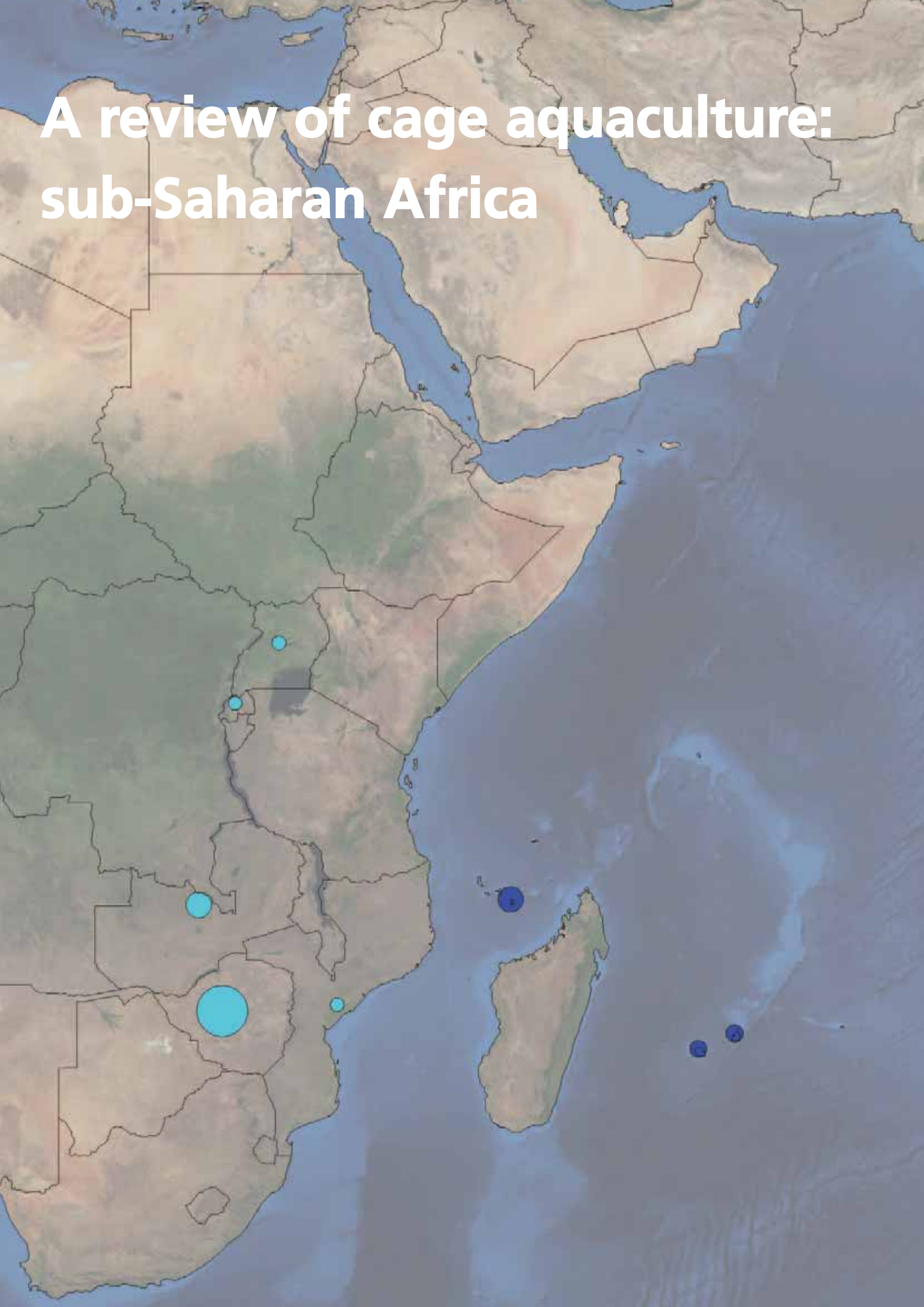
Cage aquaculture production 2005

Data were taken from fisheries statistics submitted to FAO by the member countries for 2005. In case 2005 data were not available, 2004 data were used.

Map background image *Blue Marble: Next generation* courtesy of NASA's Earth Observatory

A review of cage aquaculture: sub-Saharan Africa



A review of cage aquaculture: sub-Saharan Africa

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ABSTRACT

Cage culture is an emerging activity in sub-Saharan Africa, and there are only a handful of successful examples. However, the region offers considerable scope for the industrial-scale development of freshwater cage culture, especially in the great lakes region and in tropical West Africa. There is also potential for brackish and marine cage culture, but as yet there has been no sustained commercial development of this subsector.

Working examples of cage culture in the region are tilapia farms in Ghana, Kenya, Malawi, Uganda, Zambia and Zimbabwe. All farms grow Nile tilapia (*Oreochromis niloticus*) with the exception of those in Malawi, which use the local species *O. shiranus* and *O. karongae*, both known as "*chambo*". The growth performances of tilapias other than *O. niloticus* and of wild strains of *O. niloticus* are unlikely to be globally competitive. Therefore, the use of improved strains of Nile tilapia across sub-Saharan Africa should be reviewed and restrictions relaxed. Breeding centres in conjunction with practical hands-on training need to be established.

However, the main constraint to the development of competitive cage culture in the region is the unavailability of locally produced, high-quality extruded feeds at competitive prices. Local raw materials should be used. This issue, as well as a current lack of economies of scale, are key drivers behind high production costs in African cage aquaculture.

Other constraints include a lack of training in cage culture, a lack of processing and routes to developed markets in some countries, traditionally low prices and quality of wild-caught fish in the region, a lack of potential investors willing to take a long-term investment risk in sub-Saharan Africa, a lack of understanding and commitment by governments to the development of aquaculture in some countries and a lack of expertise in disease identification and management.

Countries will need to address these issues and should create an enabling environment for cage culture with due recognition of environmental and social aspects. National strategies and plans, the development of aquaculture zones, and public awareness campaigns, including for capital providers, will play an important role.

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INTRODUCTION

This review is part of a study commissioned by the Food and Agriculture Organization of the United Nations (FAO) on the global status of cage culture in 2006. The report reviews the history of freshwater cage culture in sub-Saharan Africa[3], highlights working examples in the region (specifically in Ghana, Kenya, Malawi, Uganda, Zambia and Zimbabwe), identifies problems facing the development of the industry and makes recommendations as to the way forward.

Aquaculture has a checkered history in Africa, and since the 1950s its development has focused on subsistence-level pond-based systems. Commercial aquaculture has not been well promoted in the region and has thus been slow to develop. Cage culture in Africa probably started as a means for fishermen to hold a suitable quantity of caught fish alive until market (Masser, 1988). Initially, cages were fabricated with wood or foliage material, and fish were fed food scraps and possibly trash or by-catch fish. More advanced cage culture started in the 1950s, and synthetic materials were used in cage construction and mooring. Research on cage culture started only in the 1960s, as before then pond culture seemed to be economically viable and was more popular, and therefore was the focus of research in academic institutions.

Cage culture was introduced on a test basis in sub-Saharan Africa in the 1980s when momentum for aquaculture development grew and the need for aquaculture research received government recognition as part of national development plans (Masser 1988). Multilateral and bilateral donors increased technical assistance, and aquaculture started to develop more solidly. Recently the general development policies of several African countries have been changed to recognize aquaculture as its own independent sector (FAO, 2001).

Cages have since been piloted in Côte d'Ivoire, Ghana, Kenya, Malawi, Rwanda, South Africa, Uganda, Zambia and Zimbabwe, and commercial cage culture is currently developing in Ghana, Kenya, Malawi, Uganda, Zambia and Zimbabwe (the authors could not ascertain the status of cage culture in Côte d'Ivoire).

[3] The sub-Saharan Africa region covers Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Congo, Ethiopia, Gabon, Gambia, Ghana, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritius, Mozambique, Namibia, Niger, Nigeria, Réunion, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Swaziland, United Republic of Tanzania, Togo, Uganda, Zaire, Zambia and Zimbabwe.

There are no major examples of pen culture or marine or brackish-water cage culture in the region. A few small-scale pilot projects of pen culture for oysters and abalone are noted in Namibia and South Africa. The main focus of this paper is thus freshwater cage culture in inland water bodies.

Tilapias are the only fish that have been farmed in cages in the region (mainly Nile tilapia (*Oreochromis niloticus*), and "chambo" (*O. shiranus* and *O. karongae*)). There have been one or two small trials with North African catfish (*Clarias gariepinus*) but as no data are available these are not mentioned further in this review

THE CURRENT SITUATION

Cage culture is currently practiced in Ghana, Kenya, Malawi, Uganda, Zambia and Zimbabwe.

Ghana

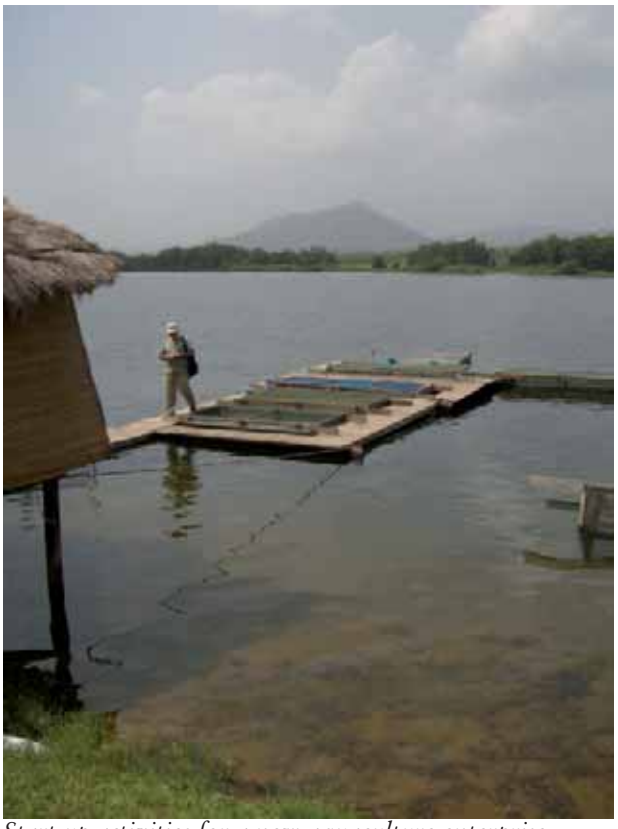
There are two cage-farming companies in Ghana: Crystal Lake Fish Ltd. and Tropo Farms Ltd. Both are situated in Lake Volta, one of the world's largest man-made lakes.

Established in the late 1990s in the Asuogyaman District of Ghana's Eastern Region, Crystal Lake Fish Ltd. grows indigenous tilapia (*O. niloticus*) in ponds and concrete tanks (breeding and juveniles) and cages (grow-out to market size). The farm has 24 circular (8 m diameter each) tanks for hatchery (8) and nursing (16) purposes. When fingerlings

Cage aquaculture sites in Africa

reach an individual weight of 5–8 g, they are transferred to one of the nine cages (32 m diameter and 5 m depth) that are located about 1 km from the shore in 25 m deep water. Stocking density is up to 100 000 fish per cage or 0.5 to 1.0 kg/m³. Fish are fed a powdered feed during the first two months to a size of 40–50 g, then they are moved to another cage at a density of 50 000 to 60 000 fish per cage for three months to reach an individual selling weight of 250 g. The total production cycle is five months. Annual production in 2006 was around 340 tonnes of whole fish, although the company wants to expand production to 1 000 tonnes per annum. Crystal Lake has an agreement with a local distribution company. All the fish are gutted and transferred to the Capital for onward distribution.

Tropo Farms has been pond farming for six years and in 2005 developed a pilot-scale cage site on Lake Volta near Akosombo Dam. Tropo grows indigenous *O. niloticus* in ponds (breeding and juveniles) and cages (grow-out to market size). Current production from cages is around 10 tonnes of whole tilapia per annum, although Tropo plans to expand its cage-culture operations. Tropo sells its fish fresh at the farm gate into the Ghana market.



COURTESY OF M. HALWART

Start up activities for a new aquaculture enterprise, Lake Volta, Ghana

COURTESY OF M. HALWART

Feeding time at Crystal Lake Fish Ltd., Lake Volta, Ghana

Species-specific information

Oreochromis niloticus is indigenous in Ghana but the local strain is considered by some fish farmers not to perform well because of slow growth rates. Selective breeding of the local strain is underway in an attempt to improve performance. Introduced strains such as GIFT (Genetically Improved farmed Tilapia) are currently not allowed to be farmed in cages in Ghana.

Cage/pen type and size and number of cages

Crystal Lake has plastic circle cages that were purchased from Europe. There are about 8 cages installed in circa 25 m deep water at Crystal Lake, each with a diameter of 15 m and a depth of 4 m. Each cage is stocked with 50 000 fingerlings of *O. niloticus* at 30 g that are cultured for six months.

Tropo has a pilot-scale cage site with eight cages of 40 m³ each. Production nets are locally made. Juveniles of 10 g are transferred to the cage site from Tropo's pond site, which is one hour by good road, and are currently being grown to a market size of around 350 g. Water exchange rates are good at Tropo's cage site and the water depth is around 20 m.

Stocking density

Stocking density at harvest is expected to be around 40 kg/m³ at both farms.

Production per cage per unit time

Crystal Lake Fish Ltd.'s annual production is around 340 tonnes of whole fish, while Tropo's current annual production from cages is around 10 tonnes of whole tilapia.

Market size and price
Tropo's market size is around 350 g, while at Crystal Lake, the fish are grown to market size of around 250 g.

Technical issues
Seed supply
Both fish farms produce their own fry. Crystal Lake has its own hatchery with concrete tanks and grows fingerlings in larger lined earthen ponds before they are transferred to floating cages on the lake.

Feeds and feeding
Obtaining high quality locally manufactured feed is the most serious constraint to commercial cage farming in Ghana. Local extruded feeds are not available. Tropo makes its own moist sinking feed on site and is working on obtaining a locally manufactured pellet. Meanwhile it is also importing high-quality extruded feed from Europe on a trial basis. The price of locally produced feed exceeds US$400/tonne due to the relatively high price of imported raw materials. Feed conversion ratios (FCRs) using their own feed have been reported as 1.7 to 2.2 by Tropo, but these results are from ponds.

Diseases
No serious disease problems have been encountered, although external bacterial infections (*Columnaris*) and fish lice (*Argulus*) have been reported.

Socio-economic issues
The overall contribution of aquaculture to the economy of Ghana has not been separated from the contribution of fisheries. Livelihood opportunities identified are usually those related to marine and inland capture fisheries. Ten percent of the population is involved in the fishing industry from both urban and rural areas (IMM, 2004a; 2004b). In the case of Crystal Lake, the farm recruits labourers from a nearby village and about 15 workers live on the farm itself.

Production costs
Production costs should be below US$1 per kg of whole fish for a large tilapia cage farm in Ghana. However, feed price is high at over US$400/tonne and the local strain of *O. niloticus* is slow growing, according to some producers. With improved economies of scale, better growth performance and the availability of a quality extruded feed at a reasonable price, tilapia cage culture could become a major industry in Ghana.


Tropo Farms cages in Lake Volta, Ghana

Marketing and prices
Demand for tilapia is strong and growing in Ghana and its neighbour Nigeria, and farm-gate prices are reported as around US$2.20/kg. The existing cage farms sell fresh whole or fresh gutted fish at the farm gate, but processing and marketing are expected to become more sophisticated as production volumes increase. Fish makes up around half of the country's animal protein consumption. Most fish products in Ghana are marketed locally and are fresh, making up for dwindling supplies from traditional capture fisheries. In the future, Crystal Lake plans to export fillets to the European Union (EU).

Employment
Tropo employs 40 staff in its pond and cage operations, while in 2005 Crystal Lake Fish was said to employ about 50 workers from the local village. Crystal Lake has demonstrated how aquaculture can help Africans fight poverty by creating employment and improve living standards

Lake Volta supports the livelihoods of 300 000 people, of whom nearly 80 000 are fishermen and 20 000 are fish processors or traders. There are 1 000 people involved in the aquaculture sub-sector, working mainly in pond culture (Mensah *et al.*, 2006).

Environmental issues
Lake Volta is a large freshwater hydroelectric reservoir fed by the Volta River. Water quality is good for tilapia culture, with consistent year-round warm temperatures. Environmental impact assessments (EIAs) are required before any cage culture is allowed in Ghana.

Pollution
Lake Volta is free of pollution and the water quality is exceptionally suitable for aquaculture

Escapes
There have been no reported escapes.

Ecological impacts
At Crystal Lake, effluent water from the fish hatchery is used to produce vegetables in a one-hectare plot that are distributed at no cost to local people.

Institutional issues
Policies and legal frameworks
Aquaculture is regulated by the Directorate of Fisheries (DoF), the Environmental Protection Agency, the Water Resources Commission and Local Assemblies. DoF is the lead agency vested with the administrative control of aquaculture. It is also the main institution responsible for planning and development in the aquaculture subsector. The Council for Scientific and Industrial Research (CSIR), an umbrella organization that supervises all research organizations, is mandated to carry out aquaculture research. Both agencies are funded by the government. Crystal Lake is privately owned and has obtained assistance from the International Finance Corporation (Africa Project Development Facility).

Training
There are several governmental institutions associated with aquaculture research and training. These include the Directorate of Fisheries, Kwame Nkrumah University of Science and Technology, the University of Ghana, the University of Cape Coast and Kwadaso Agricultural College. Part–time consultants are hired to train local supervisors and workers on fish-farm operations.

Non-governmental organizations (NGOs)
Several NGOs are involved in aquaculture but none are specifically promoting cage culture in Ghana.

Others
The World Bank has recently been involved in funding various aquaculture and fisheries projects.

Kenya

Commercial cage culture commenced in Kenya in 2005. There was a pilot cage site in the 1980s that is now defunct. The only existing fish cages are for tilapia (*Oreochromis niloticus*) and are operated by Dominion Farms Ltd. at Yala, near Lake Victoria in western Kenya.

Species-specific information
Nile tilapia is not indigenous to much of Kenya, but it is allowed for aquaculture in Lake Victoria because it was introduced there in the 1970s and has flourished. No further introductions of improved genetic material have been made. A selective breeding programme is currently underway at Yala aimed at improving the performance of the local stocks under farmed conditions.

Cage/pen type, size and number of cages
The existing cages are small (4 m^3), intensively stocked, hapa-type wooden-frame cages placed in dammed areas and irrigation canals on Dominion's large new arable farm development in Yala. There are currently 30 such cages. Production nets are made locally in Kenya.

Stocking density
Harvest stocking density is expected to reach 200 kg/m^3.

Technical issues
Seed supply
Tilapia fry are produced by Dominion Farms and juveniles are stocked into the cages from Dominion's own tilapia hatchery. The Fisheries Department has also been producing fingerlings of various species (mainly tilapia) in its fingerling production centres (Lake Basin Fry Production Centres).

Feeds and feeding
Obtaining good quality locally made feed is the most difficult constraint for commercial cage culture in Kenya. Raw materials are available locally at reasonable prices (Radull, 2005) but extrusion is currently not possible. Dominion plans to put in its own extruder. Feed cost is currently around US$350/tonne in Kenya for a tilapia grower feed.

Pilot cages in Kenya, 1980s

Diseases
No disease problems have been reported.

Socio-economic issues
Aquaculture has recently become a source of healthy animal protein in many parts of Kenya. A number of subsistence-level fish farmers have turned into small-scale commercial fish farmers. Some of the commercial farmers who are starting production want to produce for both the local and export markets; hence in the next few years aquaculture is likely to make a significant contribution to both food security and foreign exchange earnings in Kenya.

Production costs
Production costs should be below US$1 per kg of whole fish for a large tilapia farm in Kenya. However, the current poor economies of scale and poor feed quality raise the production costs.

Marketing and prices
Wild-caught tilapia and Nile perch (*Lates niloticus*) are available in Kenya at relatively low prices. However availability is declining because of over fishing and prices are rising steadily. Currently cage culture is targeting the local market for fresh and frozen whole fish and fillets.

Employment
Cage culture currently employs less than 10 people in Kenya.

Environmental issues
Lakes Victoria and Turkana offer great potential for cage culture. Water quality is good and water temperatures are warm all year round, but Kenya's eastern basin of Lake Victoria is relatively shallow and Lake Turkana is remote. These factors conspire to slow the development of cage culture.

Pollution
EIAs are required before any cage culture activities are allowed in Kenya.

Escapes
There have been no reported escapes.

Ecological impacts
The lakes have important capture fisheries that are communally owned and fished and, as in Uganda, there is some resistance to the idea of cage culture probably because this activity is either not known or not well understood. This situation is likely to change within five years in Kenya.

Institutional issues
Policies and legal frameworks
Aquaculture is controlled by the Department of Fisheries in the Ministry of Agriculture and Rural Development. The department is responsible for the administration and development of fisheries and aquaculture, enforcement of fisheries regulations including licensing, collection and reporting of fishery statistics, market surveys, fish quality assurance and control of import and export of fish and fishery products (FAO, 2004a).

Training
Aquaculture training is available in Kenya on an occasional course basis. The Department of Fisheries, in collaboration with Moi University also undertakes aquaculture extension programmes. The Fisheries Department at Moi University has developed an aquaculture facility that will be used for training, research, demonstration and extension services in the region (FAO, 2004a). However, this is basically pond culture and the authors do not have direct information on cage culture training.

Non-governmental organizations
There are several NGOs involved in aquaculture in Kenya, although none are specifically promoting cage culture. The United States Agency for International Development (USAID) has been active in rural aquaculture development since the 1990s.

Malawi

Maldeco Ltd, an old and well established fishing and fish processing company that branched into cage culture in 2004 on Lake Malawi, has the only cage culture in Malawi. It grows *Oreochromis shiranus* (locally known as "chambo") in ponds (breeding and juveniles) and cages (grow-out to market size). Annual production is currently around 100 tonnes of whole fish, but Maldeco plans to produce 3 000 tonnes per annum within five years. It processes the fish on site near Mangochi and markets its products in Malawi as frozen whole fish and fillets.

Species-specific information
Oreochromis shiranus, *O. karongae* and red-breast tilapia (*Tilapia rendalli*) are indigenous in Lake Malawi. *Oreochromis niloticus* is not indigenous in

Malawi and current policy prohibits its introduction, as well as that of other exotic species.

Screening for suitable indigenous species for aquaculture has been an ongoing activity at Malawi National Aquaculture Centre since 1960, supported by various projects. The genetic improvement of indigenous species is also encouraged. Selective breeding of *O. shiranus* and *T. rendalli* with respect to their genetic performance is ongoing at Malawi National Aquaculture Centre (Chimatiro and Chirwa, 2005).

Cage/pen type and size and number of cages

Maldeco Ltd. is located in the Mangochi District, in the southern region of the country. It has square steel cages that are 6 m deep and imported from Europe. The cage site is about 200 m offshore and in deep water, with good currents caused by the start of flow from the lake into the Shire River. Production nets are nylon and imported from Europe.

Currently Maldeco has only one cage site containing 10 cages. Juveniles are transferred from ponds and grown up to 300 g or more, which is the size for whole tilapia most in demand in Africa.

Production level

Maldeco targets to produce about 3 000 tonnes per annum from both ponds and cages.

Market

There is high demand for farmed fish in the upland areas away from the lakes and in the urban centres (Chimatiro and Chirwa, 2005) .

Technical issues

Seed supply

Maldeco breeds its own fry in earthen ponds at a site about 13 km from the cage site.

Feeds and feeding

Obtaining high quality locally manufactured feed is the most serious constraint for commercial cage farming in Malawi. Extruded feed is not available locally.

Diseases

No disease problems have been encountered.

Socio-economic issues

Aquaculture in Malawi contributes to food security in terms of increased access to food, increased food production, improved household capacity to acquire food and improved utilization of farmland for food production (Jamu and Chimatiro, 2004). Fisheries resources contribute 4 percent to the nation's gross domestic product (GDP). Aquaculture accounts for about 2 percent of the nation's fish production (Chimatiro and Chirwa, 2005).

Production costs

Production costs should be below US$1 per kg of whole tilapia for a large cage farm in Malawi. However, feed quality constraints, poor economies of scale and the research and development costs attached to developing new tilapias for cage culture all increase production costs. Actual production cost data were not available.

Marketing and prices

Maldeco markets its own fish as frozen whole fish and fillets to local supermarket chains and other outlets across Malawi. Prices are strong for whole tilapia in Malawi at over US$2/kg.

Environmental issues

Lake Malawi is one of the great African lakes. Water quality is good for cage culture although, like Zimbabwe, Malawi has a three-month cold season (June through August) that slows fish growth rates. From time to time, fish kills are reported due to overturn in Lake Malawi.

Pollution

Maldeco carried out an EIA before commencing its cage culture operations.

Institutional issues

Policies and legal frameworks

Fisheries and aquaculture are controlled by the Department of Fisheries. Fisheries is an important sector of Malawi's economy despite dwindling of the natural fishery resources of the lake over the past 20 years. Aquaculture is a target development sector in Malawi for food security reasons, because fish is the preferred source of protein and because Lake Malawi offers great scope for cage culture. Also Malawi is targeting export of farmed fish once an industry is established.

The Malawi Department of Fisheries, in the Ministry of Mines, Natural Resources and Environmental Affairs, is responsible for the management and development of the aquaculture sector.

Maldeco leases areas of Lake Malawi from the government for mooring and operating cages.

Training
Aquaculture training is available in Malawi from the National Aquaculture Centre and Bundu College. The Malawi Gold Standard Aquaculture Production System is both a model for profitable small-scale commercial fish farming and a set of extension training materials for disseminating the model to fish farmers in suitable areas of Malawi. This was developed by a 10-person team of technical experts from the World Fish Centre (WFC), Chancellor College and the Department of Fisheries, with support from USAID/Malawi – see also http://www.usaid.gov/mw/pressandinfo/aquaculture.htm.

Non-governmental organizations
There are several NGOs involved in aquaculture in Malawi, but none are specifically promoting cage culture. WFC is working with Malawi's Fisheries Department to help farmers get much more out of their land, although this is generally subsistence or rural aquaculture. USAID has been supporting the fisheries sector in Malawi.

Uganda

Cage culture is a new activity in Uganda, having commenced in early 2006, that is being encouraged by the government as a development priority. This is because revenues from the dwindling wild capture fishery are a major source of foreign currency for Uganda and the government believes that aquaculture will supplement these revenues. There are currently only three pilot-scale cage sites on Lake Victoria, in the Entebbe and Jinja areas. Son Fish Farm Ltd, United Fish Packers Ltd and one other manage these, and form part of a three-year (to 2008) USAID-funded aquaculture development programme. Cage performance results are not yet known.

Species-specific information

Oreochromis niloticus is indigenous in many parts of Uganda, although it was introduced to Lake Victoria in the 1970s, where it has flourished. No further introductions of imported genetic material have been made. A selective breeding programme is currently underway in Uganda aimed at improving the performance of the local stocks under farmed conditions. Although available data suggest that growth rates are satisfactory, the introduction of improved strains from abroad is being considered because Uganda wishes to fast-track aquaculture development.

Cage/pen type and size and number of cages
The pilot-scale cage sites all have small intensively stocked cages of no more than 5 m^3 each. There are about 15 such cages in Uganda at present. The sites are all inshore and in shallow (<5 m deep) areas. The cage frames are constructed locally using polystyrene floats and wooden walkways. Production nets are nylon and made in Uganda. Predator nets are being used as a precautionary measure, although the predation risk has not yet been determined.

Juveniles (10 g) are transferred from a government hatchery, which is to be supplemented by Son Fish Farm's commercial hatchery in Jinja. The fish are being on-grown to an export-oriented market size of 700 g and will be processed for export in any of Uganda's 17 EU-approved fish plants.

Stocking density
Stocking densities are 200 fish per m^3 in the trial cages. Harvest stocking density is expected to reach 100 kg/m^3.

Technical issues

Seed supply
Tilapia fry are produced by a government hatchery at Kajjansi (near Kampala) and are later expected to be produced by Son Fish Farm Ltd in Jinja.

Feeds and feeding
Obtaining good quality locally made feed is the most difficult constraint for commercial cage culture in Uganda. Raw materials are available locally at reasonable prices but extrusion is currently not available.

Diseases
No disease problems have been reported.

Socio-economic issues

Production costs
Production costs should be below US$1 per kg of whole fish for a large tilapia farm in Uganda but this has not yet been demonstrated.

Marketing and prices
Wild-caught tilapia and Nile perch are available in Uganda at relatively low prices. However, availability is declining due to overfishing and prices are rising steadily. Currently cage culture is targeting the European market for fresh fillets, although the regional market, especially the Democratic Republic of Congo (DRC), Kenya and

Uganda itself, is likely to become important within five years.

Employment
Cage culture currently employs less than 20 people in Uganda but is expected to become a major activity within five to ten years.

Others
The lakes have important capture fisheries that are communally owned and fished, and there is some resistance to the idea of cage culture probably because this activity is new and not well understood. This situation is likely to change within five years in Uganda.

Environmental issues
Lakes Victoria, Kyoga and Albert, and the Nile River offer enormous potential for cage culture. Water quality is good and water temperatures are warm all year round because Uganda lies on the equator.

Pollution
EIAs are required before any cage culture activities are allowed in Uganda.

Escapes
There have been no reports of escapes to date.

Institutional issues
Aquaculture is controlled by the Department of Fisheries' Aquaculture Unit. Fisheries exports are Uganda's most important source of foreign currency. Wild catch has reached maximum sustainable yield and aquaculture is being vigorously promoted for food security reasons as well as to supplement volumes and secure future export revenues. The Competent Authority responsible for managing fish quality for export is the Department of Fisheries.

Training
Aquaculture training is available in Uganda in the form of occasional courses. The National Agriculture Research System Act has resulted in aquaculture research being opened up to other public or private institutions and individuals such as universities, consultancies and training institutions with the capability to carry out the required research. The Kajjansi Aquaculture Research and Development Centre remains, however, the core institute for strategic research in the country. On-farm trials and "farmer participatory research" have been the norm. Aquaculture research has been funded by other organizations and individuals, including NGOs, universities, donor agencies and local governments, with students and farmers interested in understanding and solving issues of commercial aquaculture. The Fisheries Training Institute in Entebbe offers opportunities for research and diplomas and certificate training (Mwanja, 2005).

Non-governmental organizations
There are several NGOs involved in aquaculture in Uganda although none are specifically promoting cage culture.

Zambia

There are three small cage farms in Zambia operating on Lake Kariba in the Siavonga area that were established in the 1990s. None produces more than 10 tonnes per annum of whole fish. All farm *Oreochromis niloticus* and all produce their own fry and juveniles[4].

Lake Harvest Aquaculture in Zimbabwe is currently investigating the establishment of a satellite cage farm in Zambia.

Species specific information
Oreochromis niloticus is not indigenous in Zambia, having been introduced in the 1980s for fish farming along the banks of the Zambezi. No further introductions of improved strains have been made since then and it is likely that there is a high level of inbreeding among farmed stocks. The introduction of improved strains is being considered.

Cage/pen type and size and number of cages
All three farms have square cages of around 40 m^3, with wooden walkways. Production nets are nylon and are made in Zimbabwe or imported. No predator nets are used. The three cage sites are located in shallow (<5 m deep) inshore areas and are close enough to land to have walkways out to the sites. The total number of cages is around 30. Juveniles are transferred to the cages from pond sites, where they are on-grown to market size of around 350 g.

Stocking density
Stocking density at harvest is around 20 kg/m^3.

4 Editor's note: According to Maguswi (2003) there were 4 commercial enterprises practicing cage culture on Lake Kariba. They each used 44 cages 6 m x 6 m x 6 m (216 m^3) and 10 pens to grow *Oreochromis niloticus* and used pellet feed.

Production per cage per unit time
Average production for bigger cages (216 m³) volume is 3.5 tonnes (Maguswi, 2003).

Technical issues
Seed supply
The three cage farms each produce their own fry.

Feeds and feeding
A reasonably good quality locally manufactured extruded feed is available in Zambia but the price is high at over US$400/tonne and not all the cage farmers use it.

Tiger Animal Feeds is the largest specialized animal feed producer in Zambia. While poultry, pig and dairy feeds constitute the bulk of its production, the company is also involved in formulating and making fish and crocodile feeds. The company benefits from highly qualified staff, feed-mill equipment and agreements with a European company for fish feed. Production levels vary with demand, with poultry feeds topping the list. The company has focused on developing formulas for various feeds to ensure constant product quality and consistency. All feeds are formulated with 95 percent of high quality and laboratory-checked local raw ingredients (i.e. wheat flour, maize meal, cooking oil) (FAO, 2004b; Bentley and Bentley, 2005).

Diseases
No disease problems have been reported.

Socio-economic issues
Fish production is important to the national economy and contributes significantly to employment, income and food production. It is estimated that up to 55 percent of the national average protein intake is from fish. The importance of fish in Zambian household food expenditure increases in proportion with increasing levels of poverty. The contribution of fish to gross domestic product (GDP) is estimated to be 3.8 percent. This estimate is based largely on the contribution from capture fisheries, because production from fish culture is not regularly reported (Maguswi, 2003).

Production costs
Production costs should be below US$1 per kg of whole fish for a large tilapia farm in Zambia. However the relatively high cost of feed, as well as poor existing economies of scale make profitability marginal.

Marketing and prices
The three existing cage farms sell their fish at the farm gate in fresh form into the Zambia market. There are supply outlets in the major cities. Demand and prices are strong in Zambia.

Employment
No figures are available.

Environmental issues
Lake Kariba is a 5 000 km² freshwater hydroelectric dam-lake fed by the Zambezi River. Water quality is good for cage culture, although a three-month colder season (June through August) retards fish growth.

Pollution
An EIA is required before any cage farm operation may commence in Zambia.

Escapes
There have been no reports of escapes.

Institutional issues
Policies and legal frameworks
Aquaculture in Zambia is controlled by the Department of Fisheries under the Ministry of Agriculture and Cooperatives. In order to obtain a clear picture of the aquaculture development objectives, a National Aquaculture Development Strategy (NADS) was prepared in 2004. Zambia is a fish-eating nation and cage and pond culture is being promoted. Lake Kariba offers great industrial expansion opportunities.

Training and research
There is little formal training in aquaculture in Zambia. There are five aquaculture research centres in the country that are administered by the


One of three cage farms in Lake Kariba, Zambia

Wooden cages in Lake Kariba, Zambia

Department of Fisheries. These are the only centres in the country where aquaculture research is carried out. Programmes are drawn up in close collaboration with extension officers and farmers. The centres are supported through government grants and donor agencies. Monthly, quarterly and annual reports are submitted for follow-up actions, review of activities and verification of results. The Natural Resources Development College (NRDC) in Lusaka Province offers a three-year diploma course in fisheries that includes aquaculture. The Kasaka Fisheries Training Institute in Kafue (Lusaka Province) offers a two-year certificate course in fisheries and aquaculture for technicians who expect to be in regular contact with fish farmers (Maguswi, 2003).

Others

The Rural Aquaculture Promotion project (RAP) is primarily the fruit of a collaborative effort between the Zambian Department of Fisheries (DOF) and the United States Peace Corps since around 1996. As part of efforts to develop aquaculture, the Government of the Republic of Zambia requested the Japanese government to support service training for fisheries officers via the Japan International Cooperation Agency (JICA).

Zimbabwe

Zimbabwe's only cage culture operation is Lake Harvest Aquaculture (Pvt) Ltd (Lake Harvest). Established in 1997 at Lake Kariba in northern Zimbabwe, Lake Harvest is a modern, vertically integrated farm that grows *Oreochromis niloticus* in ponds (breeding and juveniles) and cages (grow-out from 10 g to market size). Annual production is around 3 500 tonnes of whole fish. Lake Harvest processes its fish on site and markets its products in Europe, mainly as fresh fillets, and in the region as frozen fillets and whole fish. Factory by-products are sold locally for human consumption and used by Lake Harvest's own crocodile farm.

Species-specific information

Oreochromis niloticus is not indigenous in Zimbabwe and was introduced in the 1980s by the government for fish farming along the banks of the Zambezi. No further introductions of fresh genetic material have been made since then and there is considered to be a high level of inbreeding among farmed stocks, although this has not been verified. The introduction of improved strains from abroad is being considered and selective breeding is, meanwhile, in progress.

Cage/pen type and size and number of cages

Lake Harvest uses plastic circle cages modified from the European design for Atlantic salmon. It makes its own cages, which are 1 000 m^3, although trials with smaller cages are underway. Production nets are nylon and made on site from imported net panels. Each cage has a predator net made from polyethylene trawl net that is required because Lake Kariba is home to predatory tiger fish (*Hydrocynus* spp.) and crocodiles. Lake Harvest has trained an in-house dive team that dives on the nets to check for holes, escapes and net and mooring integrity.

Each cage site consists of 14 cages. There are six sites, spaced at least 1 km apart, and a total of 84 cages. Water depth at the cage sites varies between 20 and 50 m. Juveniles weighing 10 g are transferred from Lake Harvest's ponds to "juvenile cages" where they are on-grown to 80 g. They are then transferred to "production cages" and grown to a market size of around 600 g, an average body weight providing a good blend of fish for filleting and the whole fish trade.

Stocking densities

Stocking densities are 250 juveniles per m^3 and 80 growers per m^3. Harvest stocking density is up to 45 kg/m^3.

Technical issues

Seed supply

Lake Harvest produces its own fry (up to 5 million per month) and has developed a selective breeding programme to improve growth performance. The company overproduces fry and selects out slower growers at 3 g. New genetic material is being sought. Lake Harvest also sells fry to third parties for dam-lake stocking programmes, although demand is low in Zimbabwe at present.

Feeds and feeding
Obtaining high quality locally manufactured feed is the most difficult constraint for commercial cage farming in Zimbabwe. Problems with local availability of raw material, high price and product quality have been experienced since Lake Harvest's start-up. Extrusion is available but of poor quality. Price varies between US$275/tonne and US$400/tonne delivered for a tilapia finisher. FCRs of 2.1 to 2.4 have been reported.

Diseases
No serious disease problems have been encountered, although some fish show skin lesions from time to time that are infected with *Aeromonas hydrophila*. This problem is being managed.

Socio-economic issues
Production costs
Production costs should be below US$1 per kg of whole fish for a large tilapia farm in Zimbabwe. However hyperinflation and a difficult economic environment have raised production costs, making profitability marginal.

Marketing and prices
Lake Harvest has its own sales and marketing office in Luxembourg that sells mainly fresh fillets to major distributors across northern Europe. The main outlets are fresh fish counters and pre-packs in supermarket chains. Lake Harvest also sells about 45 percent of its production as frozen fillets and whole fish in Zambia, Zimbabwe, Botswana, Malawi and South Africa. Demand is growing in these markets and prices are firming.

Employment
Lake Harvest employs about 200 people in its fish farm operations; 90 employees are in cage operations while the remainder is involved in pond operations, net making and mending, maintenance and administration.

Environmental issues
Lake Kariba is a 5 000 km² freshwater hydroelectric dam-lake fed by the Zambezi River. Water quality is good for cage culture, although a three month colder season (June through August) slows fish growth.

Pollution
Lake Harvest's operation has not resulted in any adverse impact on the lake environment, which the independently managed Environmental Monitoring Program can confirm.

Escapes
Lake Harvest uses a double netting system on its cages to reduce the chance of fish escaping directly into the lake.

Ecological impacts
Lake Harvest carried out a detailed EIA before installing cages. It now has biannual environmental audits done by the University of Zimbabwe, the results of which are submitted to the relevant authorities. Lake Kariba is in a national park operated by Zimbabwe's Parks and Wildlife Authority. No significant environmental change has been identified by the audits over the nine years that cages have been operated.
An increase in the wild fishery catches around the cages has been noted in recent years, as well as an increase in the relative abundance of *Oreochromis niloticus* in the eastern basin of the lake where the cages are located. This could be due to natural stocks of *O. niloticus* being attracted to the fish feed in the area.

Institutional issues
Policies and legal framework
Aquaculture is ultimately controlled by the Parks and Wildlife Authority, although public health issues in fish processing are managed by the Department of Livestock and Veterinary Services. Aquaculture is an emerging sector in the Zimbabwean economy but is not well known by the institutions despite its high potential for expansion on Lake Kariba and in the Zambezi Valley. Lake Harvest leases areas of Lake Kariba from the Parks and Wildlife Authority for mooring and operating cages.

Training
There is no training in aquaculture in Zimbabwe besides on-the-job training at Lake Harvest.

Non-governmental organizations
There are no NGOs involved in cage culture in Zimbabwe.

THE WAY FORWARD

Socio-economics and marketing

National plans and targets
A recent technical workshop concluded that cage aquaculture represents an important development opportunity for many African countries, but will

require an effective policy framework to ensure that structural constraints to development are overcome and that development is equitable and sustainable. Successful development of cage aquaculture will depend on many factors. The challenge for both government and the private sector is to work together to address these issues comprehensively at the farm, local, national and regional levels (Halwart and Moehl, 2006).

Commercial aquaculture is developing at a very slow pace in all the countries listed. There is growing interest in cage culture but support from investors is needed. There is a need to improve the development and application of policies, strategies, and legal and regulatory frameworks to enable not only cage culture but all types of commercial aquaculture in sub-Saharan Africa.

During the last five years, there has been a marked emergence of commercial aquaculture and this appears to be related to increasing fish price (Hecht, 2006). The FAO National Aquaculture Sector Overviews from sub-Saharan Africa reveal that the commercial sector contributes approximately 65 percent to the total fresh and brackish-water fish production, while nearly 100 percent of mariculture production is from the commercial sector (Awity, 2005; Chimatiro and Chirwa, 2005; Maguswi, 2003; Mwanja, 2005) . The potential for cage culture in inland waters such as Lake Kariba, Lake Malawi and Lake Victoria has been proven and production is set to grow.

Mariculture of prawns in Mozambique, oysters in South Africa and Namibia and abalone in Namibia has been established and has laid a foundation for increased production and the commercialization of other species.

In Zimbabwe, hyperinflation and a difficult economic environment has raised production costs, making profitability and expansion of its cage culture operations difficult.

In order to provide a sound platform for commercial aquaculture, public-sector support is required for manpower training, research and development, technology development and transfer, zoning of aquaculture areas, regulatory and product certification frameworks, facilitating environmental assessment processes for key projects, species screening and selection, access to long-term credit and coordinated public sector decision making.

Production for domestic consumption or export

Due to the high cost of production in most cage-culture systems, most commercial farms would like to export their products to international markets such as the European Union (EU) where they are likely to obtain better profit margins. For example, Lake Harvest exports fillets to the EU and Namibian oyster farmers export to the Far East. Because of their low volumes and intensity of production, small-scale cage farmers usually target domestic markets.

Existing fillet processing plants as in Uganda, Ghana, Tanzania and Malawi act as an exporting advantage.

There is also growing interest in aquaculture products within the region and demand is said to have surpassed supply. Countries with better or growing economies (e.g. South Africa, Nigeria and the DRC) are slowly becoming major markets for aquaculture products within the region.

Pricing and value addition for aquaculture products

Tilapia has recently been introduced on world markets, mainly as an alternative to marine whitefish and has become a popular food fish, not only in developing countries but also in the developed world. The global tilapia market is expanding rapidly, with the United States being the most important market. Because of tilapia's ability to adapt to the environment and the relatively simple way it can be farmed, many newcomers are entering the industry and international competition is growing.

Processed product forms are usually marketed as fresh fillets, super-chilled fillets, frozen fillets and whole/round/gutted fish.

Employment and gender issues

Since cage culture is still an emerging activity in sub-Saharan Africa, employment is still very low, but has a great potential for growth.

Women are increasingly involved in technical light-weight production jobs such as net mending and are also very active as processing hands in many processing plants and in land-based hatchery operations. However, offshore duties are still dominated by men.

Technical and environmental issues

Site and choice of water body

Inland water bodies in all the mentioned countries are ideal for cage culture, as they have suitable water quality and temperatures.

The EIA should address issues on the physical environment and identify the desirable places to

locate the cages within the lakes and reservoirs. Lake Harvest Aquaculture has its own practical and robust environmental monitoring programme. All farmers need to develop routines for adjusting the environmental impact to the local carrying capacity.

Some of the cage sites studied in this paper conducted an EIA prior to setting up the cage farms, which shows that environmental issues are taken seriously from the beginning. The cages have been set up in areas free from aquatic vegetation and with good current flow, as currents help to remove sediments and replenish oxygen.

Special care should be taken when planning for cage culture in inland water bodies that are also resources for other users. Lake Victoria is home to commercially viable stocks of Nile perch that provide a source of livelihood for many artisanal fishermen. Lake Kariba and Lake Malawi contain tourist attractions; hence cage culture should be in harmony with these other operations.

Cage-culture projects should be designed to work in close harmony with the local environment and need to follow the stipulated operational regulations in order to be a sustainable business. They should comply with all applicable environmental laws and regulations, strive to attain international standards and always maintain a constructive dialogue with legislative authorities.

Waste control and effluent management

Cage-farm wastes are usually in the form of uneaten feed and fish faeces. Feed is usually the major input to the cage-farm operations. Feed suppliers should aim to meet rigorous quality standards to ensure that feed wastage is kept to a minimum. Many operators now use extruded fish feed diets of improved digestibility to maximize assimilation and minimize loss to the environment. Use of floating feed is vital for cage-farm operations.

Mooring cages in deep waters and where good currents flow results in cage wastes being easily flushed away, thereby avoiding organic build up under the cages.

Species selection and aquatic animal movements

Lucas and Southgate (2003) define the choice of aquaculture species as the balance between the biological knowledge and economics of the species. It is interesting to note most cage sites visited grow Nile tilapia (*O. niloticus*), which has become one of the most commercially important species of cultured freshwater fishes. In 2004 global production of Nile tilapia constituted some 82 percent of the total production of all tilapias.

Nile tilapia is a good fish for warm-water aquaculture, as it is easily spawned, uses a wide variety of natural foods as well as artificial feeds, tolerates poor water quality and grows rapidly at warm temperatures. These attributes, along with relatively low input costs, have made tilapia the most widely cultured freshwater fish in tropical and subtropical countries today.

Consumers like tilapia because of its firm flesh and mild flavour, hence markets have expanded rapidly in the United States, the EU and Asia during the last 10 years, mostly based on foreign imports.

Feeds and feed management

Availability of a quality feed at a competitive cost is one of the biggest problems in commercial aquaculture in sub-Saharan Africa. In southern Africa there are very few dedicated aquaculture feed manufacturing companies. AquaNutro in South Africa is the only dedicated aquaculture feed manufacturer providing 80 percent of South African aquaculture feeds. Tiger Animal Feeds in Zambia is the largest specialized aquafeed producer that is also capable of producing floating feeds (Bentley and Bentley, 2005).

Cage farmers need to be trained or well informed in feed management practices, feed formulations, and feed manufacturing and distribution trends. They need a better understanding of daily feed rates and feed tables, practical feeding methods (use of hand feeding and demand feeders) and the fish feed response.

Fish disease and health management

Fish diseases were not a major threat at any of the cage sites visited. Most fish diseases are caused by overcrowding, malnutrition, unfavourable water quality or poor handling techniques. Thus good husbandry practices should be adopted to avoid occurrences of disease (e.g. use of known broodfish stocks for initial fry production). Furthermore a consistent fish health monitoring programme that includes preventive, regulatory and disease control measures is needed. Coordination with international and national aquatic animal health organizations is also vital should there be outbreak of serious fish disease.

CONCLUSIONS

Although aquaculture is not a traditional activity in Africa, sub-Saharan Africa offers enormous potential for cage culture in fresh, brackish and marine waters. Some countries offer more potential than others, especially those with large, warm (>25 °C) freshwater resources (e.g. the great lakes region and West Africa). Freshwater cage culture has begun to develop in some countries over the past 20 years but there are only a handful of successful operations (e.g. farms in Ghana, Kenya, Malawi, Uganda, Zambia, and Zimbabwe) and the scale is still small except in the case of Zimbabwe. Marine and brackishwater cage culture has not yet developed at all in the region.

General aquaculture development issues

The technical problems facing cage culture in sub-Saharan Africa are, in order of importance, lack of good sites with potential for industrial-scale expansion and year-round warm (>25 °C) water temperatures; lack of good quality, fast-growing tilapia and catfish fry; lack of good quality extruded feed at an affordable price (i.e. US$350/tonne and below for tilapia); and lack of access to export and higher value markets, which is currently limited due to poor logistics, poor infrastructure and/or institutional barriers (e.g. many countries are not approved to export fish into the EU).

A key problem for cage culture in sub-Saharan Africa is that *Oreochromis niloticus* is not allowed for introduction in many countries where it is not indigenous and, even where it is indigenous, better performing strains are often not allowed to be imported. This is usually because of concerns about escapes and their effect on genetic biodiversity. The problem with this restriction is that *O. niloticus* (especially the GIFT strains developed over twenty years or so in Asia) is well known to be the best performing tilapia for aquaculture, making it difficult to be cost efficient with other species and lesser performing strains. Other tilapia species also present a marketing hurdle for exports outside Africa because *O. niloticus* is now the best known of the tilapias in Asian, EU and United States markets.

Socio-economic issues

Socio-economic problems constraining the development of cage culture in sub-Saharan Africa include relatively high production costs (often >US$1 per kg of whole tilapia at the farm gate) due to poor economies of scale and expensive feed, and the traditionally low price and quality of fish in many countries. This has lead to difficulty in penetrating local and regional markets with higher price/higher quality cage-farmed fish, particularly given the poor cold chain distribution in many countries, which leads to the rapid loss of fish quality in local retail outlets. Drying and salting tends not to add value to higher quality farmed fish and so is not appropriate for cage-farmed fish.

Lack of capital, especially working capital.

In many countries cage-culture operations need to be vertically integrated from fry production through marketing, because of a lack of reliable suppliers, fish hatcheries, fish processors and other links in the value chain. This requires individual company investments to be large (often more than US$8 million if processing is also included), in order to achieve economies of scale. There are very few investors willing to invest such sums in aquaculture in African countries because aquaculture is considered a technically risky activity offering medium to long-term returns.

Training

Few countries in sub-Saharan Africa offer training in aquaculture at a practical hands-on level. Farms have to do their own on-the-job training, which is time consuming and a significant cost for investors, who can choose to invest in other continents. There is too much "re-inventing of the wheel" by fish farmers in Africa because of a lack of technical training in aquaculture as well as a lack of exposure of fish farmers in the region to successful cage operations.

Institutional issues

The main institutional problem facing cage culture in sub-Saharan Africa is that aquaculture is usually controlled by fisheries departments and sometimes there is no dedicated aquaculture unit within those departments. The problem is that aquaculture is an entirely different activity to fisheries, requiring different disciplines that are more akin to intensive agriculture such as poultry farming than to capture fisheries. There is often a lack of understanding of aquaculture by fisheries personnel in some countries and this can lead to aquaculture not getting the promotion and support it needs at the policy-making levels.

There are few successful demonstrations of cage aquaculture in sub-Saharan Africa, and this leads to a lack of understanding of the sector at the policy-

making levels in some countries. Consequently some governments find it difficult to promote aquaculture successfully.

Few countries in sub-Saharan Africa have identified aquaculture development zones and even fewer have the necessary legal frameworks to accommodate investments in cage culture readily (e.g. leases for cage sites).

RECOMMENDATIONS

The following recommendations are made towards the promotion and development of freshwater cage culture in sub-Saharan Africa:

Technical recommendations

- The use of *Oreochromis niloticus* and its improved strains (especially GIFT) needs to be reviewed across sub-Saharan Africa. Unless restrictions on the use of this species are relaxed, Africa may find it difficult to be competitive in cage tilapia culture. There are already examples of tilapia farmed in Asia entering inland African markets at prices lower than local production costs. Those countries that continue to ban the use of *O. niloticus* should consider investing properly in the selective breeding and husbandry of local strains.
- Breeding centres need to be established in East, West and Central/Southern Africa. Selective breeding should not be left to individual farms, as good breeding requires a higher degree of expertise than individual farms can afford. The centres should focus on the selective breeding of tilapia and catfish, and sell or make available their improved strains to multiplier hatcheries.
- An aquaculture training centre(s) should be established in the region that offers practical hands-on training at the supervisory and management levels.
- The sector needs support for the development of locally made, high quality extruded feeds. Local raw materials should be used whenever possible in order to avoid the high road transportation costs seen in most African countries.
- The sector needs support in the form of expertise in nutrition, husbandry, and disease identification and management.

Socio-economic recommendations

- There is a need to encourage larger and more experienced aquaculture investors to participate in the sector, as these would provide solid foundations for the growth of industrial-scale cage-aquaculture development in sub-Saharan Africa. Big investors will bring with them, among other things, new hatcheries, technical expertise, improved growth performance, feed quality improvements, economies of scale, routes to market, processing, etc.

Environmental recommendations

- Aquaculture zones should be established. This will simplify the investment process, as sites will already have been identified within such zones, EIAs already carried out, leases simplified, etc.
- Environmental monitoring and advice should be provided as a service to cage farmers by the relevant authorities.

Institutional Recommendations

- An enabling environment needs to be created that is investor friendly. Aquaculture departments should be created that provide one-stop shops for possible cage culture investors.
- Local and international banks should be educated in aquaculture investment.
- Restructuring of government support should be considered; duties and tariffs on imported aquaculture equipment and feed should be reviewed so as to encourage investment in cage culture.
- In some countries, public awareness campaigns should be carried out so that the way is eased for the introduction of cages in certain water bodies (e.g. Lake Victoria).

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