?

It may pay to employ a suitably qualified farm manager →

- **Fish farming requires a broat range of skills, more so than the operation system and animal husbandry, to ensure the chosen operation is successful.**

ACTION: To gain additional information and competence, consider enrolling in an aquaculture training course. Contact the specialized institute of scientific research, (Institute of Development of Artisanal Fisheries and Aquaculture) for available information on how to grow a particular species and by attending field days. The Institute also provides some documentation and relevant aquaculture books, journals and magazines in the library. The participation in seminars conferences, workshops and other meetings associated with particular relevant aquaculture issues can be of great help.

3. Business planning

YES	NO	Have you developed a business plan ?

Bio-economic feasibility →

- **Aquaculture activity is a very capital intensive investment**
- **Is essential determined the bio-economic feasibility of the operation and decide whether to proceed.**

- Starting an aquaculture activity offers the prospect of good returns, but also has an element of risk. It is essential to determine if the business concept is sound.

  - Is there adequate profitable market (s) for the service or product?
  - Are the financial projections realistic, robust and consistent?
  - Is the management team capable and experienced in aquaculture operations?

ACTION: Answer these questions and write a document to serve as a plan to guide the operation. Follow up with periodic evaluation and revision of business plan.

4. Environmental Impact Assessment (EIA)

YES | **NO**

Have you developed an Environmental Impact Assessment (EIA) Process for aquaculture operation?

Regulation No. 39 of 2005 on Aquaculture Licensing requirements →

• EIA is needs according to the aquaculture regulation and others relevant regulations and legislation.

• The EIA process is carried out before the licence is issues.

- EIA estimate the possible environmental impact resulting from an aquaculture project development.
- EIA process is applicable only for semi-industrial and industrial aquaculture not for small scale operations as an integral part of rural development.
- EIA is conducted by the developer.

ACTION: Before a license is approved, it is necessary to do assessment of environmental aspects in order to evaluate possible environmental effects of the proposed aquaculture operation and to start environmental monitoring routines.

5. Aquaculture licensing requirements

YES | **NO**

Do you need an aquaculture licence?

Regulation No. 39 of 2005 on Aquaculture Licensing requirements →

• The Angola Ministry of Fisheries is responsible for licensing aquaculture operations.

- For inland aquaculture operations, aquaculture license is only issued after obtaining a license or concession of private waters resource use for aquaculture purposes.

- In the case of an application for an aquaculture license that involves private use of water resources, the competent Ministry will request comments from the Water Resources Management office of the Ministry of Energy and Waters.

- In the case of an application for an aquaculture license that involves infrastructure development in agricultural areas, forests or that it is complemented with land use for agricultural purposes, the responsible Ministry shall request comment from the Ministry of Agriculture.

ACTION: If you are unsure as whether you require a license, contact the National Department of Aquaculture Office of the Ministry of Fisheries.